Innovative Networks

CO-OPERATION IN NATIONAL INNOVATION SYSTEMS

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FOREWORD

Innovation through the creation, diffusion and use of knowledge has become a key driver of economic growth and provides part of the response to many new societal challenges. However, the determinants of innovation performance have changed in a globalising knowledge-based economy, partly as a result of recent developments in information and communication technologies. Innovation results from increasingly complex interactions at the local, national and world levels among individuals, firms and other knowledge institutions. Governments exert a strong influence on the innovation process through the financing and steering of public organisations that are directly involved in knowledge generation and diffusion (universities, public labs), and through the provision of financial and regulatory incentives. They need a sound conceptual framework and an empirical basis to assess whether and how the contribution of public policy to national innovation performance could be improved.

Through a decade of academic research and policy analysis, the National Innovation Systems (NIS) approach has been developed to provide such framework and quantitative information. The OECD Committee for Scientific and Technological Policy (CSTP), and its Working Party on Technology and Innovation Policy (TIP), has contributed to this development through its NIS project, conducted in two phases.

The first phase of the NIS project involved country case studies, the development of internationally comparable indicators and thematic analytical work by six focus groups, including one on clusters. Its main results are reported in *Managing National Innovation Systems* (OECD, 1999). This work provided new evidence on the systemic nature of innovation, articulated a new rationale for technology policy and identified broad directions for the improvement of national policies.

The second and last phase of the NIS project was devoted to deepening the analysis on three themes: clusters; innovative firms and networks; and human resource mobility. The work on innovative networks has been led by Austria and co-ordinated by Wolfgang Polt and Andreas Schibany of Joanneum Research, in close collaboration with Svend Remoe of the OECD Secretariat.

This publication summarises the main results of this work that analysed the role of networks in innovation and technology diffusion, reviewed policy initiatives to promote efficient networking in selected OECD countries, and drew the main implications for public policy. It provides both fresh conceptual insights and new factual information on this important mechanism of innovation-led growth. The report is published on the responsibility of the Secretary-General of the OECD.

TABLE OF CONTENTS

Chapter 1. Innovation and Networks: An Introduction to the Theme
Andreas Schibany and Wolfgang Polt 7

Part I. Theoretical Framework

Chapter 2. The Comparative Advantage of Networks in Economic Organisation: Efficiency and Innovation in Highly Specialised and Uncertain Environments
Timo Hämäläinen and Gerd Schienstock..... 17

Part II. Applied Analysis of Co-operation/Collaboration/Networking

Chapter 3. Innovative Activity and Firm Characteristics: A Cluster Analysis of Swiss Manufacturing using Firm-level Data
Spyros Arvanitis and Heinz Hollenstein 49

Chapter 4. Innovation Modes in the Swiss Service Sector: A Cluster Analysis based on Firm-level Data
Heinz Hollenstein..... 77

Chapter 5. Technological Collaboration, Firm Size and Innovation: A Study of UK Manufacturing Firms
Richard Torbett..... 101

Chapter 6. Exchange of Employees, Prototypes and Use of Electronic Media in Product Development Collaboration: Results from a Danish Study
Preben Sander Kristensen and Anker Lund Vinding 123

Chapter 7. Inter-firm Technological Collaboration in Australia in an International Context: Implications for Innovation Performance and Public Policy
Ester Basri 143

Chapter 8. Differences in the Propensity to Innovate between Less and More Developed Regions: How a System of Innovation Approach Can Explain Them
Bianca Potì 169

Chapter 9. Networking Impacts of the EU Framework Programme
Terttu Luukkonen 193

Chapter 10. Knowledge Spillovers through R&D Networking
Michel Dumont and Aggelos Tsakanikas..... 209

Part III. Interactions between Knowledge Institutions and Industry

Chapter 11. Interactions between Universities and Enterprises in Austria: An Empirical Analysis on the Micro and Sector Levels
Andreas Schibany and Doris Schartinger 235

Chapter 12. Collaboration between Manufacturing Firms and Knowledge Institutions on Product Development: Evidence from Harmonised Surveys in Australia, Austria, Denmark, Norway and Spain
Jesper Lindgard Christensen, Andreas Schibany, Anker Lund Vinding 253

Chapter 13. University-Industry Research Co-operation in Chinese Taipei
Feng-Shang Wu 279

Part IV. Policy

Chapter 14. The Role of Governments in Networking
Wolfgang Polt 307

Chapter 15. Concluding Remarks
Wolfgang Polt and Andreas Schibany 321

****

Annex: Policy Case Study: Austria 327
Wolfgang Polt

Chapter 1

INNOVATION AND NETWORKS: AN INTRODUCTION TO THE THEME

by

Andreas Schibany and Wolfgang Polt
Joanneum Research, Austria

Introduction

Since the 1980s, many empirical and theoretical studies have focused on co-operation and have underlined the increasing use of that strategy by firms, especially in high-technology industries (telecommunications, biotechnology, new materials, etc.). During the same period, many European countries and the European Union have played an essential role in financing private technological development through large co-operative R&D programmes such as the Framework Programmes. It has become widely recognised that price competition in the market does not constitute the only form of co-ordination of economic relations and, thus, economic actors find more satisfactory modes of economic regulations through new organisational forms, in particular through different forms of co-operation among firms.

Continuous technological change and innovation are among the main determinants of productivity growth and as such are necessary conditions for the welfare of nations and regions. As the processes that lead to technological innovations are exceedingly complex, firms rarely innovate in isolation; instead, they generate their innovations through interactions with a number of other actors. Today, even the largest and most technologically self-sufficient organisations require knowledge from beyond their boundaries. In order to access alternative knowledge sources, the innovation strategies of firms will combine different innovation activities. It follows that innovations do not originate only from individuals or individual organisations but rather from their often-complex patterns of interactions. Within this innovation systems approach, the key importance of interactions by a set of actors is due to the associated flows of knowledge. In order to increase the social value of knowledge, the system's ability to support and improve the procedures for distributing and utilising knowledge is as important as its ability to promote procedures for generating knowledge. That is why the focus of the system approach lies in the inter-relatedness between heterogeneous actors and knowledge fields: between firms and the knowledge infrastructure; between different functions within the firm; or between users and producers (Lundvall, 1992). Within this systemic framework, innovation networks have gained significant importance as a means for co-ordinating innovation and industrial research and development (R&D) processes.

Knowledge transfer through co-operation networks can take manifold forms. These have multiplied under the combined impact of the rapid evolution of consumer needs, the increase in worldwide competition, a redefinition of the role of the public authorities in economic development,

and, as a major factor, the revolutionary changes in information and communication technologies (ICTs) which have led to the "information revolution" and the knowledge-driven economy.

Since technological development is broadly defined as a combination of knowledge, skills and artefacts (Metcalfe, 1995), it depends on the creation of competencies and knowledge – and networking plays an essential role in this process. Successful innovations hinge upon the development and integration of new knowledge into the innovation process. Put simply, firms must become processors of knowledge, with innovations occurring as the result of these learning processes. Learning leads to the creation of new knowledge, and firms use this knowledge to develop or improve products and production processes. Within this context, networks and inter-firm linkages should be analysed from the dynamic perspective of learning and innovation.

In the literature, networks are seen as standing somewhere between markets and hierarchies. Rather than a simple mechanistic connection between the elements, they represent coherence without contract or command and, as such, signal a new stage in organisational forms. Network capability (Kogut, 1998) is increasingly regarded as a source of value to firms, contributing to learning and knowledge generation. Social and economic networks are affected by physical networks (*e.g.* telecommunication and traffic networks), but have also become significant as a distinctive organisational form. Metcalfe (1995) suggests that "networks can be seen as economic clubs acting to internalise the problems of effective knowledge transmission".

The design of a specific innovation network can vary along a spectrum between formal contractual agreements and loosely coupled informal networks (Freeman, 1991). Informal networks have proven especially capable of incorporating tacit knowledge into their learning processes – behind every formal network (research co-operations, joint ventures, etc.), there are various informal networks which give it life. In addition, the rapid growth in complex technologies is accompanied by a parallel growth in the importance of distinct organisational networks comprising a variety of actors at all levels in the economy (Lundvall, 1992).

The potentially wide-ranging impact of collaborative arrangements both on their participants and on the economy as a whole has led to a growing amount of research on the topic. These studies have shown that collaborative agreements are widely used as an mechanism for knowledge sharing and exchange. On the other hand, competition among firms is commonly regarded as the driving force behind innovation. Hence, it is essential to maintain a high degree of competition. This explains why networks have become an important component of technology and innovation policy, especially in European countries. By stimulating co-operation among the different actors in the innovation system, policy makers expect that the innovation potential can be better exploited in firms, both existing and new, in research, and in society as a whole. However, the issue of appropriate policies is not clear-cut: there is a need to develop and refine the rationale and instruments for facilitating networking with the aim of generating optimal knowledge circulation and sharing in a context of intense competition.

Previous results and current objectives

The work of the Focus Group started with the objective "... to provide a better understanding of the role of inter-organisational collaboration and industrial networks in promoting innovation" (Christensen *et al.,* 1998). Earlier work focused on the systematic collection of empirical data to enable cross-country comparisons and a deeper insight into the importance of inter-firm linkages and linkages between firms and knowledge institutions. The main lessons to be drawn from these studies included (Christensen *et al*., 1998; OECD, 1999):

- *Firms rarely innovate alone:* Firms have become more specialised and increasingly focus on their core competencies. For complementary knowledge and know-how, they increasingly rely on interactions with a variety of actors (*e.g.* equipment and component suppliers, user, competitors and non-market research institutions such as universities and contact research organisations).

- *The importance of knowledge-intensive services is growing:* The service sector plays an increasingly important role in the innovation process. The survey carried out by the Focus Group and the CIS surveys concur in estimating that between 30% and 50% of innovative firms are involved in such interactions.

- *Informal networks and trust are important:* Network-building is a slow process that relies on affinity and builds loyalty. It takes time and resources to build efficient communication channels which seemingly rest on more "soft aspects", such as culture, personal experience and mutual trust.

- *Internationalisation goes hand-in-hand with strengthened domestic networks:* Although inter-firm collaboration remains predominantly inward-oriented, foreign partners, especially suppliers of materials and components and private customers, play a significant and growing role in national innovation networks. Increased international competition strengthens national patterns of collaboration and opens it to international customers and suppliers.

- *National innovation systems are characterised by different patterns of interactions:* Countries differ with regard to the extent, nature and motives of inter-firm collaboration. There are important differences in the way innovation is pursued. These differences are reflected in institutional frameworks and the orientation of public policies.

Current objectives

Today, the context of co-operation and networking, as well as the theoretical analysis of the rationale of public policy, is wide-ranging, including different sectors, innovation modes and specifications of R&D-co-operation. The work of the Focus Group was thus organised along different research topics including a new conceptual framework for the analysis of network and co-operation.

The aims of the Focus Group were to explore patterns of CCN (co-operation/collaboration/ networking) in innovation, and to develop and refine policies to facilitate networking. The Focus Group's goal in developing a conceptual framework included different approaches and concepts concerning the economics of networking and innovation as well as the analysis of different types of governance failures that could warrant government intervention or other types of organisational solutions. The work of the Focus Group concentrated on the following activities:

- Developing a conceptual framework of networking.

- Empirical analysis to explore patterns of CCN in innovation.

- Policy analysis and case studies.

Key themes

Conceptual framework

As the work of the Focus Group is part of the overall OECD NIS project, the conceptual work built the link to the overarching questions of the NIS project. Network co-operation has become an increasingly efficient and innovative way of organising interdependent activities in modern economies. Despite the growing volume of research on networks, the comparative organisational advantage of networks in advanced economies has not been adequately explained in the literature. The conceptual framework of the Focus Group developed by *Timo Hämäläinen* and *Gerd Schienstock* makes an attempt to explain how the current paradigm shift in the world economy has increased the comparative advantage of networks in economic organisation. It analyses the specifications of co-operative networks as an important element of the new techno-economic paradigm and explores the context in which markets, hierarchies and networks co-exist in modern economies. In this context, they refer to the organisational determinants of collaboration and co-operation as more loose form of interactions, which could involve also just two partners, while networking is a sustained interaction between a greater number of partners.

Innovation modes

Early empirical studies, such as that carried out by Penrose (1959), revealed that even firms within the same industry differ widely in terms of product quality, distribution channels, competitive strategies, etc., resulting in different profit rates within industries. Recent surveys such as the CIS or DISKO show that innovative activities of firms differ in many respects (intensity, orientation, use of external knowledge, etc.). It is thus an open question to what extent innovation processes are determined by endogenous firm-specific factors or exogenous industry-specific factors, and how these two interact.

One of the most widely used approaches is to rank industries by innovation intensity. However, this approach requires a sufficient degree of homogeneity of industries with regard to certain indicators. A more evolutionary view stresses the heterogeneity of firms, *i.e.* firms have a certain degree of freedom in their choice of an innovation strategy, even when they are faced with similar economic and/or technological conditions. Using Swiss data, *Spyros Arvanitis* and *Heinz Hollenstein* developed innovation modes according to different indicators including non-technical aspects, resulting in the identification of five clusters. They investigate the relationship between innovation modes and industry composition, and measure average firm performance by each of the clusters. They show that there is some concentration of innovation modes on specific industries, although the overlap is far from perfect. Thus, in accordance with the heterogeneity hypothesis, firms dispose of a certain degree of freedom in selecting an economically viable innovation strategy in similar economic and technological environments. However, their room of manoeuvre is restricted by structural characteristics that are closely related to the hierarchy of industries in terms of innovation intensity, factor endowments, etc. *Heinz Hollenstein* uses this approach for the analysis of innovation modes in service industries of the Swiss economy.

What are the factors that influence the propensity of firms to enter into formal collaborations on technological innovation projects? Envisaging this research question, many theoretical approaches predict that larger firms are more likely to collaborate than smaller ones. This relationship has wide-ranging implications for understanding how collaboration is used by firms, and the economic effects of such collaborations. Following the approach of the DISKO method, *Ester Basri* explores patterns of

collaboration between Australian firms, focusing on the extent, character and location of collaborative behaviour by firms in the innovation process.

The relationship between technological collaboration and innovation is explored by *Richard Torbett*. Using CIS2 data for the United Kingdom, this author argues that there is a strong positive relationship between firm size and the propensity to collaborate and that this effect is independent of sectoral differences. The effect of those collaborations on the internal structure of innovation as well as on performance varies considerably between size bands, thus emphasising the structural role of firm size in exploring new technical fields.

The chapter by *Preben Sander Kristensen* and *Anker Lund Vinding* explores the different media used in collaborative development projects. By applying quantitative techniques to a survey, they examine the importance of three types of knowledge transfer – exchange of employees, exchange of prototypes, and use of electronic media. Thus, the importance of both the tacit and codified dimension of knowledge is discussed. A key result is that a collaborative relationship tends to build on more than one type of media.

The role of regions is receiving increasing attention in innovation research and innovation policy. Like clusters, they form intermediate structures between the macro and micro levels that contain inherent propensities for networking and innovation. However, regions have different capacities in this respect. Using Italian data, *Bianca Potì* examines regional differences in innovation propensity that can be explained by local externalities, inter-firm networking and public policies.

Links between industry and knowledge institutions

In most economies, technology policy has sought to bring the worlds of scientific and commercially oriented research closer together. Innovation and technological development depend increasingly on the ability to utilise knowledge produced elsewhere and combine it with the stock of knowledge available in the firm. For this purpose, absorptive capacities, transfer capacities and the ability to learn by interaction are crucial success factors in innovation (Cohen and Levinthal, 1989, 1990; Foray and Lundvall, 1996). New and commercially useful knowledge is thus the result of interaction and learning processes among various actors in innovation systems, *i.e.* producers, users, suppliers, public authorities, and scientific institutions. Universities and other public research institutes, as major producers of knowledge, are increasingly expected to contribute to this process.

At the heart of the system approach are interactions between the constituent elements of the system, in particular firms and knowledge institutions. Knowledge, learning and the resulting capacity to react to changing demand play a crucial and growing role for firms and hence can be seen as one important dimension that determines the performance of a national innovation system. Useful products and processes result from knowledge inputs from a variety of sources, and meet performance constraints along multiple dimensions. The current focus on knowledge – combined with the interactive theory of innovation – has led to the analysis of specific factors which determine successful innovations or influence the absorption of knowledge created outside the firm. Interactions with universities and knowledge institutions rest, at least to some degree, on formalisation and personal contacts and allows for the transfer of the tacit knowledge that is considered to be a critical factor of success in learning and innovation.

The rationale for the attention to the linkages between industry and science (knowledge institutions) is clear: a large share of research is carried out at universities and public research institutions. In order to reap commercial benefits from this research, an efficient interface between

public research and commercial exploitation is warranted. Furthermore, universities represent the largest and most diverse pool of scientists and researchers within the national innovation system and are the major producer of human capital through their role of professionally transferring scientific knowledge through education.

Part of the work of the Focus Group has been devoted to reviewing existing data on inter-firm linkages and exploring ways to overcome their shortcomings. The chapter by *Jesper Lindgard Christensen*, *Andreas Schibany* and *Anker Lund Vinding* presents the results of a comparative analysis based on a harmonised survey on innovation activities (DISKO). They used data from the second phase of the NIS project to focus upon a key feature of the innovation system; namely, collaboration between firms in manufacturing and what are broadly termed "knowledge institutions". The chapter investigates which types of firms undertake this kind of collaboration and whether there are country differences in this respect.

Enterprises and knowledge institutions use a variety of channels to exchange knowledge and technology, in ways that are by no means as straightforward as a linear view of the innovation process would imply. The functioning of the science system is governed by rationales and different institutional settings that are different from those prevailing in the enterprise sector. Moreover, when the sectoral pattern of knowledge interaction is analysed, the dependency on the type of interaction becomes apparent. The chapter by *Andreas Schibany* and *Doris Schartinger* explores the interaction between universities and enterprises in Austria by taking a micro- and sectoral perspective. From the sector-specific perspective, the chapter shows that the sectors with the highest intensity of interaction with universities only partially correspond with common rankings of knowledge-intensive sectors.

Based on survey data, the chapter by *Feng-Shang Wu* explores the major influences on science-industry co-operation in Chinese Taipei, including the motives behind co-operations, communication types and commitments, as well as some mediating factors.

R&D co-operation

The EU Framework Programmes were launched as a targeted initiative to improve industrial competitiveness. Using the mechanism of collaborative research, the objective was to link up the diverse and complementary technical and scientific capabilities of firms, universities and research laboratories in European countries in pursuit of common technological goals. However, the most important effect of the Framework Programmes is that they have gradually become the driving force behind the formation of dynamic networks which go beyond formal collaboration. By bringing together researchers from the best laboratories in European firms, they give private firms the opportunity to benefit from a larger pool of resources than is available in a single nation. They have unquestionably fostered the emergence of closer linkages and the creation of a critical mass through networking. In addition, they provide stable financial support, reduce unnecessary competition among researchers and between researchers and industry, and provide access to complementary skills, means and tools.

Within the Framework Programme, university-enterprise or public sector research institute-enterprise relationships are important because they offer an important avenue for the interaction between knowledge-seeking (firms) and knowledge-producing (universities and research centres) organisations around research agendas of common interest. As part of the trend towards the internationalisation of research, the Framework Programmes represent a useful vehicle for carrying out transnational and multi-sectoral RTD joint ventures. The chapter by *Terttu Luukkonen* draws attention

to cross-sector and inter-firm collaboration and shows that the Framework Programme has promoted complex networking structures and enhanced the pattern of collaboration across national boundaries.

R&D collaboration can be used as a proxy for knowledge spillovers between firms. Such spillovers are, from a policy perspective, a rationale for promoting inter-firm collaboration. As spillovers increase, R&D co-operation becomes increasingly attractive. In such situations, R&D co-operation is welfare-enhancing. The magnitude and specifications of spillovers are crucial for the rationale of public policy aimed at promoting R&D collaboration. *Michel Dumont* and *Aggelos Tsakanikas* use data on the co-operative R&D project of the EU Framework Programme to measure inter-firm spillovers. The study is based on the policy rationale that public support of R&D depends to a great extent on the magnitude and specifications of the spillovers yielded by the subsidised networks. While existing approaches are mainly based on input-output tables that comprise more embodied spillovers, their proposed method complements existing methods by focusing on the disembodied knowledge spillovers that result from R&D networks. However, they warn that, in the case of R&D agreements which extend to the product market, the positive welfare implications may no longer hold.

Conclusions and policy implications

In the first of the two concluding chapters, *Wolfgang Polt* and *Andreas Schibany* summarise some of the main findings of the studies compiled in this volume. With regard to the theoretical and conceptual work from various strands of economic theory, they highlight recent progress but also point to some open questions and stress the need for further research. With respect to empirical studies, they find that a number of studies have underscored the growing importance of networking, traced the developments of the various forms of networking, and identified some of the main benefits to be gained from networking. However, in terms of more policy-oriented empirical work (*e.g.* a thorough identification of market and systemic failures as a rationale for setting up a programme, empirical assessment of the effects of network-oriented polices), much remains to be done.

The final chapter by *Wolfgang Polt* discusses trends and developments in network-oriented policies on the basis of policy case studies which have been carried out for Austria, Denmark, Finland, Greece, Hungary, Italy, Switzerland and Chinese Taipei. These case studies looked in a structured way into examples of policies that address co-operation and networking in the respective countries. They identify both “good practices” (especially from some recent programmes) and caveats which need to be applied in the design of policies addressing co-operation and networking. The Austrian case study is presented in Annex to Chapter 14 as a potential template for further empirical research.

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PART I

THEORETICAL FRAMEWORK

Chapter 2

THE COMPARATIVE ADVANTAGE OF NETWORKS IN ECONOMIC ORGANISATION: EFFICIENCY AND INNOVATION IN HIGHLY SPECIALISED AND UNCERTAIN ENVIRONMENTS

by

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Introduction: emergence of the network paradigm

The world economy is currently undergoing a historical transformation comparable to the First and Second Industrial Revolutions. The primary forces underlying this transformation are: *i)* globalisation of economic activities; *ii)* increasing specialisation and complexity of value-adding systems; *iii)* rapid advance and diffusion of modern information and communication technologies (ICTs); and *iv)* growing integration, differentiation and dynamism of markets. These forces have challenged the old organisational, institutional and political structures of industrialised countries. They have also changed the nature of competition in modern industries.

In a growing number of industries, low production costs and good quality no longer yield a sustainable base for competitive advantage. Today, all international firms must be able to produce high-quality products at low cost, sell them at a reasonable price and deliver them quickly and in time (Stahl *et al.*, 1993, p. 15). The same competition criteria are also imposed on local firms by their larger customers and by subsidiaries of multinational enterprises. Thus, low cost and good quality have become necessary, but not sufficient, conditions for competitive success.

The competitive advantage of firms depends increasingly on their capacity to continuously come up with new products and processes that better meet the demands of customers. Innovative firms enjoy first-mover advantages in the product market and can charge premium prices as long as their competitors are struggling to catch up. With demand patterns becoming more differentiated and dynamic, innovation processes are being increasingly tailored to the needs of particular customers and their specific socio-institutional contexts.

This introductory chapter will examine an important element of the current paradigm shift in the world economy: the emergence of networks. Co-operative networks are an important part of the new techno-economic paradigm. The productivity benefits of the new ICTs could not be reaped without complementary changes in the prevailing organisational arrangements (OECD, 1996; Brynjolfsson and Hitt, 2000). This gives rise to a number of questions. When exactly are co-operative networks the most efficient and innovative organisational alternative? When do network relationships have a comparative advantage over market mechanisms or private and public hierarchies? After all, markets,

hierarchies and networks all co-exist in modern economies. Only their relative importance in particular contexts has changed.

Despite widespread use, there is no consensus about the appropriate definition of networks. They are often characterised by the concept of "loose coupling": various independent actors develop relatively loose relationships linking them in the pursuit of common goals (Johannison, 1987, p. 9). Network relationships and co-operation usually take a relatively long period of time to develop. Once established, co-operative networks tend to be characterised by high degree of specialisation and interdependence, intensive communication, reciprocity and high levels of trust (Hämäläinen, 1993; Nahapiet and Ghoshal, 1998). However, occasional conflict and power-asymmetry may also characterise networks. The focus of network analysis is more on the relationships and interactions between interdependent actors and organisations than on these actors or organisations themselves.

Although the volume of research on networks is growing rapidly, their comparative organisational advantage in advanced economies has not been adequately explained in the literature. Most theorising takes a partial approach and neglects many important dimensions of organisational efficiency and innovativeness. For example, the transaction cost literature does not include production and co-ordination costs as key determinants of economic efficiency, nor has it anything to say about the value-adding or innovation consequences of alternative organisational arrangements (Hämäläinen, 1993). This chapter will make an attempt to provide a more holistic theory of economic organisation that takes these organisational determinants more seriously. In particular, we will attempt to explain how the current paradigm shift in the world economy has increased the comparative advantage of networks in economic organisation. Network co-operation has become an increasingly efficient and innovative way of organising interdependent activities in modern economies.

The chapter is divided into seven sections. The second section will analyse the comparative efficiency of networks *vis-à-vis* the market mechanism and private sector hierarchies. Our analysis will demonstrate that networks have become more efficient relative to markets and hierarchies during the present transformation of the world economy.

The third section will focus on the innovatory capacity of markets, hierarchies and networks. We will argue that networks are particularly effective in bringing together and combining the diverse but complementary knowledge sets required for innovation. In highly specialised economies, hierarchical organisations cannot usually internalise all the necessary knowledge and capabilities. As a result, modern innovation competition tends to favour networks over markets and hierarchies.

The fourth section will argue that there are two fundamental forces that have made networks more important organisational arrangements during the current paradigm shift: the growing specialisation and uncertainty of economic activities. These twin forces have increased the dissimilarity of productive resources in value-adding systems, raised their transaction and co-ordination costs, and emphasised the need for intensive inter-firm communication and close co-operation. Overall, these changes have made networks more efficient and innovative relative to markets and hierarchies in highly specialised and uncertain environments.

The spread of the network paradigm has not been limited to the private sector. Public sector hierarchies have faced similar organisational challenges to their large private counterparts. The fifth section will argue that network arrangements within the public sector and between public and private sector organisations have also become more efficient and innovative.

Social capital plays an important role behind all organisational arrangements, but it is particularly important for the success of network arrangements. The sixth section will analyse the different types of social capital, how it affects economic organisation and performance, its development mechanisms

and contexts, the role of the welfare state in its creation, and why social capital has become more important in recent years.

All organisational arrangements have their own specific strengths and weaknesses. Hence, the comparative advantages of markets and governments have been assessed against specific "market failures" and "government failures", respectively. There is a large body of literature on these two types of organisational failures (Hämäläinen, 2001). On the other hand, potential "network failures" have received far less attention in the literature. The last section of this chapter will discuss factors which may cause networks to fail.

When are networks efficient?

Networks are not always the most efficient arrangement for organising particular economic activities although their comparative advantage seems to have risen in recent years. The market mechanism and corporate hierarchies have their own organisational strengths and weaknesses which give them a comparative advantage in some industry environments. In this section, we will examine the factors which determine the relative efficiency of networks *vis-à-vis* markets and hierarchies. The following section will analyse the impact of these organisational arrangements on innovation processes and outcomes.

The comparative advantages of markets, hierarchies and networks have been analysed in New Institutional Economics. This relatively new branch of economics has applied the transaction cost theory (TCT) of Coase, Williamson and others to argue that economic activities are organised according to their transaction cost characteristics (Coase, 1937; Williamson, 1975, 1985). In particular, TCT suggests that markets can efficiently organise economic activities whose relationships are characterised by low "asset specificity" and transaction costs; hierarchies are superior with activities of high asset specificity and transaction costs; while networks or "hybrids" have a comparative advantage with activities characterised by intermediate levels of asset specificity and transaction costs (Williamson, 1991). However, despite its considerable achievements, TCT has been increasingly criticised in recent years (Chandler, 1979; Duning, 1988; Demetz, 1991; Perrow, 1981). Hence, we need to develop a richer theoretical framework of economic organisation.

In our framework, the comparative organisational advantage of markets, hierarchies and networks is determined by four characteristics of the value-adding system:

- Similarity of resources and knowledge required by interdependent activities.
- Level of transaction costs between such activities.
- Co-ordination needs of interdependent activities.
- Nature of innovation processes.[1]

Our key argument is that all four organisational determinants influence organisational decisions. Hence, partial theories (such as transaction cost theory) which neglect important factors, do not provide a satisfactory explanation of economic organisation. The relative importance of each determinant depends on the particular nature of the value-adding system and its context.[2] We will examine the first three organisational determinants in this section. The organisation of innovation will be analysed in the following one.

Similarity of resources and knowledge

The resource-based theory of the firm (RBT) became popular among strategy scholars in the late 1980s and early 1990s (Penrose, 1959; Rumelt, 1984; Wernerfelt, 1984; Barney, 1986; Teece *et al.*, 1990; Peteraf, 1993). RBT looks at firms in terms of their unique bundle of resources. The resources that provide a firm's competitive advantage can take several forms: favourable location, proprietary technology and know-how, good reputation, superior organisational culture and routines, and so forth. In the early 1990s, the resource-based approach was applied to explain the boundaries of firms, particularly the limits to their diversification (Teece *et al.*, 1990; Prahalad and Hamel, 1990; Peteraf, 1993).

Richardson (1972) analysed the organisation of industry with the concepts of resource similarity and complementarity. He argued that a firm's resources and capabilities support closely-related or similar activities. In a specialised value-adding system, these activities must be co-ordinated with other, complementary, activities. Due to specialisation, these complementary activities are often undertaken by other firms possessing different kinds of resources (see also Miles and Snow, 1986; Itami, 1987; Demsetz, 1991; Kogut and Zander, 1992; Quinn, 1992).

Although insightful, resource-based theory neglects firms' transaction and co-ordination costs. High transaction and co-ordination costs can sometimes overwhelm the resource- and knowledge-based advantages in organisational decisions. RBT is also rather static; it emphasises firms' existing value-adding capabilities and production costs rather than their innovation capabilities and needs. The organisational determinants of innovation have been the focus of the more recent "knowledge-based theory of the firm" (SMJ, 1996). We will discuss the implications of this theory in the next section.

Transaction costs

Transaction costs are caused by the search for appropriate exchange partners, negotiation and enforcement of contracts with them, and the problems of opportunism (*e.g.* adverse selection, moral hazard and principal-agent problems) related to the "bounded rationality" of economic agents. Transaction cost theory argues that transaction costs tend to increase with the "asset specificity" of value-adding activities (Williamson, 1985). The more co-specialised the productive resources of interdependent value-adding activities, the higher will be the transaction costs of market exchange (Williamson, 1985). Above a certain threshold of asset specificity, increasing transaction costs will begin to favour "hybrids", or network arrangements, over market transactions. However, at the highest levels of asset specificity, only hierarchical solutions can efficiently reduce the behavioural uncertainties and transaction costs related to highly co-specialised resources (Williamson, 1991).

In addition to asset specificity, transaction costs are also affected by the political and institutional framework in which the transactions are embedded (North, 1990; Williamson, 2000). Transaction costs are increased, *e.g.* by uncertain property right regulations and low levels of trust among exchange partners. Different industries and local cultures may have widely differing institutional environments and transaction costs (see, for example, Fukuyama, 1995).

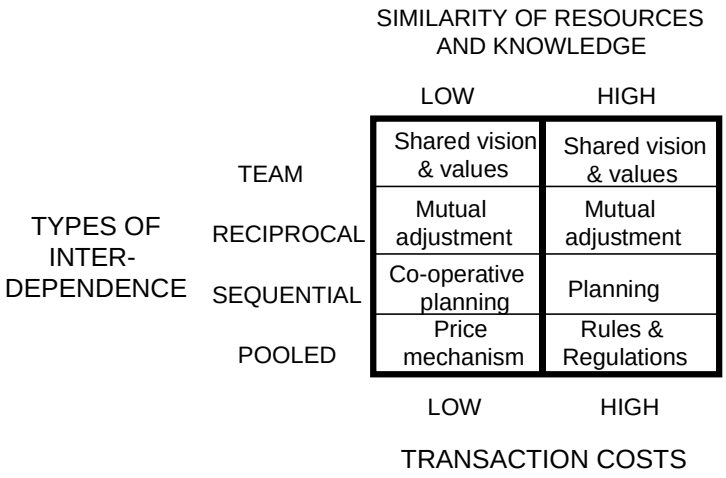
Co-ordination costs

The co-ordination costs and mechanisms of value-adding systems are determined by the nature of interdependence among their different value-adding activities. These interdependencies are characterised by the "richness" of the required information flows among value-adding activities; more specifically, the number of specific aspects that must be co-ordinated between interdependent activities (Galbraith and Kay, 1986; Daft and Lengel, 1986; Simon, 1991). A traditional market exchange involves only two quantitative links: price and quantity. However, interdependent value-adding activities often have qualitative links which require the matching of specific operation plans (Richardson, 1972; Simon, 1991). For example, marketing, R&D and production functions may have to co-ordinate numerous aspects of their highly-interdependent plans during a product development project (Kline and Rosenberg, 1986; Teece, 1992). The richer the information links between value activities, the more powerful the co-ordination mechanisms needed to facilitate the information exchange (Thompson, 1967; Richardson, 1972; Galbraith and Kay, 1986; Daft and Lengel, 1986; Simon, 1991).

Thompson provides a useful typology of interdependence for our purposes by differentiating between the pooled, sequential and reciprocal relationships of hierarchically organised value-adding activities (Thompson, 1967). In pooled interdependence, the value activities are interrelated only in that each activity contributes to the overall goal of the firm (*e.g.* the firm's cafeteria and marketing department). In sequential interdependence, one value activity must be performed before the other (*e.g.* components manufacturing before components assembly). In reciprocal interdependence, value activities have feedback loops – *i.e.* they relate to each other as both inputs and outputs (marketing and R&D activities in dynamic industries) (Kline and Rosenberg, 1986; Scott, 1987). Van de Ven, Delbecq and Koenig have added a fourth type of interdependence to Thompson's typology, namely team interdependence (Van de Ven *et al.*, 1976; Grant, 1996). This is a systemic interdependence which involves several reciprocal links within a group of economic agents.

The co-ordination of interdependent activities requires different mechanisms at different levels of interdependency and co-specialisation (Figure 1). In hierarchical organisation, pooled interdependence will be co-ordinated by rules and standards, sequential interdependence by planning, reciprocal interdependence by mutual adjustment (Thompson, 1967), and team interdependence by group meetings (Grant, 1996) and shared understandings, values and visions (Hämäläinen, 2001).

Figure 1. **Co-ordination of interdependent activities**



If the interdependent activities are internalised by different organisations (low resource and knowledge similarity, low transaction costs) and the interdependence is of a pooled nature, the activities will be co-ordinated by the market mechanism where price equates supply and demand quantities (Richardson, 1972; Williamson, 1985; Galbraith, 1986). At higher levels of interdependence, firms will have to co-operate more closely to achieve qualitative co-ordination (Richardson, 1972; Simon, 1991). Similar to hierarchical organisation, sequential interdependence requires co-operative planning, reciprocal interdependence mutual adjustment, and team interdependence calls for network meetings and the development of shared understandings, values and visions among the co-operating partners.

In a competitive economy, firms will try to economise the use of different co-ordination mechanisms (Thompson, 1967; Grant, 1996). Co-ordination by rules, standards and the price mechanism requires least resources, particularly information (Hayek, 1945; Simon, 1991). Thus, the stronger and more resource-intensive forms of co-ordination – planning, mutual adjustment, group meetings and the development of shared understandings, values and visions – will only be used at the higher levels of interdependence (Thompson, 1967).

At the highest levels of economic specialisation and uncertainty, top decision makers of large hierarchical organisations are challenged by the enormous information and knowledge requirements of co-ordinating highly interdependent value-adding systems (Hämäläinen and Laitamäki, 1993; Hodgson, 1999). These information and knowledge requirements can only be met by dividing and decentralising the co-ordination task to lower levels of the value-adding system. Such "semi-decomposable" sub-systems (Simon, 1962) have the necessary knowledge of the "particular circumstances of time and place" (Hayek, 1945). The overall co-ordination of the value system must now take place through shared understandings, visions and values.

Hierarchical co-ordination problems can also be reduced by focusing the organisation on its "core competencies" and activities (Prahalad and Hamel, 1990). This kind of specialisation is usually associated with the externalisation of some "non-core" activities to related organisations. The resulting smaller hierarchy is easier to co-ordinate than a large diversified one. To sum up, increasing co-ordination problems will lead to the use of stronger and more horizontal co-ordination mechanisms, decentralisation of hierarchies and the growth of inter-organisational networks.[3]

Although important, the three efficiency-related determinants of organisation are not the only ones. In dynamic industries, organisational decisions are influenced by innovation considerations. Markets, hierarchies and networks provide quite different contexts for innovation processes.

When are networks innovative?

Since the seminal work of Schumpeter (1942), innovation researchers have recognised that organisational arrangements have a significant impact on modern innovation processes. This impact cannot be ignored in a world of increasing innovation competition and rapidly-eroding resource and cost advantages. Moreover, the importance of innovation to organisation is likely to vary across industries. Innovation is likely to play an important role in the organisation of high-tech industries; while resource and cost considerations will receive greater attention in the more mature industries.

The organisational determinants of innovation and learning have recently been studied by scholars developing the new "knowledge-based theory of the firm" (KBT) (see, for example SMJ, 1996, Nahapiet and Ghoshal, 1998). Kogut and Zander even define a firm as "a social community specialising in speed and efficiency in the creation and transfer of knowledge" (Kogut and Zander, 1996, p. 503).

The KBT carefully analyses the different types of knowledge with particular emphasis on the different implications of tacit (implicit) and codified (explicit) knowledge for competitiveness, communication, information systems and organisations (see, for example, Kogut and Zander, 1992; Nonaka and Takeuchi, 1995; Spender, 1996; Brown and Duguid, 2000). For example, Spender argues that sustainable competitive advantage can best be built on socially shared and tacit knowledge (Spender, 1996). Nonaka and Takeuchi emphasise the dynamic interaction between an organisation's tacit and codified knowledge bases for the development of new knowledge (Nonaka and Takeuchi, 1995). Daft and Lengel, in turn, underline the importance of informal face-to-face communication mechanisms in highly complex and uncertain situations where the established cognitive frames must be changed (Daft and Lengel, 1986). In their view, simple and stable communication environments tend to favour more formal communication mechanisms such as memos, faxes and e-mail. Informal face-to-face communication is characteristic of innovation processes where different types of cognitive frames and complementary knowledge must be combined to produce new insights (Bierly and Hämäläinen, 1995).

The knowledge-based theory of the firm emphasises four organisational factors which influence the innovativeness of firms: diversity of knowledge, intensity of communication, availability of complementary assets and social capital. The first three of these factors will be discussed in this section. Social capital will be analysed in a later section since it influences all four determinants.

The principal means of advancing social and scientific knowledge is through new combinations of existing knowledge sets (Schumpeter, 1934; Kogut and Zander, 1992). When these sets are held by different individuals, their combination requires interaction and exchange between the various knowledge holders. The new combinations may involve different types of knowledge that have not been combined before or the same knowledge elements combined in a new way (Grant, 1996; Nahapiet and Ghoshal, 1998). Today, individual knowledge sets tend to be so specialised that the required diversity of knowledge for major innovations can only be reached, when two or more experts combine their different knowledge sets and create a new, partially shared knowledge base (Grant, 1996; Pavitt, 2000; Yli-Renko *et al.*, 2000; Hage and Hollingsworth, 2000).

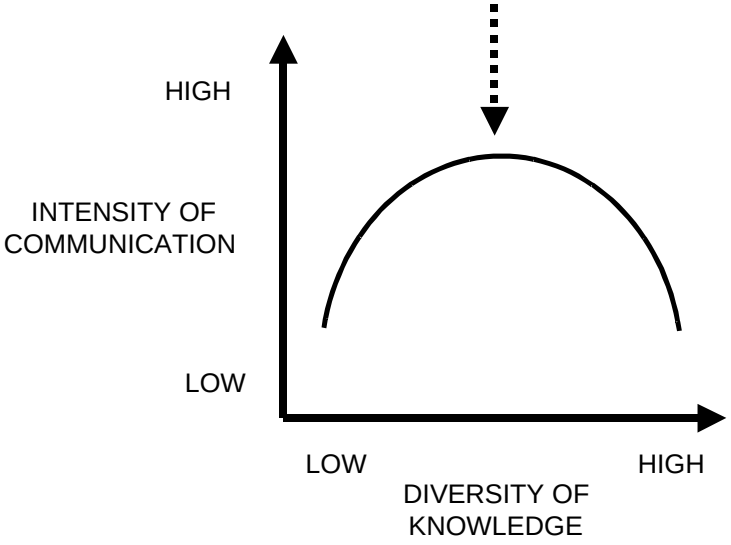
The knowledge held by different individuals cannot easily be exchanged, combined or shared. The first prerequisite for combination is that the individuals have access to each other, *e.g.* through membership in the same community. Combination also requires the development of a common cognitive frame, shared language, overlapping knowledge structures (absorptive capacity) and a meta-level recognition of each other's knowledge domains (Nahapiet and Ghoshal, 1998; Hage and Hollingsworth, 2000). The combination and reframing process involves both codified and tacit knowledge, the latter being very difficult to communicate. However, once established, the shared frame, knowledge base and language allow individuals to exchange and combine aspects of knowledge which are not common among them (Grant, 1996). This provides new insights, perspectives and meanings which would not otherwise emerge.

The development of shared knowledge bases among individuals with different knowledge sets requires intensive and long-term communication.[4] The more diverse the individuals' knowledge sets are initially, the more difficult such communication becomes. At one extreme, when the individuals' knowledge bases are totally different, communication, and hence the creation of shared knowledge, becomes impossible. On the other hand, when the knowledge sets are very similar, both communication and the creation of shared knowledge are facilitated. However, the low diversity of knowledge does not encourage learning and invention.

Figure 2 shows that the relationship between knowledge diversity, intensity of communication and inventiveness (knowledge creation) tends to take the shape of an inverted U (Nahapiet and Ghoshal, 1998; Hollingsworth, 2000). The intermediate levels of knowledge diversity, where the

combination of different knowledge sets is still possible, provide the most fertile ground for major inventions. Moreover, the "radicality of innovations" can be expected to grow with the diversity of knowledge combined (Nahapiet and Ghoshal, 1998).

Figure 2. **Point of maximum inventiveness**



Source: Hollingworth (2000).

Finally, the initial inventions do not become successful innovations until they are combined with many different complementary assets and activities and brought to the market (Teece, 1987). This may require "systemic innovation", where the missing pieces of the idea-innovation chain are either acquired or created or other value-adding activities are adjusted to the demands of the new invention. The initial invention may involve any part of the value-adding system (sourcing, technology, production, marketing, etc.); systemic innovation takes place in the other, complementary, parts of the system.

The intensive communication required for creating new innovations cannot take place through the market mechanism (Nahapiet and Ghoshal, 1998; Hage and Hollingsworth, 2000). Nahapiet and Ghoshal argue that rich communication flows require hierarchical organisation. This is consistent with Brown and Duguid, who note that new knowledge is typically created in closely interacting "communities of practice" which have a shared frame, professional code and knowledge base. Small firms may only have one community of practice; larger firms may have several functionally divided communities (Brown and Duguid, 1991, 1999).

The diversity of knowledge and other resources may not be adequate for major innovations within highly specialised organisations, however. Often the necessary co-specialised assets can only be found in other organisations. Since markets do not support intensive inter-organisational communication, networks become a natural organisational arrangement for innovative processes in these kinds of environments (Hage and Hollingsworth, 2000).

An organisation's access to the diverse knowledge and resource base of occupational "networks of practice" may become a particularly valuable asset for its innovation processes (Brown and Duguid, 1999). Such horizontal networks consist of experts engaged in similar activities in different organisations. Their knowledge bases, frames and language overlap to a larger or smaller extent. As a

result, networks of practice can provide an attractive continuum of knowledge and resource diversity and combinative capability for innovative activities.

The previous two sections have argued that all four organisational determinants play an important role in organisational decisions. However, the four determinants do not always lead to same organisational conclusions. Organisational decision making involves important trade-offs between the different determinants. We will discuss some of these trade-offs below.

First, there is often a trade-off between the resource- and knowledge-based advantages of two organisations and the transaction cost advantages of internalising a transaction and the related value-adding activities into one hierarchy. Depending on the relative importance of resource and knowledge advantages and transaction costs, a network or hierarchical arrangement may be suggested.

Another trade-off can be found between transaction and co-ordination costs. At high levels of economic specialisation and uncertainty, high transaction costs might suggest hierarchical co-ordination while co-ordination challenges would require decentralisation and network co-operation. Again, the relative importance of transaction and co-ordination costs must be evaluated in the organisational decision. These two trade-offs will become less important as the interdependence of the value activities decreases and markets become more efficient. Indeed, in perfect markets, both transaction and co-ordination costs would be zero.

A third trade-off can be identified between innovation and transaction costs. As discussed above, networks often provide the most fertile ground for innovation in highly specialised and uncertain value-adding systems where the necessary resources and knowledge cannot all be found in the same organisation. However, as we have seen, such value-adding systems may also be characterised by high transaction costs which would favour hierarchical organisation. In this situation, the static efficiency benefits of hierarchies must be traded off against the larger innovation potential of networks.

In practice, the existence of organisational trade-offs has led to the development of "hybrid" organisations which attempt to combine the best features of different "ideal types". For example, the traditional hierarchical "machine bureaucracy" with its rigid top-down command culture and alienated employees is becoming increasingly rare in the modern business world. Most large corporations have introduced various horizontal co-ordination mechanisms, employee involvement programmes, flexible decision-making procedures, corporate visions, cultures and values, and so forth. Large hierarchies also tend to be active participants and co-operation partners in numerous external networks. They also use markets for acquiring more standardised inputs and raw materials. Hence, the organisation of complex value-adding systems tends to involve markets, hierarchies and networks in different combinations and mixes.

Why have networks become more competitive in recent years?

The world economy is currently going through a major transformation driven by the globalisation of markets and the rapid development of ICTs. The four determinants of economic organisation have been fundamentally influenced by this paradigm shift. As a result, network arrangements have increased their comparative advantage in economic organisation relative to markets and hierarchies.

Despite the growing importance of information networks, ICTs are *not* a major explanatory factor in the emergence of the network paradigm. ICTs have made all organisational alternatives more efficient; they have not favoured any particular organisational arrangement over the others. Markets have clearly become more efficient as more information can be accessed and processed more easily. This is particularly evident for simple and standardised goods whose product attributes are well-

known to all market participants (financial instruments, raw materials, standard consumption goods). However, these goods were traded in markets well before the recent information revolution.

Hierarchies and networks have also benefited from easier information processing and communication. Large multinational corporations have been able to relocate their specialised activities to the most attractive locations around the world and co-ordinate them tightly through the new ICTs. Also, networks of firms and other interdependent organisations increasingly use ICTs to jointly optimise their operations. Hence, the growing importance of network arrangements cannot easily be explained by the new ICTs.

Two other features of the current paradigm shift seem to offer a better explanation for the growing importance of networks. The growing specialisation and uncertainty of economic activities has increased the comparative advantage of networks in economic organisation. This section will analyse the impact of these twin forces on the four organisational determinants discussed above.

The rapid growth of both national and international markets after the Second World War, as well as the increasing competitive pressures that followed the integration of markets, has led to an ever-increasing specialisation of economic activities (Hämäläinen, 1993). Although there are no statistics available, the specialisation and complexity of value-adding systems are likely to be at their historical highs today (see, for example, Hodgson, 1999; Hämäläinen, 2001).

At the same time, the uncertainty of economic activities has increased. The increasing specialisation and globalisation of economic activities, combined with the rapid structural change of modern economies, has challenged the information-processing capacities and cognitive frames of economic agents (Hämäläinen, 2001). They have become increasingly dependent on highly specialised and complex production systems without having full information, nor understanding, of their different parts and behaviour. The uncertainty of producers about future demand patterns has also risen due to longer production processes and the unpredictable behaviour of wealthier and more individualised consumers. Moreover, the growing specialisation of value-adding activities has led to growing indeterminacy in the production system by increasing the number of agents who can send "shock waves" through the system (Ranta, 1998).

Globalisation, in turn, has expanded the stock of potentially important business information, exposed firms to unpredictable foreign competitors, and challenged the relevance of established managerial frames (Hämäläinen, 2001). It is well known that international business activities involve more uncertainty than purely domestic ones (Johanson and Vahlne, 1977).

The old cognitive frames of economic agents have also been challenged by the increasing specialisation of production and the current paradigm shift in the world economy. The dynamic and complex processes of the "New Economy" cannot always be explained and understood with old theories and mental maps (see, for example, Arthur, 1994). Furthermore, the specialisation of cognitive frames has increased the behavioural uncertainties related to information asymmetries among interdependent agents (Hämäläinen, 2001).

Similarity of resources

The growing specialisation of productive activities has led to increasingly specialised and dissimilar resources and knowledge in value-adding systems. In terms of the transaction cost theory, the "asset specificity" of value-adding systems has increased (Williamson, 1985). As firms focus on their "core competences", they tend to develop closely related (similar) resources and capabilities internally and rely on co-operative ventures (networks) for the acquisition of more distant (dissimilar) but co-specialised resources (Kogut and Zander, 1992). The growing uncertainty of economic activities has also emphasised the need for networking by making organisations' future core resources and knowledge less certain. Particularly in high-technology industries, large corporations have formed numerous strategic alliances with small high-technology firms to obtain an "option" on their potentially valuable resources and knowledge.

Transaction costs

It has often been argued that the rapid development of ICTs has reduced the transaction costs of economic activities and thus made the market mechanism more efficient in recent years (see, for example, *The Economis*t, 1996). However, recent changes in the efficiency of markets depend on the types of goods and markets analysed. The greatest beneficiaries of modern ICTs have been markets for simple and standardised goods such as financial instruments, raw materials and commodities. These types of markets have clearly become more efficient with the new ICTs.

On the other hand, many service markets (personal services, training, etc.) and most markets for technology-intensive and highly specialised intermediate products and services (tailor-made parts and other inputs, management consulting, advertising, etc.) involve rich information flows which are difficult to codify for the modern ICTs. More importantly, the dynamic forces of the world economy have increased the transaction costs of markets:

- First, the growing specialisation of economic activities has led to increasing asset specificity, knowledge diversity and information asymmetry among economic agents (Williamson, 1985; Hodgson, 1999).

- Second, the increasing division of labour has reduced the impact of shared ideologies and values on individual and firm behaviour (Durkheim, 1893, reprinted 1964). This tends to undermine trust and other social constraints to opportunistic behaviour (North, 1981; Casson, 1990).

- Third, the increasing specialisation and differentiation of firms' resources and buyers' preferences has led to a proliferation of new products and product attributes in the marketplace. This has increased the search, measurement and enforcement costs of boundedly rational economic agents (Piore and Sabel, 1984; Willinger and Zuscovitch, 1988; Eliasson, 1990).

- Fourth, the bounded rationality of economic agents has been further challenged by the information explosion related to the globalisation of markets. Firms' exposure to new types of customers, competitors, institutions and cultures creates new information needs and uncertainties which cannot properly be dealt with in contractual exchange. It is well known that the transaction costs of international business activities are greater than those in purely domestic markets (Buckley and Casson, 1976; Hennart, 1982).

- Finally, the rapidly growing markets for information and knowledge products involve more uncertainty and transaction costs than do markets for more traditional goods and services (Arrow, 1962).

To sum up, the transaction costs of value-adding activities have been influenced by two opposing forces: ICTs have reduced the transaction costs of markets for simple and standardised goods; while increasing economic specialisation and uncertainty have increased the transaction costs of markets for more specialised, differentiated, complex and knowledge-intensive products. As a consequence, markets for the former types of goods have become more efficient in recent years while those for the latter types of goods have become less efficient. The growing transaction costs have increased the competitive advantage of networks and hierarchical organisations relative to markets in highly specialised and uncertain industries (Hämäläinen, 1993). In such industries, high transaction cost activities would require hierarchical organisation; while those that involve intermediate levels of transaction costs could be co-ordinated through co-operative networks (Williamson, 1991).

Co-ordination costs

The co-ordination costs of value-adding systems have also been increased by the growing specialisation and uncertainty of economic activities. The growing specialisation increases the co-ordination costs of value-adding systems by multiplying the number of activities that must be co-ordinated and increasing the specificity and richness of information links between them (Hämäläinen, 1993). The co-ordination of highly co-specific activities requires large information flows and effective communications between the interdependent activities (Daft and Lengel, 1986). The costs of communication, in turn, are increased by the growing diversity of individual knowledge sets and frames. As we have seen in Figure 1, the increasing specialisation and interdependence of value activities requires more effective and costly co-ordination mechanisms. These mechanisms can be used in both hierarchies and networks.

We have argued earlier in this chapter that hierarchical co-ordination becomes problematic at the highest levels of economic specialisation. The co-ordination tasks of top management can exceed their co-ordination capabilities and thus increase the co-ordination costs. As Kaldor (1934) and Robinson (1934) have noted, increasing co-ordination costs reflect the limited mental capabilities of top managers and the indivisibility of the co-ordination task.

Robinson (1934, p. 253) has also argued that hierarchical organisation can be extended indefinitely without a loss of efficiency only on two assumptions: first, that the necessary knowledge for decisions is small; and second, that the maximum amount of co-ordination is achieved at each level of the organisation, and the knowledge required for co-ordination at the next higher level need not descend into the lower levels. In managerial practice, neither of these assumptions are likely to hold.

The nature of the co-ordination challenge is also influenced by the amount of environmental change. Kaldor (1934) has argued that organisations can become larger in “quiet” periods when environmental change is less rapid. One such period of relative environmental “quietness” was experienced during the decades immediately following the Second World War (Piore and Sabel, 1984). The seemingly unstoppable growth of large hierarchies during this period led some researchers to doubt the practical effectiveness of the co-ordination cost limit to the growth of hierarchical organisations (Penrose, 1959, p. 18). However, the growing specialisation and uncertainty of modern value-adding systems has re-emphasised the “managerial limit” to organisational growth during the past two decades.

As we have argued, the increasing co-ordination costs tend to favour decentralised organisational solutions which economise the scarce co-ordination capability of individuals by dividing the overall co-ordination task into more manageable parts. To a certain extent, this decentralisation can take place within hierarchical organisations through divisionalised structures and improved accounting procedures (Chandler, 1979). The divisional structure divides the co-ordination and supervisory tasks of management into semi-decomposable units, thus maximising the co-ordination capability of the top management team. However, hierarchical solutions to co-ordination problems are limited.

At some point, the further growth of hierarchical organisation will be limited by the increasing co-ordination costs related to the bounded rationality of the management (Kaldor, 1934; Robinson, 1934; Simon, 1991). The growing size of the hierarchy also magnifies the agency problems, organisational politics, splintering of ideologies, bureaucratic alienation, and loss of information, which increase the monitoring and supervision costs (Williamson, 1975). This is where the benefits of decentralised information processing and co-ordination within networks of closely co-operating firms overwhelm the additional costs of inter-firm communication and co-ordination (Hämäläinen and Laitamäki, 1993).

Innovation

We have argued above that major inventions tend to take place when different types of knowledge are exchanged and combined. The growing specialisation on "core activities" has reduced the diversity of knowledge within organisations. The required complementary resources and knowledge cannot often be found within the boundaries of a single firm.[5] Hence, innovation processes increasingly demand inter-firm co-operation and networking.

In a highly specialised system, complementary resources and knowledge are likely to be highly specialised. Such highly specialised resources and knowledge cannot always be found in the innovating organisation's home location but needs to be sought in other locations in the same region, country or even abroad. Narula and Dunning (1998) note the rapid growth of international strategic technology partnerships (STPs) during the past two decades. They explain this growth primarily with the firms' innovation needs: STPs are an efficient way of combining firms' different knowledge bases.

We have also noted that the exchange and combination of different knowledge sets requires intensive long-term communication, shared language and overlapping cognitive frames. The growing specialisation of value-adding activities has led to increasingly diverse experiences among individuals, splintering of their cognitive frames and differentiation of language. Nahapiet and Ghohal suggested that these communication problems can be better resisted within corporate hierarchies than in firms which co-ordinate their activities through arm's length markets (Nahapiet and Ghoshal, 1998). However, high-trust networks can also support the rich communication flows needed for exchanging and combining diverse knowledge sets (Hage and Hollingsworth, 2000).

In this section, we have argued that the growing specialisation and uncertainty of economic activities has increased the comparative advantage of networks *vis-à-vis* markets and hierarchies. In the highly specialised and uncertain environment, networks allow deeper economic specialisation than hierarchies, reduce transaction costs relative to markets and co-ordination costs relative to hierarchies, and provide the most fertile ground for innovation. In the modern world economy, co-operation through networks is often the most efficient and innovative organisational arrangement.

Networking in the public sector

Public organisations have been challenged by the same dynamic forces as their private sector counterparts. The growth and specialisation of public sector activities has made them increasingly interdependent, giving rise to important cross-cutting policy issues and areas – such as environment, competitiveness, education – where public policies cannot easily be co-ordinated within the traditional "stovepipes" of government (Peters, 2000). Co-ordination costs have been raised by the increasing specialisation of public sector knowledge and organisational cultures which reduce the effectiveness of communication between related organisations. The systemic adjustment needs of societies caused by the rapidly changing techno-economic environment have created additional co-ordination challenges for public sector organisations (Hämäläinen, 2001).

The growing co-ordination problems of public sector organisations require stronger co-ordination mechanisms rather than rules and regulations or hierarchical planning. Moreover, the earlier strategy of decentralisation and disaggregation of public sector activities is no longer sufficient. In terms of Figure 1, horizontal co-ordination must increasingly rely on mutual adjustment as well as shared vision, strategy, understandings and values. This is a major challenge for governments which have traditionally focused their creative energies on finding new and more efficient hierarchical co-ordination mechanisms and structures (for a good review, see Peters, 2000). In addition to the visionary leadership of top policy makers and the horizontal day-to-day co-ordination of civil servants and other public sector employees, an efficient and innovative public sector requires effective vertical communication and co-ordination among the different levels of government. Otherwise, the visions and strategies lose touch with the realities of grassroots policy making and the former are not effectively communicated to all public sector employees.

The growing specialisation of public sector organisations has also made their resources and knowledge increasingly specific and dissimilar from other public and private sector organisations. As a result, the necessary complementary resources and knowledge often lie in other public or private sector organisations. If such resources and knowledge are supplied by multiple competing private sector organisations, the public sector organisation can acquire them through competitive bidding or "quasi-markets" (le Grand and Bartlett, 1993). On the other hand, if there are only few specialised suppliers, closer co-operation and co-ordination in the form of public-private partnerships (PPPs) may be called for. Quasi-markets and PPPs are typically used for the provision of public services.

Quasi-markets and PPPs can also be used for the commercialisation of certain public goods, such as basic research or infrastructure. The growing patenting and licensing activities of universities and their increasing co-operation with firms in basic research are good examples of such activities (Nelson, 2000; Lennon, 2001). Similar to the private sector example, quasi-markets use the price mechanism for co-ordination while public-private partnerships call for co-operative planning, mutual adjustment together with shared visions, strategies, understandings and values.

If public-private co-operation involves policy making or implementation, PPPs are often called "policy networks" (Schneider and Kenis, 1996, p. 42). Such networks can utilise the knowledge and capabilities of widely dispersed actors in different sectors and levels of the society.[6] Policy networks can also help to create a collective vision for society and commit the key stakeholders to implementing the chosen strategies. On the other hand, they can also tie the hands of policy makers if the necessary decisions would threaten the interests of some key players in the network (Olson, 1982). This may slow down society's structural adjustment process during a techno-economic paradigm shift.

As noted above, the organisational reality is more complex and dynamic than the "ideal" organisational alternatives might suggest. Private and public hierarchies have responded to the organisational challenges by introducing market and network elements *within* themselves. Most large

firms in dynamic industries actively use horizontal co-ordination and flexible network arrangements in their internal operations. Public sector hierarchies have more experience in introducing market-based mechanisms and pricing for their internal service relationships (see, for example, OECD, 1994). Such hybrid solutions require very skilful and difficult balancing of the features of different organisational alternatives.

Recently, some management experts have argued that, in some countries, the market-based reforms may have gone too far in commercialising government activities (Mintzberg, 1996; Kuttner, 1997). In their view, public sector organisations need a mixture of co-ordination mechanisms and the appropriate role for market-mechanism might not be as large as is often thought.

Henry Mintzberg provides four stylised models of government that correspond to the four co-ordination mechanisms discussed earlier in this chapter: rules and standards, hierarchical planning, mutual adjustment, and shared vision, strategy, understandings and values (Mintzberg, 1996). The "government as a machine" model is based on rules and standards. This model was originally developed by Frederick Taylor at the beginning of the 20th century, although it remains the dominant model of co-ordination in most governments.

"The machine model developed as the major countervailing force to corruption and to the arbitrary use of political influence. That is why it became so popular earlier in this [20th] century. It offered consistency in policy and reliability in execution. But it lacked flexibility and responsiveness to individual initiative, so now it has fallen out of favour" (Mintzberg, 1996, p. 80).

The "performance-control" model of government aims to run government more like a business. Co-ordination mechanisms are adopted from the divisionally structured business conglomerates: the overall organisation is split into "businesses" that are assigned performance targets for which the managers are held accountable. The "headquarters" plans and controls while the operating units execute. A heavy emphasis on planning and measured performance reinforces the hierarchical control.

In the "government-as-network" model, government is viewed as one intertwined system, a complex network of temporary relationships fashioned to solve problems as they arise and linked by informal channels of communication (see also Dunning, 1992). At the operational level, the work is organised around projects – for example, a project to develop new policy on social welfare or to develop new measures to increase service sector employment. Policy networks rely on mutual adjustment in the co-ordination of interdependent activities.

The "normative model" of government is based on shared visions, values and beliefs. Four other key elements characterise this model:

- People are chosen for their values and attitudes rather than simply on their credentials.
- Thorough socialisation ensures that civil servants are dedicated to an integrated social system.
- All members share responsibility; they feel that they are trusted by their leaders who practice a craft style of management, rooted in experience.
- Performance is judged by experienced people, including the recipients of the service.

According to Mintzberg, there is no best model: governments need to use them all. However, he also argues that there is currently an overemphasis on the machine and performance models which rely on rules and standards and planning as co-ordination mechanisms, respectively (Mintzberg, 1996).

Much more could be made of the network and normative models (see also Dunning, 1992; Chang and Rowthorn, 1995). The network model is necessary for the many complex, unpredictable and cross-cutting activities of today's governments. The normative model, in turn, is needed because there is no substitute for a clear vision, strong values and human dedication when decision making involves numerous vagaries, nuances and difficult trade-offs among conflicting interests (Mintzberg, 1996; Peters, 2000).

Mintzbergs's conclusions can be well understood in the light of our previous analysis. Both private and public sector hierarchies have come under increasing pressure as the technological and economic environment began to change more rapidly after the mid-1970s. Due to the growing size and specialisation of government, cross-cutting policy issues and systemic adjustments became increasingly difficult to co-ordinate hierarchically, not to mention rules and standards. As a result, top policy makers became overloaded with responsibilities, decisions became less coherent and co-ordination costs began to grow (Grimm, 1991, p. 133). At the same time, the growing specialisation of sectoral organisations increasingly insulated them from external stimuli and complementary knowledge which reduced the potential of major policy innovations.

The network and normative models of government can reduce the co-ordination costs of public sector organisations by delegating operational co-ordination activities to lower levels of organisations, while top policy makers will focus on developing and strengthening shared visions, strategies, understanding and values. These higher-level co-ordination mechanisms guide the day-to-day horizontal co-ordination (mutual adjustment) of interdependent activities at all levels of the organisation (Aoki, 1990). Planning, as well as rules and standards, are applied to more simple co-ordination tasks where the need for rich horizontal information exchange is less important.

Social capital and networks

Earlier in this chapter, we suggested that organisational arrangements are influenced by certain cultural factors surrounding organisations. These factors are often grouped under the term "social capital". This term is somewhat misleading since "capital" has traditionally referred to a productive input. As we will see in this section, social capital describes the social context in which productive inputs are organised and used.[7] We will analyse here the different characteristics of social capital, how it affects economic organisation and performance, the mechanisms through which it accumulates, and why it has become so important in recent years.

There are various definitions of social capital, all of which emphasise the social relationships and norms among individuals, their ability to co-operate and the resources that can be mobilised through such co-operation (Fukuyama, 1995; Nahapiet and Ghoshal, 1998). In this section, we will use the more refined definition proposed by Nahapiet and Ghoshal, who distinguish between three dimensions of social capital: structural, relational and cognitive.

The structural dimension describes the overall configuration of linkages among people (network ties). These linkages can be measured in terms of their density, connectivity, redundancy and hierarchy. The relational dimension describes the kinds of personal relationships and behavioural norms that people have developed with each other through a history of interactions. Such relationships are characterised, *inter alia*, by friendship, respect, trust, obligations and identity. The cognitive dimension refers to shared understandings, mental frames, language, narratives and meanings among a group of individuals. As we can see, social capital is jointly owned by the parties in a relationship. Since it can yield both private and public benefits, it has public good characteristics (Kajanoja, 1999; Woolcock, 2000).

The amount of social capital in a society has a significant influence on its economic performance. James Coleman showed that the amount of social capital in families and neighbourhoods had an important impact on the creation of human capital in the United States (Coleman, 1988). According to Robert Putnam, social capital could also explain differences in economic performance among Italian regions (Putnam, 1993). Douglas North, in turn, has shown how the institutional framework of societies has been an important determinant in their economic performance throughout economic history (North, 1990). North's definition of "informal institutions" corresponds to an important part of relational social capital; it includes culturally embedded norms, customs, traditions, conventions, customs, sanctions and codes of conduct. More recently, the World Bank has started to study the impact of social capital on economic development and growth (Woolcock, 2000).

Economic analyses of social capital have focused primarily on its transaction-cost-reducing properties (see, for example, Casson, 1990; Fukuyama, 1995). However, the economic impact of social capital is much wider and more important. It shapes all of our four determinants of economic organisation: specialisation, transaction and co-ordination costs, and innovation. First, a high degree of economic specialisation is not possible without social capital. As we have seen, specialisation and division of labour create interdependencies and uncertainty by exposing economic agents to the behaviour of their exchange partners. The uncertainty of such relationships is greatly reduced by strong relational and cognitive social capital (trust, norms, reciprocity, shared frames). This is also the reason for the lower transaction costs in "high-trust" societies (Casson, 1990; Fukuyama, 1995). The lower transaction costs, in turn, make markets and network arrangements more efficient.

High levels of social capital also tend to reduce co-ordination costs in value-adding systems. Shared behavioural norms reduce the information-processing needs of individuals as they can take certain types of behaviour for granted and the same norms guide their own behaviour towards socially acceptable ends. Perhaps more importantly, the effectiveness of the stronger co-ordination mechanisms is highly dependent on social capital. The size and structure of an individual's network of personal relationships shapes his information about systemic co-ordination needs (Nahapiet and Ghoshal, 1998). Strong relational and cognitive social capital, in turn, facilitates horizontal co-operation, mutual adjustment and the creation of shared visions, understandings, values and strategies.

Besides facilitating economic specialisation and reducing transaction and co-ordination costs, social capital has a positive impact on the innovation processes. Wide inter-personal networks increase the diversity of knowledge available to individuals and organisations. The relational part of social capital influences the access of individuals and organisations to different sources of complementary knowledge and their motivation to exchange it (Yli-Renko *et al.*, 2000). Finally, a shared language and cognitive frame support the intensive communication required for combining different knowledge sets. Hence, the social capital shapes the individuals' and organisations' "combinative capabilities" (Kogut and Zander, 1992).

In conclusion, the amount of social capital in an economic system will not only influence its transaction costs but also its productivity (through specialisation), co-ordination costs and innovativeness. Hence, social capital is a fundamental determinant of economic performance at the level of value-adding systems, industries, regions and even nations (Casson, 1990; Yli-Renko *et al.*, 2000; Putnam, 1993; Fukuyama, 1995). Moreover, as we will show below, its role in value-adding systems has become even more important in recent years.

However, the economic impact of social capital is not always positive. Particularly during major paradigm shifts, strong social capital can lead to mental and behavioural rigidities among decision makers which may prevent the necessary organisational and institutional adjustments to changing environmental conditions (Nahapiet and Ghoshal, 1998; Hämäläinen, 2001). A strongly shared

cognitive frame and language can make individuals insensitive to contradictory information and totally new perspectives (Festinger, 1957). Strong inter-personal relations, in turn, can make individuals unwilling to take new actions (or make new combinations) which could harm well-established societal interests (Olson, 1982; Yli-Renko *et al.*, 2000). During the past decade, the inability of Japanese society to renew its post-war institutional structures despite a prolonged recession has provided an interesting example of such a situation.[8]

Social capital has to be relevant to the changing needs of the economy in order to have a positive impact on economic performance. A rapidly changing environment can make previously beneficial social capital economically irrelevant or even counter-productive, and *vice versa*. Wolfgang Streeck gives the example of Northern Italy whose small artisanal family firms embedded in dense family ties and local networks of parties, unions and employers' associations were deplored as a sign of backwardness in the 1960s. These same firms came to be regarded as a principal source of the region's impressive competitive performance of the 1970s and 1980s when the technological and market environment changed (Streeck, 1997, p. 211).

The fact that social capital has such an important effect on economic efficiency and innovation raises the question: How does it develop? Also, from a policy perspective, how could social capital be built and renewed? Based on their extensive review of the literature on social capital, Nahapiet and Ghoshal conclude that the development of social capital is significantly affected by factors that shape the evolution of social relationships: interaction, time, interdependence, closure and co-location (Nahapiet and Ghoshal, 1998).

Social capital develops in interactions among individuals. Social interaction and communication build all three dimensions of social capital: structural, relational and cognitive. Interactions with previously unknown individuals build social networks, while continuous interactions with established contacts accumulate relational and cognitive social capital. Without continuous interaction, social capital begins to decay (Bourdieu, 1986, p. 250).

The development of the relational and cognitive dimensions of social capital require long-term interaction and shared experiences. It takes time to build trust and a shared frame among individuals who did not previously know each other. Usually, such long-term relationships were not designed for the creation of social capital, rather social capital accumulates as a by-product of other activities. However, policy makers can facilitate the creation of social capital by bringing people together in meaningful long-term interactions and co-operation.

As noted long ago by Durkheim, the relational part of social capital is shaped by the degree of specialisation and interdependence among people (Durkheim, 1893, reprinted 1964). High levels of interdependence both build and require high levels of trust, mutual obligations and shared expectations among individuals. On the other hand, social capital is eroded by factors which make people less dependent on each other (Coleman, 1990).

Finally, the creation of relational and cognitive social capital tends to require co-presence and co-location. Building trust and shared understanding requires a long period of rich communication and active interaction which is difficult to achieve if people are physically distant from one another. Modern ICTs do not replace the need for face-to-face communication in complex learning and reframing processes (Daft and Lengel, 1986; Bierly and Hämäläinen, 1995). Telecommunications can only complement face-to-face communication in such processes (Woolcock, 2000).

The determinants of social capital limit the institutional contexts in which it can be accumulated. The natural bases for long-term and relatively closed interactions characterised by a high level of interdependence and co-location include families, neighbourhoods, work places, schools, universities,

military service and social associations. More temporary relationships, such as holiday or conference trips, business projects or training courses can also build social capital among their participants.

Different organisational arrangements have different relationships to social capital. Market relationships are not conducive to the creation of social capital (Nahapiet and Ghoshal, 1998). These relationships tend to be temporary, impersonal, loose and dynamic. None of these characteristics facilitates the development of social capital. However, markets are dependent on social capital. As we have seen, economic specialisation and market transactions are greatly facilitated by social capital.

Nahapiet and Ghoshal argue that organisations have a special advantage in the creation of social capital. They facilitate long-term interaction, interdependence, closure and co-location. Hence, organisations are better environments for innovation and learning than are markets. In their capacity to accumulate social capital, networks fall somewhere in between markets and hierarchies. They clearly foster greater interaction and closer interdependence among agents than markets; but their inter-personal relationships are usually somewhat looser, more temporary and open than those in hierarchical organisations. As a result, the functioning of networks is dependent on external sources of social capital. This may explain why the interest in social capital has increased in tandem with the rise of the network paradigm. We will return to this topic below.

It is important to note that the members of a particular culture may share some social capital although their relationships do not necessarily meet the above criteria of long-term interaction, interdependence, closure and co-location. If the members of a culture are sufficiently homogenous in their historical experiences, educational background, living and working conditions, and media consumption they can extend the relational and cognitive dimensions of social capital also to those members of the culture whom they have never met before. Thus, people may, to a certain extent, trust and understand members of their own culture even without long-term experience of their behaviour and thoughts. Such cultural social capital is particularly evident in "high-trust" societies such as Finland and Japan (Casson, 1990). Culturally heterogeneous societies must rely more on other sources and types of social capital (Fukuyama, 1995).[9]

Social scientists and policy makers from various sectors have become increasingly interested in the concept of social capital during the past decade (Woolcock, 2000). The growing interest in social capital is closely related to the current transformation in the world economy. First, as we have seen, co-operative networks have become increasingly efficient and innovative *vis-à-vis* markets and hierarchies. However, networks cannot themselves create all the social capital necessary for their success. They need be embedded in social capital produced outside the network.[10] Thus, the emergence of the network paradigm has increased the demand for social capital, particularly in comparison to the old hierarchical paradigm. The efficiency and innovation advantages of networks cannot be reached without sufficient social capital.

The other main reason behind the growing interest in social capital is related to its diminishing supply in advanced economies. Some authors have even argued that social capital might become the most scarce production factor in the future (Lundvall, 1998). The changing nature of work and social values associated with the current paradigm shift have led to a decay of many traditional sources of social capital (Fukuyama,1999; Putnam, 2000).

The growing specialisation of work has produced increasingly differentiated work experiences and cognitive frames among workers. Unlike the agricultural work of the pre-industrial era, or the simple factory work of the industrial one, the, highly differentiated modern working life offers very few widely shared experiences that could form the basis for common understandings, norms and identity.

The techno-economic paradigm shift has also changed the nature of employment relationships. A surprisingly large and growing fraction of the labour force works in "contingent" or "non-standard" jobs: part-time workers, temps, independent contractors (consultants), "on-call" workers (substitute teachers, rush-hour help, etc.), and the like (Putnam, 2000; Suikkanen *et al.*, 2001). As Putnam notes, the instability of jobs has weakened the social capital at work places. Building social relationships takes time and requires stable contacts.

The last few decades have seen the rise of individualistic values in advanced societies (Inglehart, 1977; Putnam, 2000). The rapid accumulation of wealth during the post-war decades has pushed a large part of the population in industrialised countries to income levels where their basic needs have already been met. From a Maslowian perspective, rising individualism, or even selfishness, is related to the growing importance of a need for self-actualisation in today's society. Wealthy individuals actively pursue their favourite hobbies and leisure activities, often at the expense of time spent with their families, relatives, friends and associates. Moreover, today's leisure activities tend to be more individualistic than before (Putnam, 2000). Hence, they do not generate social capital in the way the more social leisure activities of the past did.

In summary, the economic importance of social capital has increased in recent years due the demands of the new network paradigm and the diminishing supply of social capital in families, among relatives and friends, and in social associations. Social capital has become a scarce resource in economic organisation and performance.

Network failures

The comparative organisational advantage of markets, hierarchies, networks and governments depends on their relative strengths and weaknesses in particular contexts. The advantages and disadvantages of markets, hierarchies and governments have been thoroughly analysed by economists, management scholars and political scientists. Hence, "market failures", "bureaucratic failures" and "government failures" are well-established terms in the literature. This chapter has focused on the comparative advantages of networks in economic organisation. It is now appropriate to discuss the potential weaknesses of network arrangements, or "network failures". This area of organisational analysis has been neglected by most network research.[11]

Networks may become inefficient if their environment changes dramatically and calls for large systemic adjustments. Since networks involve multiple partners with diverse interests, achieving swift and well co-ordinated adjustments in the system can pose problems. Some partners may favour more rapid adjustments than others and the negotiation process may delay action. Systemic adjustments may also be slowed down by poor contacts and communication among some actors of the network (Hage and Hollingsworth, 2000).

Large network-specific investments and close interdependency can make network partners conservative and risk averse as rapid change can have unintended and unpredictable consequences. As we argued with social capital, this problem will further slow down systemic adjustments and can lead to technological and structural "lock-ins".

Networks are vulnerable to conflicts. Network co-operation requires continuous negotiation and mutual adjustment which may lead to conflict if systemic trade-offs cannot be properly resolved. Networks produce economic benefits and involve tangible costs, which have to be allocated among their members. There is no predetermined formula for doing this. Conflicts among network partners can arise from asymmetric power relationships. If the leading organisation in the network misuses its powerful position, it may undermine the social capital among partners. Trust, reciprocity and fairness

are the key characteristics of well-functioning networks. On the other hand, some partners may also free-ride the network-building investments and activities of leading organisations. Free-riders pick up the benefits of co-operation but do not contribute their fair share of the network's operating costs. This too will diminish the social capital underlying the network.

Over time, established networks will create internal routines, conventions and rules, which facilitate their day-to-day operations. These internal "institutions" may begin to insulate the network from outside organisations. As a result, the network may become "fossilised" and more or less closed to the outside world and particularly to potential new partners. Sometimes, isolation may be planned in order to exclude other organisations from the network. Some of the social benefits of networking are, of course, lost through such isolation.

It is important to note that the above network failures are related to problems with social capital. First, the co-ordination of complex systems is supported by strong social capital. Hence, scarcity of social capital will lead to co-ordination problems. A small network of partners will limit the available co-ordination information, while weak relational and cognitive social capital will make horizontal co-operation and co-ordination difficult. In addition to co-ordination problems, a lack of relational and cognitive social capital will increase the probability of inter-personal conflicts, misuse of power and free-riding in the network.

On the other hand, too strong social capital can cause other problems. During a transformation, strong inter-personal and inter-organisational relationships may cause behavioural rigidities, conservatism and lock-ins in the network because the short-term personal costs of change (loss of trust, reciprocity, friendship, etc.) are clear, while the long-term outcomes of systemic adjustment may be uncertain. The isolation of a network from the outside world is another example of a situation where strong relational and cognitive social capital may have undesirable consequences (Yli-Renko *et al.*, 2000).

In sum, the reduction of network failures seems to call for a careful balancing of the three types of social capital: the structural one, on the one hand, and relational and cognitive ones, on the other. To employ Woolcock's terms, there is a need for optimising the balance between the "extra-community networks" and "intra-community ties" (Woolcock, 2000).

Conclusion

The emergence of the network paradigm of organisation is an important part of the current transformation of the world economy. This chapter analysed the comparative advantage of networks in economic organisation. We argued that networks provide particular efficiency and innovation advantages relative to markets and hierarchies in highly specialised and uncertain value-adding systems. Our organisational framework focused on four characteristics of value-adding systems: *i)* similarity of resources and knowledge in different activities; *ii)* level of transaction; *iii)* co-ordination costs; and *iv)* the nature of innovation processes. These four factors influence the organisational arrangements in value-adding systems. Thus, single factor theories, such as the transaction cost theory, do not provide a full picture of the organisational processes.

The transformation of the world economy has increased the comparative advantage of networks in economic organisation by raising the level of specialisation and uncertainty in economic systems. These twin forces have made productive resources and knowledge increasingly dissimilar, raised the transaction and co-ordination costs in value-adding systems, and emphasised the systemic nature of innovation. Taken together, these trends have favoured network arrangements over markets and

hierarchies in recent years, with network arrangements becoming more common both within the public sector and between the private and public sector organisations.

Social capital plays an increasingly important role in modern economies. It supports a high degree of specialisation and productivity, reduces the transaction and co-ordination costs of complex value-adding systems, and improves the "combinative capabilities" of innovators. In the past, large hierarchical organisations produced a large part of the social capital required by the economy. However, loosely coupled, open and dynamic networks cannot by themselves create all the necessary social capital. They are dependent on other external sources of social capital. As a result, the importance for social capital has become increasingly evident with the rise of the network paradigm. The importance of social capital has been further emphasised by recent changes in the nature of work, social values, concentration of economic activities and cultural pluralism which have undermined the traditional sources of social capital in society.

Finally, networks involve their own specific failures which are comparable to traditional market, bureaucratic and government failures. These network failures are often related to the imbalance between the different types of social capital underlying networks. Hence, social capital can both facilitate and hinder the functioning of networks.

NOTES

1. The framework focuses on the economic determinants of organisation, although we acknowledge that, in some situations, power motives may also play a role in organisational decisions. For a discussion of the relative merits of economic and power approaches to organisational analysis, see Perrow (1981), Williamson and Ouchi (1981), Francis, Turk and Willman (1983) and Williamson (1991).

2. Indeed, measuring the relative weight of each factor and the trade-offs between them in particular contexts forms an important challenge for organisational research. In this chapter, we will take initial steps in that direction.

3. The destruction of large hierarchical organisations in the US computer industry during the 1990s provides a good example of these trends (Hämäläinen and Laitamäki, 1993).

4. Hage and Hollingsworth argue that the more frequent and intense the communication among actors, the more tacit knowledge is communicated among them. Less frequent and intense communication tends to involve only codified knowledge (Hage and Hollingsworth, 2000).

5. The number of potential combinations of different elements of knowledge grows very rapidly as the number of elements increases. As a result, networks – which involve more diverse elements of knowledge than hierarchies – have a substantially higher potential for innovative combinations.

6. The close co-operation between the top decision makers of the state and the central labour market organisations in corporatist countries is a traditional example of policy networks (Pekkarinen *et al.*, 1992). Today, however, policy networks can involve actors from many different levels and sectors of society.

7. The use of term "social capital" in the context of organisational arrangements has made the discourse more legitimate among economists, particularly those of the neo-classical tradition. In that tradition, markets are assumed to function efficiently, thus making organisational issues irrelevant for economic performance (Hämäläinen, 2001). In this section, we will argue that social capital is important precisely because it facilitates efficient and innovative organisational arrangements.

8. Woolcock suggests that the negative consequences of strong social capital can be reduced by an appropriate balance between "intra-community ties" and "extra-community networks" or, in our terminology, the structural dimension of social capital, on the one hand, and the relational and cognitive dimensions, on the other (Woolcock, 2000).

9. A recent study by Alesina and La Ferrara (2001) using US data shows that African-Americans and members of racially mixed communities were far less likely than whites or others living in racially homogenous communities to trust people from outside their communities.

10. Miettinen *et al.* (1999) provide examples of major Finnish innovations where key individuals in innovation networks had learnt to know and trust each other long before they began to co-operate. The close relationships were not built specifically for the network, rather, the network utilised the social capital built up much earlier. Hence, the development and accumulation of social capital may have unpredictable consequences years or even decades later.

11. Network failures must be distinguished from failures in setting up networks. The latter will be discussed in the concluding chapter of this book. Network failures, in turn, cause existing networks to fail or perform below their potential. In this section, we will focus on the problems of existing networks.

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PART II

APPLIED ANALYSIS OF CO-OPERATION/COLLABORATION/NETWORKING

Chapter 3

INNOVATIVE ACTIVITY AND FIRM CHARACTERISTICS: A CLUSTER ANALYSIS OF SWISS MANUFACTURING USING FIRM-LEVEL DATA

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Introduction

The innovation process is a complex phenomenon characterised by several stages, ranging from basic research to the penetration of the market with new products. Therefore, a whole series of indicators is needed to describe and measure a firm's innovative activities, each of which stresses specific aspects but also gives rise to measurement errors. Based on such a system of indicators, one may look either for specific patterns of innovative activity ("innovation types") or for a ranking of firms according to a composite measure of innovativeness ("innovation intensity").[1] The first (classificatory) procedure is less restrictive because, in contrast to the ranking approach, it does not enforce "homogenisation" upon the basically heterogeneous nature of the innovation process. In addition, in concordance with the evolutionary view of technological change, it allows for the co-existence of different innovation types which, at least during a certain period of time, may be viable in economic terms. This feature may reflect specific economic environments and/or a certain freedom for strategic choices by firms.

The present chapter is based on such a classification approach. It aims to describe the innovation process in Swiss manufacturing, in terms of the prevalence and importance of specific innovation types and their impact on productivity. Drawing on firm-level data from the 1996 KOF/ETH Innovation Survey, which in its core questions is comparable to the first "Community Innovation Survey" (CIS), conducted in most European countries, we are able to determine a number of innovation types using of cluster analysis.

What are the criteria to be applied in defining such innovation types? We think that such an exercise should be based on a set of:

- *Innovation indicators*, representing different aspects of the innovation pattern of firms, *i.e.* the input and output sides of technological innovation as well as its impact on firms' revenues.

- *Knowledge sources*, which a firm may use in its innovative activities both in an informal way and through formal R&D co-operations depicting the network of the firms' knowledge linkages.

Innovation types based on these two categories of variables are described by a number of additional variables relevant for the innovation process; these include human capital intensity, appropriability, market conditions or demand perspectives as well as some general firm characteristics such as size, activity field (two-digit industries) and export orientation and, finally, some measures of economic performance. In this way, a comprehensive picture of the structure of Swiss firms' innovative activity emerges.

The (analytical) point of reference for this investigation is the typology proposed by Pavitt (1984). However, the present chapter is based on a statistical method (cluster analysis). Arundel *et al*. (1995) also used cluster analysis to classify firms with respect to several innovation indicators and knowledge sources, although they refrained from combining the two types of information in a systematic way. In addition, because their work is based on information for the 500 largest European firms, it is representative of only part of the economy. A recent study by Cesaratto and Mangano (1993), whose methodological procedure was adopted in the present chapter, is less comprehensive; their cluster analysis is restricted to innovation indicators. In this perspective, our work may add some knowledge to the body of literature on typologies of innovative firms.

The chapter is structured as follows: The database and the innovation indicators, as well as the variables depicting the knowledge sources, are briefly described in the following section, which also describes the procedure used to identify innovation types. The empirical results with respect to innovation indicators and knowledge sources are presented and discussed in the third and fourth sections, respectively. In the fifth section, we analyse the relationships between groups of firms based on their innovation and knowledge patterns. Finally, we draw some conclusions and propose some elements for future research.

Data and method

The data used in this study are taken from a survey on innovative activity of Swiss private enterprises conducted in 1996, which was based on a stratified random sample (17 industries and three firm size classes for each industry with full sampling of the upper size class). The present analysis is confined to the sub-sample of 2 966 manufacturing firms (17 industries), which were asked to fill in a questionnaire about their innovative activities and a large set of other variables relevant to the description of the innovation process and the explanation of innovation performance during 1994-96. Valid answers were received from 1 048 firms, *i.e.* 35.3% of the original sample (see Arvanitis *et al*., 1998, Ch. 2 for the details of the survey). The search for innovation types was based on the sub-sample of innovative firms (804 companies, or 77% of the respondents), which had to be further reduced because of missing values for some of the innovation and knowledge source variables. This reduction led to a final data set of 516 firms with some over-representation of large companies and firms in the machinery industry. On the whole, the structure of the data set can be considered as representative of the original sample.

The information collected enabled us to construct 15 innovation indicators. Eight of these refer to the input- and output-sides of the generation of innovations, with separate measures for product and process innovations; the third type of indicator is oriented towards the introduction of novelties on the market. These variables, together with the corresponding measurement scale and value ranges, are listed in the upper part of Table 1. All of the input- and output-oriented measures used are qualitative variables measured on a five-point Likert scale. The corresponding quantitative measures; for example, R&D expenditures or total innovation costs as a percentage of sales, although available, are not used in the present study because of the considerably higher number of missing values compared to ordinal measures. In earlier work, we found the information content of the two types of measurement to be very similar (Arvanitis and Hollenstein, 1994, 1996). The three market-oriented

indicators referring to different definitions of innovative products are quantitative variables measured as sales shares. Furthermore, the survey identifies 17 external sources of knowledge, the importance of which had to be assessed by respondents, again on a five-point Likert scale (see lower part of Table 1). These sources of knowledge can be grouped in four categories: the first referring to knowledge from other firms; the second to the "science sector" as a whole; the third to generally accessible knowledge; and the last one to knowledge embodied in several input factors.

The search for innovation types is based on two pieces of cluster analysis, the first referring to the innovation indicators listed in Table 1, the second based on the knowledge sources cited in the same table. However, cluster analysis was not conducted with the original variables. In a preliminary step, these two sets of 15 and 17 measures, respectively, were condensed separately to a small number of new variables by means of a factor analysis (principal component factor analysis). In a second step, we performed a cluster analysis to group the firms into a number of categories which were, with respect to the variables under investigation, as homogenous as possible (small within-cluster variance) and at the same time as different as possible from each other (large between-cluster variance). In a third step, these two sets of clusters were characterised in terms of the underlying variables (*i.e.* innovation indicators and knowledge sources, respectively), a number of additional variables relevant for the innovation process (human capital intensity, appropriability conditions, intensity of R&D co-operation), some general firm characteristics (size, industry, export orientation, market conditions, demand perspectives), and some measures of economic performance.

Innovation clusters

The preliminary step of factor analysis, shown in detail in Annex Table A1, leads to statistically satisfactory results. The four factors extracted in the analysis account for 68% of total variance. The factor solution is also convincing in economic terms, as can be seen from the factor pattern depicted in the same table. The first factor accounts for 21% of total variance and gives high weights to input- and output-oriented indicators for product innovations. The second component, capturing 18% of the variance, shows high loadings with respect to market-oriented indicators, which, by definition, refer to product innovation only. The third factor, explaining 17% of total variance, refers primarily to the engineering/design activities and follow-up investments, and the fourth one to R&D activities (12% of total variance).

In the second step, we conducted a non-hierarchical cluster analysis based on the four principal components extracted in the factor analysis of the first step. This led to a grouping of the firms in terms of innovation indicators into five categories.[2] The achieved solution shows satisfactory statistical properties in terms of the relationship of within-cluster as compared to between-cluster variance. The approximate expected overall R^2 of .56 points to a rather good fit of the data to the underlying clustering model.

Before describing the single clusters in some detail, a general characterisation may be helpful. The innovative activities of firms belonging to Cluster 1 are fairly intensive, primarily based on engineering/design as well as follow-up investments for both products and processes. Cluster 2 is characterised by a low innovation intensity referring to products improved through some engineering/design efforts. Cluster 3 is the analogue of Cluster 2 with respect to process innovation with an (almost exclusively) investment-based innovation pattern. The firms of Cluster 4 are very innovative in all of the aspect examined here for both types of innovation and are the most research-intensive. Cluster 5 contains a small number of innovators who develop new products which are considered as new to the world market ("world novelties"), based on heavy development and engineering activities. Let us now turn to a closer examination of the five clusters in terms of the information given in the Tables 2, 3 and 4 and of some additional data.

Cluster 1

This is the largest cluster in terms of number of firms and employment as a share of the total of our sample (36% and 39%, respectively). Compared to the average of the manufacturing sector, this cluster is heavily composed of medium-sized enterprises. The export share is distinctly above-average, although lower than that of Clusters 4 and 5. Firms of the metalworking and transport equipment industries are most prominent in this cluster, although the machinery sector as well as the paper and the printing industry are more strongly represented than on average.

Innovative activities of firms belonging to Cluster 1 are concentrated on engineering/design as well as follow-up investments, while development inputs are almost equal to the average; own research is totally absent. Innovation intensity, as measured by input- as well as output-oriented indicators, is high for both products and processes. Consistent with this pattern of innovative activities is the focus on in-depth product improvements, but not on world novelties which require large amounts of R&D. In sum, the innovation strategy of this cluster, although incremental in nature, is substantial in outcomes leading to high-quality improvements to existing products.

No specific traits can be found with respect to market conditions in terms of concentration (number of competitors at world scale), intensity of price and non-price competition as well the medium-term development of the market potential.[3] The same holds for the two measures of economic performance used in this study, the ratio of value added to labour input and the share of capital income to total value added. In view of the relatively large share of firms in this cluster and their substantial employment share, the innovation pattern of Cluster 1 is representative of a considerable part of Swiss manufacturing.

Cluster 2

This cluster comprises almost as many firms as Cluster 1 (32% *vs.* 36%), but its employment share is much lower (19% *vs.* 39%), reflecting both the absence of large firms and the over-representation of very small firms with less than 50 employees. The export orientation of the firms in this cluster corresponds to the average of the manufacturing sector. Firms of the food, the textiles and clothing and the watch-making industries are particularly well-represented in Cluster 2; chemicals (excluding pharmaceuticals), non-metallic mineral products and metal production are also represented to a quite substantial extent.

The innovative activities of Cluster 2, which are exclusively product-oriented, are rather modest. They are concentrated on development and engineering/design, leading primarily to improvements of (existing) products whose importance in technological as well as economic terms is clearly below average. This pattern reflects a purely incremental, low-profile innovation strategy.

Rather surprisingly, we do not find any clear features with respect to economic and market conditions, except for slightly below-average growth perspectives for the product market.

Cluster 3

This cluster is small both in terms of the number of companies (9%) as well as employment (4%). Two-thirds of its firms employ less than 100 workers. Most of the firms in this sector are strongly oriented to the home market; more than half do not export at all. The most important industries are wood processing, printing, chemicals (excluding pharmaceuticals), non-metallic mineral products and metal production. In addition, the food industry and the industry for electrical machinery (primarily

the segment producing equipment for the construction industry), are fairly well represented in this category of firms.

Innovation in this cluster is exclusively oriented towards the introduction of new processes and primarily involves the acquisition of capital goods; follow-up investment is the only innovation input with an above-average relevance for these firms. In view of this innovation pattern, it is surprising that the market-oriented indicators show higher shares of improved products than for Cluster 2 with its purely product-oriented innovative activities. Clearly, in many instances, investments in new production techniques lead to substantial modifications to existing products.

With respect to market conditions, Cluster 3 differs from all of the other clusters (and also from average of the manufacturing sector). The firms in this cluster are confronted with more competitors on the product market; in addition, they face more intensive price competition and unfavourable demand. One would expect the economic performance of the firms belonging to this cluster to be worse than that of the other four categories. However, this is not confirmed by the performance indicators presented in Table 3, presumably due to the above-average capital intensity characterising the activities of firms in Cluster 3 (for a more detailed analysis of this aspect, see below).

Cluster 4

This category ranks third in terms of the number of companies (19%), but second with respect to its share in employment (36%). Cluster 4 contains by far the highest proportion of large enterprises (500+ employees). Furthermore, it is very strongly oriented towards foreign markets (although not quite as pronounced as Cluster 5). Compared to the sector average, the paper, the pharmaceutical and the plastics industries show the highest share of firms in this cluster. Other very important industries in this cluster include non-metallic mineral products, the machinery sector, electronics/instruments, and watch-making.

Cluster 4 firms have a very high level of innovative activities linked to all stages of the innovation process, from research to the introduction of new products in the marketplace, and aiming at both new products and new production techniques. R&D activities play a dominant role, whereas the intensity of engineering/design and follow-up investments is somewhat lower. The high innovation input, which is also reflected in a very intensive use of human capital, leads to a distinctly above-average sales shares of new/highly improved products and, to a somewhat lesser extent, of world novelties. In sum, the innovation pattern of this cluster may be characterised as a high-profile, strongly R&D-based strategy which aims at major changes of products and processes.

The firms of Cluster 4 operate under significantly different market conditions than do those in the first three clusters. Almost 40% of them compete with less than five other companies on fast-growing global markets. In line with the innovation strategy, non-price competition is far more intensive than on the markets where the firms of the other clusters operate. The performance measures, however, show, on average, values that are not significantly higher than those of total manufacturing.

Cluster 5

Finally, there is a small cluster made up of 4% of all manufacturing firms, which employ only 1% of total employment. These firms are predominantly very small, and about 60% of them have less than 50 employees. None of the firms in this cluster employ more than 500 employees, which is not surprising since more than one-third of these firms are start-ups from the 1990s. Export orientation is even higher than in Cluster 4, with almost 60% of the firms selling more than two-thirds of their

output abroad. Firms in this cluster belong almost exclusively to the machinery and electronics/instruments industries.

Innovative activity in Cluster 5 is very intensive and almost exclusively oriented towards new products. The firms of this group rely very strongly on human capital and use it primarily in development and engineering/design activities, and to a lesser extent in research (less than Cluster 4 but more than the other three groups). These activities yield a very innovative product mix, with a sales share of world novelties of about 50%. In sum, this cluster contains small, young, high-technology firms of the machinery and electronics/instruments industries, which presumably supply narrowly defined niche markets.

Sixty per cent of the firms, *i.e*. twice the manufacturing average, operate in markets with less than five competitors where price competition is not very intensive. Most importantly, the growth potential of the markets supplied by the firms in Cluster 5 is very high and even larger than that of Cluster 4. With respect to the economic performance of these high-technology companies, a plausible assessment based on the available indicators seems very difficult; value added per employee, for example, is below average, while the value added share of capital income is above average.

In sum, we can identify five innovation clusters which are characterised by specific innovation strategies which differ primarily with respect to:

- The (in-house) *intensity* of innovative activities: high in the case of Clusters 4 and 5, medium in Cluster 1 and low in the remaining two clusters.

- The *direction* of innovation efforts: product as well as process in the case of Clusters 1 and 4, product only in the Clusters 2 and 5 and process only in Cluster 3.

- The *type of resources* primarily used in innovative activities: development and engineering/design in the case of Cluster 5 and to some extent also in Cluster 2, these two components and follow-up investments in Cluster 1, only follow-up investments in Cluster 3, and all types of inputs with special emphasis on R&D in Cluster 4.

- The *impact* of innovative activities on sales: high importance of world novelties in the case of Clusters 4 and 5, high-quality improvements/new products in Cluster 1 and purely incremental product changes in the case of Clusters 2 and 3.

The five clusters also differ systematically in terms of other characteristics such as human capital intensity, firm size, export orientation, market conditions and demand potential, while the performance indicators used show rather similar values for all clusters. However, a closer look based on regression analysis in a production function framework, which allows to control for inter-firm differences with respect to physical and human capital intensity, shows that, in terms of the *impact of innovation on economic performance*, the five clusters may be grouped in two categories. The highly innovative Clusters 4 and 5 exhibit a significantly (in statistical terms) higher economic performance than the other three (less innovative) clusters, whereas the performance differences between these two very innovative clusters were not statistically significant.

The relationship between industries and clusters is not unequivocal in most cases. The majority of industries are distributed to a significant extent in two or three (or even more) clusters. This points either to a heterogeneous structure of industries in terms of product lines and/or to the existence of a certain room for individual firms to choose specific innovation strategies in similar technological and economic environments.

To conclude this section, we briefly compare these results with those of Cesaratto and Mangano's (1993) analysis of the manufacturing sector of Italy. The latter study is, to our knowledge, the one which is most comparable to our own study in terms of its approach, the type of indicators used and the characteristics of the underlying sample. The authors of this study identified six clusters representing specific innovation strategies. Some of these clusters correspond more or less to certain of the innovation clusters we found for Switzerland, but there are also important differences. The latter reflect primarily, on the one hand, the very different composition of the two manufacturing sectors, *e.g.* with respect to high-technology industries, and, on the other hand, the obvious comparative disadvantage of the small Swiss economy with respect to scale-intensive industries/product lines.

More specifically, in both countries there is a cluster with top-performers in terms of product as well as process innovations; however, in the Swiss case, this cluster covers 36% of employment, in Italy, only 2%. The second type of top-performing cluster of Swiss manufacturing, with a very small employment share (1%) which is exclusively oriented towards product innovations, was not found in the Italian case. In both countries, there is a cluster of rather small firms concentrating on process innovations based on little in-house innovative activity; however, while in Italy, almost half of manufacturing employment is concentrated in this category, the share is only 4% in Switzerland. Furthermore, in both countries, there exists a cluster of firms following a low-profile incremental product-oriented innovation strategy with a similar employment share (22% in Italy *vs.* 19% in Switzerland). The largest cluster (39% of employment) in Switzerland is characterised by a high-profile incremental strategy based on some development activities but primarily on engineering/design and follow-up investment and oriented towards in-depth product improvements and, to a lesser extent, process innovations. There is no cluster in Italy comparable to this one, although two of the Italian clusters show similar traits: the first one follows an incremental strategy based on engineering/design and exclusively oriented towards new products; a second cluster is active in both types of innovative activity but emphasises the R&D component. The latter, together with another strongly process-oriented cluster, is characterised by an important share of large firms which are able to exploit economies of scale, an element which is rarely present in the Swiss case.

This comparison shows that each economy exhibits important specifications in terms of innovation patterns which have to be taken into account in policy design. It would be interesting to see to what extent this conclusion still holds in a comparison of other countries of similar size and industry structure. Finally, we would like to point to a common finding of the Italian and Swiss studies which, if corroborated by further studies, is very important: In both cases, the relationship between industries and innovation clusters is rather loose, perhaps reflecting, as mentioned above, a non-negligible degree of freedom to choose firm-specific innovation strategies; this interpretation of the results would be in concordance with a basic assumption of evolutionary economics.

Knowledge clusters

The first step comprised a factor analysis. As shown in detail in Annex Table A2, this leads to statistically satisfactory results; the four factors extracted in the analysis account for 52% of total variance. The factor solution is also convincing in economic terms, as can be seen from the factor pattern depicted in the table. The first factor accounts for 19% of total variance and is related to the sources of scientific knowledge produced by the science sector and science-based firms and diffused through technology policy programmes. The second component, reflecting 12% of the variance, stands for knowledge acquired through the recruitment of experts and/or the acquisition of licences as well as knowledge generated within the company group or by the acquisition of knowledge-intensive firms. The third factor, explaining 11% of the variance, refers to knowledge gained from other firms (except suppliers) and from freely available sources (fairs, professional journals, etc.). Finally, there is a fourth factor, which accounts for 10% of the variance and represents embodied and disembodied knowledge

offered by suppliers of materials and capital goods. In a second step, the firm-level data, condensed to four factors, were grouped into four categories using cluster analysis. The result shows satisfactory statistical properties in terms of the relationship of within-cluster variance compared to between-cluster variance. The approximate expected overall R^2 of .46, although not overwhelming, reflects a satisfactory fit of the data to the underlying clustering model.

Before describing the single clusters in some detail, a general characterisation may be helpful. Firms of Cluster 1 draw heavily on knowledge stemming from market partners and some freely accessible sources. Firms of Cluster 2 absorb very intensively all types of external knowledge and are oriented mostly towards acquiring knowledge from the science sector. Cluster 3 contains firms which rely almost exclusively on knowledge from suppliers. The firms of Cluster 4 rank second in terms of the absorption of scientific knowledge; in addition, they make intensive use of specific knowledge acquired through the recruitment of experts. A more detailed characterisation of these knowledge clusters is given below, based on the information listed in Tables 5 to 9 and additional data.

Cluster 1

A quarter of all firms, representing only 13% of overall employment, belong to this category; it thus contains a high proportion of small companies. The firms of Cluster 1 show an almost average export orientation. Compared to manufacturing as a whole, the food, clothing and plastics industries show the highest company share in this cluster. The metal working industry, the machinery industry and the production of transport equipment are also well represented.

The innovative activity of these firms is sustained through intensive contacts with customers and through information obtained from competitors; in addition, general accessible knowledge sources are very important compared to the average of manufacturing. All other external knowledge sources are of low importance. Moreover, the intensity of formal R&D co-operation with other firms and institutions is low: almost 60% of the firms in this cluster have no such arrangements with Swiss partners, and two-thirds have no co-operation across the national border. The effectiveness of knowledge protection is almost the same as for manufacturing as a whole, with the time lead in introducing new products playing the major role. Human capital and R&D-intensity, which may be used as proxies for the firm's internal efforts in innovation, are slightly below average, pointing to rather modest capabilities in acquiring and absorbing external knowledge.[4] The indicators of economic performance of the firms of Cluster 1 show about average values.

In sum, the knowledge pattern of Cluster 1 is quite strongly geared to market-oriented sources, with informal knowledge links dominating and the intensity of overall use of external knowledge somewhat below average.

Cluster 2

Cluster 2 also contains about a quarter of all firms, many of them medium-sized or large ones; the employment share amounts to 45%. Cluster 2 is highly export-oriented, with 40% of firms selling abroad more than two-thirds of their output. Compared to total manufacturing, the chemicals/pharmaceuticals, non-metallic mineral products, metal production, electrical machinery and transport equipment industries show the highest company share in this cluster. Also strongly represented are the paper, plastics, machinery and electronics/instruments industries.

Firms of Cluster 2 draw heavily on external knowledge; they are the most intensive users of 14 out of the 17 sources of knowledge. In contrast to the other clusters, in particular Clusters 1 and 3,

the links to the science sector are strong (universities, technical colleges, other public and private research institutions as well as public technology-oriented promotion programmes). In many instances, the use of external knowledge is institutionalised through formal R&D co-operations. Almost half of this cluster's firms are engaged in three or more such arrangements in Switzerland, and a third in co-operations abroad (compared to 34% and 18%, respectively, in total manufacturing). An above-average endowment of human capital, a high R&D intensity and effective protection against imitation based on formal as well as informal strategies, helps to build a favourable environment for the absorption of external knowledge. Surprisingly, the economic performance of Cluster 2 is not above average, presumably due to the poor quality of the performance indicators used.

In sum, the knowledge pattern of Cluster 2 is strongly outwards-oriented, reflecting the use of all relevant external sources of knowledge. The absorptive capacity for such knowledge is strong given the high level of intramural innovative activities. The specific trait of this cluster is the intensive use of scientific knowledge and the existence of formal R&D links with many domestic and foreign partners.

Cluster 3

Cluster 3, again, contains about a quarter of all firms which, similar to Cluster 1, are predominantly small. As a result, the employment share is only 16%. The export orientation of Cluster 3 is the lowest of all categories. Compared to manufacturing as a whole, textiles, wood products, paper, printing/ publishing and metal working are the most prominent industries; food and clothing are also well represented, but to a lesser extent.

The knowledge pattern of Cluster 3 is characterised by a very strong specialisation towards the use of information from suppliers of materials/components and equipment as well as the acquisition of (embodied) knowledge through the purchase of capital goods; the importance of all other sources is significantly below average. Therefore, it is no surprise that formal R&D co-operation is rare and both R&D and human capital intensity are very low. The fact that external knowledge contributes significantly to innovative activity only in the case of new production techniques is consistent with this knowledge pattern. The economic performance indicators show values which are only slightly (if at all) below average.

In sum, the knowledge pattern of Cluster 3 shows a rather low profile and is very specialised towards the utilisation of embodied and disembodied knowledge from suppliers of materials and equipment, therefore strongly oriented towards the introduction of new production techniques.

Cluster 4

28% of firms with about 26% of total employment belong to Cluster 4. This category shows a polarised size structure with both a large share of very small firms (35% with less than 50 employees) and large firms. This cluster is the most export-oriented one with almost half of the firms selling more than two thirds of their output abroad. Compared to total manufacturing the machinery industry, electronics/instruments and watch-making show the highest company share in this cluster. To a lesser extent, also textiles and non-metallic mineral products are well-represented in this cluster.

Firms of Cluster 4, like those of Cluster 2, are intensive users of science-based knowledge (through universities, technical colleges, other public research institutes, government support programmes for new technologies, patent disclosures and recruitment of experts). However, the extent of absorption of this type of knowledge, although above average, is lower than that of Cluster 2. In addition, the knowledge pattern of Cluster 4 is far more specialised, as can be seen from the below-

average use of all other knowledge sources. The conditions for the absorption of external high-tech knowledge are very favourable in terms of endowment of human capital and R&D intensity; in this respect Cluster 4 ranks highest. Appropriability is also high, although most protection mechanisms are not as effective as in Cluster 2. The intensive use of external knowledge is reflected by a high percentage of firms with many domestic R&D co-operations; however, the frequency of such arrangements with foreign partners is below the average for the manufacturing sector. Economic performance is almost the same as in the other clusters.

In sum, the knowledge pattern of Cluster 4 is characterised by the strong and exclusive orientation towards science-based knowledge which is reflected in a high number of R&D partnerships primarily with Swiss partners.

To sum up, the cluster analysis with 17 extramural sources of knowledge allows four knowledge clusters to be identified whose properties seem plausible. The four groups may be labelled as users of knowledge sources related, first, to market-oriented knowledge; second, to all types of sources, with scientific knowledge being particularly important; third, to supplier-based knowledge; and, finally, to scientific knowledge alone. In addition, the four clusters differ with respect to the intensity of formal R&D co-operation (low in the case of Clusters 1 and 3, high for Clusters 2 and 4, but only with domestic partners in the last case) and to the internal preconditions for the absorption of external knowledge in terms of human capital and R&D intensity (high in the case of Clusters 2 and 4, low for Cluster 3 and medium for Cluster 1). The four clusters also differ significantly in terms of some structural characteristics of firms (size, export orientation). No substantial differences seem to exist with respect to proxies for economic performance. This result remains unchanged if we control for inter-firm differences with respect to physical and human capital intensity in the frame of a regression analysis of a production function. The relationship between industries and clusters is not clear-cut but seems to be stronger than in the case of innovation clusters; perhaps the available space for positioning a firm in the knowledge network is smaller than for choosing specific innovation strategies.

The relationship between innovation and knowledge clusters

In a final step, the outcomes of the two pieces of cluster analysis are confronted with each other in order to see how innovation patterns and the pattern of knowledge sources are inter-related. Of particular interest is the question of the extent to which the innovation and knowledge clusters overlap.

Table 10 shows for each innovation cluster (row), the corresponding distribution of firms with respect to the four clusters of knowledge sources (percentage share of firms). Innovation Clusters 1 to 5 are reordered according to the intensity and the range of innovative activities (product, process or both types of innovation). A similar ordering of the knowledge clusters is not completely possible. Cluster 2, which is highly intensive in the use of all sources of knowledge, unequivocally takes the first place (column 4), followed by Cluster 4 which is the one with the largest affinity to Cluster 2 (column 3). The other two clusters are “ranked” according to the presumed relationship to the innovation clusters; that is, the process-oriented innovation pattern is considered to be related to supplier-based knowledge sources; and product-oriented innovation to market-oriented knowledge.

The table shows that there is no clear-cut correspondence of the two types of clustering. To take an example, row 1 shows that one-half of the process-oriented innovators belong to other knowledge clusters than that related to supplier-based knowledge. Nevertheless, given our *a priori* ordering of the two types of clusters, we find an ordinal correspondence which, although not very high, is statistically significant at the 1% level (Goodman-Kruskal $\gamma = 0.19$).

A closer look at Table 10 shows a series of plausible combinations of the two types of clusters:

- About 50% of process-oriented innovators (row 1) use primarily supplier-based knowledge (cell 1,1 of the table).

- For the firms in row 2, *i.e.* product-oriented innovators with a relatively low innovation intensity, correspondence with the market-oriented knowledge cluster (cell 2,2) is not surprising; however, this cell contains only about 30% of the firms in this row, with the rest distributed to all other cells.

- The product/process innovators with an intermediate innovation intensity (row 3) are fairly evenly distributed among all knowledge clusters. Since the innovation efforts of this cluster are primarily based on engineering/design and follow-up investment and not on R&D activities (see Table 2), the close relationship to supplier-based and market-oriented knowledge clusters (cells 3,1 and 3,2), with about 50% of this row's firms belonging to these two knowledge clusters, seems intuitively plausible.

- The product-oriented innovation cluster with a high intensity of innovative activities (row 4) is strongly associated with the two clusters for which science-based knowledge is important (columns 3 and 4). The corresponding cells 4,3 and 4,4 contain about 60% of the firms, with a significantly lower share in cell 4,4 (to combine with the cluster of firms which, in addition to scientific knowledge, use all other sources very intensively).

- A similar correspondence may be observed for the cluster whose firms are highly innovative in the product as well as the process field (row 5). Sixty-four per cent of the firms are found in the cells 5,3 and 5,4, in this case equally distributed among the two cells.

In sum, about 50% of all firms are covered by these economically plausible combinations of the two types of clustering. These pertain to five innovation types/modes which are quite well defined: First, process-oriented innovators using primarily supplier-based knowledge; second, incremental product-oriented innovators drawing on market-oriented knowledge; third, incremental product-process innovators drawing primarily on supplier-based and market-oriented knowledge sources; fourth, fundamental product-oriented innovators using in the first place scientific and expert knowledge; and fifth, high intensity product-process innovators combining scientific knowledge with an intensive use of all other knowledge sources. The share of these innovation types in the total number of firms seems rather high if one takes into consideration that the innovation cluster of row 3 in Table 10 has partly the character of a residual intermediate stratum.

Because of the far from perfect concordance of the two types of clustering and the small differences among the innovation clusters, as well as among the knowledge clusters with respect to economic performance, one could conclude that firms may dispose of a rather large degree of freedom in selecting an innovation mode to pursue their economic objectives. This view, which is consistent with evolutionary economic thinking, requires, however, further investigation since it is possible that other variables used to describe (but not construct) innovation and knowledge clusters would help to explain those cells of Table 10 which are not intuitively plausible. These variables are firm size, export orientation, industry, R&D co-operation, appropriability, human capital intensity, market conditions and demand perspectives.

Conclusions

With the help of a cluster analysis of Swiss manufacturing firms, we identified specific patterns with respect to innovative activities as well as to the use of external sources of knowledge. The combination of these two types of clusters yielded five innovation types/modes, of which only two seem to be slightly superior than the others in terms of economic performance. This finding is in line with a basic assumption of evolutionary economics, according to which several modes of economic behaviour may coexist, at least during a certain period of time. In addition, the relationship between specific industries and innovation types is not straightforward; individual firms seem to dispose of a certain freedom in selecting an economic viable innovation strategy. This result, which is to some extent at variance with the notion of a sectoral taxonomy proposed by Pavitt (1994), based on data for the United Kingdom, corresponds to the findings of Cesaratto and Mangano (1993) for Italy and Arundel *et al.* (1995) for European industry.[5]

It seems rather difficult to compare the innovation types proposed in these three studies with each other and with our findings because of different approaches, different sample structures, different data bases, etc. In particular, a comparison with Arundel *et al.* (1995) makes sense only for very large companies. This reservation holds in particular for Switzerland because its manufacturing sector is characterised by a very large share of small and medium-sized firms (72% of firms with between five and 200 employees). Therefore, it is not surprising that, in contrast to Britain and Italy, no scale-intensive cluster is found for Switzerland. Pavitt's supplier-dominated cluster, consisting primarily of small firms that combine process-oriented innovation with supplier-based sources of knowledge and characterised by low appropriability, has been also identified in the studies for Italy and Switzerland.

Furthermore, all investigations find a science-based cluster which, according to Pavitt, is characterised by a high innovation intensity both in the product and the process field, the dominance of internal R&D and scientific external knowledge sources as well as highly effective legal and informal appropriability mechanisms. This statement, however, needs some qualifications: first, it seems that firms of this type exploit intensively not only science-based external knowledge but all types of knowledge sources (labelled as "externally oriented" knowledge source clusters in the European and the present study); second, many of these firms also draw heavily on engineering/design activities (Italy, Switzerland). Finally, Pavitt's specialised production-intensive cluster (product-oriented, dominance of engineering/design activities, users as primary knowledge source, informal appropriability mechanisms) must be differentiated in several respects; in the Swiss case, for instance, this category is made up by three clusters which differ in terms of innovation intensity (three different levels), direction of innovative activity (one of the three groups is also highly active in the process field), knowledge sources (one category, for example, is an intensive user of scientific knowledge); in the Italian case, some differentiation would also seem to be called for.

Although Pavitt's seminal contribution dates back to the early 1980s, there is a need for further research on this topic. First, the relationship between innovation and knowledge clusters should be investigated with more scrutiny along the lines described in the above text. Secondly, the present analysis has to be extended towards the rapidly growing (private) service sector. Third, studies for other countries based on the methodology and type of data used in the present study would enable cross-country comparisons, of which those between countries of similar size and level of economic development would be most interesting (*e.g.* Sweden *vs.* Switzerland); these could reveal whether significant country-specific differences with respect to innovation types can still be found after controlling for the two factors mentioned above.

At this stage of analysis, one should be cautious in drawing policy conclusions. At any rate, it can be stated that, in assessing or shaping a certain policy, one must take account of the variety of existing innovation types since firms belonging to specific clusters may have different needs with respect to public support. Process-oriented innovators drawing primarily on supplier-based knowledge, for example, may profit most from programmes directed to facilitating the diffusion of advanced manufacturing technologies, while firms looking out for scientific knowledge may be supported, in the first place, by strengthening the production of this type of knowledge as well as by measures to improve knowledge transfer to the business sector. If it is true that the overlap between industry structure and innovation as well as knowledge clusters is not very large and that economic performance differences across innovation types are rather small, it may be advisable not to direct policy measures towards specific sectors (*i.e.* through "classical" industrial policy) or types of firms (*e.g.* preferring R&D-intensive against engineering/design-oriented firms).

Table 1. **Innovation indicators and knowledge sources**

Variable[1]	Measurement scale	Value range
A. Innovation indicators		
1. Input-oriented measures		
Research input	ordinal	1, 5
Development input	ordinal	1, 5
Engineering/design input	ordinal	1, 5
Follow-up investment	ordinal	1, 5
2. Output-oriented measures		
Technological assessment of innovations	ordinal	1, 5
Economic assessment of innovations	ordinal	1, 5
3. Market-oriented measures		
Sales share of world novelties (%)	metric	0, 100
Sales share of highly improved or new products (%)	metric	0, 100
Sales share of new and all types of improved products (%)	metric	0, 100
B. Knowledge sources		
1. Other firms		
Customers/users of products	ordinal	1, 5
Suppliers of materials/components	ordinal	1, 5
Suppliers of equipment	ordinal	1, 5
Competitors	ordinal	1, 5
Subsidiaries/mother firms	ordinal	1, 5
2. Institutions, consulting		
Universities/technical schools	ordinal	1, 5
Other government research institutions	ordinal	1, 5
Private scientific laboratories/consulting firms	ordinal	1, 5
Government technology programmes	ordinal	1, 5
Technoparks/other technology transfer agencies	ordinal	1, 5
3. Generally accessible information		
Patent disclosures	ordinal	1, 5
Fairs/expositions	ordinal	1, 5
Professional conferences/journals	ordinal	1, 5
4. Acquisition of inputs		
Recruitment of experts	ordinal	1, 5
Acquisition of licences	ordinal	1, 5
Acquisition of capital goods	ordinal	1, 5
Acquisition of other firms	ordinal	1, 5

1. The input- and output-oriented indicators are measured separately for product and process innovations; the market-oriented measures are related only to product innovations.

Table 2. **Description of innovation clusters based on the innovation variables used in the statistical analysis**[1]

Variable	Cluster					Final data set
	1	2	3	4	5	
Number of observations	184	167	47	96	22	
1. Input-oriented measures						
Research						
Product	1	7	0	40	15	12
Process	0	0	0	42	14	8
Development						
Product	57	27	0	76	82	47
Process	32	7	15	70	23	29
Engineering/design						
Product	71	26	4	47	73	46
Process	46	4	26	45	18	29
Follow-up investment						
Product	52	15	4	43	46	34
Process	60	7	49	44	5	36
2. Output-oriented measures						
Technological assessment of innovations						
Product	69	39	21	80	77	57
Process	59	22	55	71	18	47
Economic assessment of innovations						
Product	71	42	21	81	82	60
Process	75	26	53	79	32	56
3. Market-oriented measures						
World novelties (%)	4	2	3	11	52	7
Highly improved or new products (%)	24	14	18	31	78	24
All types of improved/new products (%)	53	31	48	58	89	48

1. The figures for input- and output-oriented indicators represent the percentage share of firms with the values 4 ("high") or 5 ("very high") on a five-point Likert scale, for market-oriented indicators the sales shares of innovative products (%).

Table 3. **Description of innovation clusters in terms of general characteristics of firms and performance measures**

Variable	Cluster					Final data set
	1	2	3	4	5	
Number of observations	184	167	47	96	22	
	Percentage shares					
A. General firm characteristics						
1. Firm size (number of employees)						
5 - 49	22	41	47	29	59	33
50 - 99	17	17	17	16	14	17
100 - 199	26	20	17	19	18	22
200 - 499	23	16	13	19	9	18
500 and more	12	6	6	18	0	10
2. Industries						
Food/beverages/tobacco	2.2	9.0	8.5	6.3	0	5.7
Textiles	3.8	4.8	0	4.2	0	3.7
Apparel/leather/footwear	0.5	4.2	0	1.0	0	1.7
Wood products	3.3	2.4	14.9	1.0	0	3.5
Paper	2.7	1.8	2.1	3.1	0	2.3
Printing/publishing	5.4	4.8	10.6	0	0	4.5
Chemicals/pharmaceuticals[1]	1.1	6.0	10.6	7.4	0	4.7
Plastics	4.9	4.8	0	7.3	0	4.7
Non-metallic mineral products	1.6	6.6	8.5	7.3	0	4.8
Metal production	2.2	3.0	4.3	1.0	0	2.3
Metal working	20.7	14.9	15.0	15.6	13.6	17.1
Machinery	21.2	14.3	8.5	20.8	45.5	18.8
Electrical machinery	6.5	4.2	6.4	6.3	0	5.4
Electronics/instruments	12.0	11.4	2.1	13.5	40.9	12.4
Watches	1.6	2.4	0	2.1	0	1.7
Transport equipment	3.8	1.2	0	1.0	0	1.9
Other manufacturing	6.5	4.2	8.5	2.1	0	4.8
3. Sales share of exports (%)						
0	10	21	53	13	0	18
1 - 33	32	38	17	23	29	30
34 - 66	22	16	13	19	14	18
67 - 100	36	25	17	45	57	34
4. Vocational skills (% of employees)						
University, other high qualifications	15.2	13.8	11.9	24.6	37.1	17.1
High and intermediate qualifications	57.7	55.0	56.2	65.3	76.4	58.9
B. Performance measures						
Value added per employee (CHF '000)	136	135	148	145	126	138
Value added share of capital income (%)	39	42	41	41	45	41

1. Inspection shows that Cluster 4 is dominated by pharmaceutical firms, while the firms in Clusters 2 and 3 produce primarily other chemicals. This pattern is more accentuated if we take account of two very large pharmaceutical firms, not included in the cluster analysis, which would clearly belong to Cluster 4.

Table 4. **Characteristics of innovation clusters**

Cluster 1 (35.6% of firms, 39.4% of employment)	
Innovation pattern: Firms with a good innovation performance for both products and processes strongly based on engineering activities and follow-up investments leading primarily to significantly improved products.	
Firm size	Medium and large
Industry	Metal working and transport equipment and, to a lesser extent, paper, printing/publishing, machinery, electrical machinery and other manufacturing
Export orientation	Quite high
Human capital intensity	Low
Economic performance	Average
Cluster 2 (32.4% of firms,19.3% of employment)	
Innovation pattern: Firms with a low innovation intensity solely based on new products reflected primarily by some development and engineering activities leading to incremental product improvements.	
Firm size	Small
Industry	Food, textiles, clothing and, to a somewhat lesser extent, chemicals (except pharmaceuticals), metal production, non-metallic mineral products and watch-making
Export orientation	Average
Human capital intensity	Low
Economic performance	Average
Cluster 3 (9.1% of firms, 4.0% of employment)	
Innovation pattern: Firms with a very low innovation intensity solely based on new processes reflected primarily by high follow-up investments.	
Firm size	Small
Industry	Wood products, printing/publishing, chemicals, non-metallic minerals products, metal production and, to a lesser extent, also food, electrical machinery as well as other manufacturing
Export orientation	Very low
Human capital intensity	Very low
Economic performance	Average
Cluster 4 (18.6% of firms, 36.2% of employment)	
Innovation pattern: Firms with an extremely high innovation intensity for products as well as processes leading to fundamental (and incremental) innovations based on a high level of R&D.	
Firm size	Average and some very large firms
Industry	Paper, pharmaceuticals, plastics and, to a lesser extent, also non-metallic mineral products, machinery, electrical machinery, electronics/instruments and watch-making
Export orientation	Very high
Human capital intensity	Very high
Economic performance	Average
Cluster 5 (4.3% of firms, 1.1% of employment)	
Innovation pattern: Firms with an extremely high product innovation intensity leading to fundamental (world) novelties based (primarily) on very high development activities.	
Firm size	Very small
Industry	Machinery, electronics/instruments
Export orientation	Very high
Human capital intensity	Extremely high
Economic performance	Average

Table 5. **Description of clusters for knowledge sources based on the variables for knowledge sources used in the statistical analysis**[1]

Variable	Cluster				Final data set
	1	2	3	4	
Number of observations	123	118	116	138	
1. Other firms					
Customers/users of products	86	74	46	40	60
Suppliers of materials/components	52	66	74	17	50
Suppliers of equipment	20	43	67	4	32
Competitors	49	58	24	14	36
Subsidiaries/mother firms	27	49	11	17	25
2. Institutions, consulting					
Universities/technical schools	14	48	6	33	24
Other government research institutions	7	34	9	22	17
Private scientific laboratories/consulting firms	9	27	8	8	12
Government technology programms	1	20	3	19	11
Technology transfer agencies	6	32	3	15	14
3. Generally accessible information					
Patent disclosures	13	34	4	20	17
Fairs/expositions	82	59	42	33	53
Professional conferences/journals	55	64	39	38	47
4. Acquisition of inputs					
Recruitment of experts	24	73	24	37	38
Acquisition of licenses	2	30	5	9	11
Acquisition of capital goods	9	34	42	11	23
Acquisition of other firms	7	47	2	7	15

1. The figures in this table are percentage shares of firms with the values 4 (“high“) or 5 (“very high“) on a five-point Likert scale.

Table 6. **Description of clusters for knowledge sources in terms of general characteristics of firms and performance measures**

Variable	Cluster 1	2	3	4	Final data set
Number of observations	123	118	116	138	
	Percentage shares				
A. General firm characteristics					
1. Firm size (number of employees)					
5 - 49	39	20	32	35	33
50 - 99	18	13	23	15	17
100 - 199	23	30	22	15	22
200 - 499	13	23	16	22	18
500 and more	7	14	7	13	10
2. Industries					
Food/beverages/tobacco	7.3	1.7	6.9	5.8	5.7
Textiles	1.6	0.8	6.0	5.1	3.7
Apparel/leather/footwear	3.3	0.0	2.6	1.4	1.7
Wood products	3.3	0.0	6.9	2.2	3.5
Paper	0.8	4.2	5.2	0.0	2.3
Printing/publishing	0.8	2.5	12.1	0.7	4.5
Chemicals/pharmaceuticals	3.3	6.8	5.2	4.3	4.7
Plastics	6.5	5.9	3.4	2.2	4.7
Non-metallic mineral products	3.3	6.8	4.3	5.8	4.8
Metal production	1.6	3.4	2.6	1.4	2.3
Metal working	18.7	16.2	20.7	13.8	17.1
Machinery	23.5	22.1	6.9	24.0	18.8
Electrical machinery	4.9	7.6	3.4	5.8	5.4
Electronics/instruments	10.6	16.2	3.4	20.4	12.4
Watches	0.8	0.8	0.9	4.3	1.7
Transport equipment	2.4	2.5	1.7	1.4	1.9
Other manufacturing	7.3	2.5	7.8	1.4	4.8
3. Sales Share of Exports (%)					
0	15	14	22	15	18
1 - 33	35	26	37	25	30
34 - 66	22	20	18	13	18
67 - 100	28	40	23	47	34
4. Vocational skills (% of employees)					
University, other high qualifications	14.7	20.1	11.2	22.6	17.1
High and intermediate qualifications	60.6	63.6	51.1	60.6	58.9
B. Performance measures					
Value added per employee (CHF '000)	142	139	133	144	138
Value added share of capital income (%)	42	41	41	41	41

Table 7. **Description of clusters for knowledge sources in terms of measures of the intensity of R&D co-operation**[1]

Variable	Cluster 1	2	3	4	Final data set
Number of observations	123	118	116	138	
Number of types of R&D co-operation partners		***Switzerland***			
0	59	41	51	38	47
1	11	8	6	12	9
2	8	5	14	10	10
3	8	16	13	15	13
4	9	14	9	12	11
5	3	7	4	7	5
6	1	5	3	4	3
7	0	3	0	1	1
8	1	1	0	1	1
Number of types of R&D co-operation partners		***Abroad***			
0	67	50	62	50	57
1	8	10	11	19	12
2	12	9	15	17	13
3	5	11	6	7	7
4	4	7	4	5	5
5	2	6	1	2	3
6	2	3	1	0	1
7	0	3	0	0	1
8	0	1	0	0	1

1. The figures in this table are percentage shares of firms with the corresponding number of types of R&D cooperation partners. Considered are 10 types of R&D-cooperation partners: (a) customers, (b) suppliers,(3) competitors, (d) firms from other industries (without customers and competitors), (e) firms of the same conglomerate, (f) universities/ technical colleges, (g) other research institutions and (i) technology transfer agencies.

Table 8. **Description of clusters for knowledge sources in terms of variables measuring the effectiveness of various appropriability mechanisms**[1]

Variable	Cluster				Final data set
	1	2	3	4	
Number of observations	123	118	116	138	
Effectiveness as means of protection					
1. Product innovations					
Patents/other legal means	25	34	14	28	25
Secrecy	28	36	18	28	27
Complexity of product design	39	48	36	46	42
Time lead when introducing new products	74	80	60	71	69
Retention of specifically qualified personnel	25	42	21	31	30
Intensive sales and service efforts	56	69	49	48	54
2. Process innovations					
Patents/other formal means	7	17	9	10	11
Secrecy	21	40	18	26	25
Complexity of process design	29	43	37	38	36
Time lead when introducing new processes	46	63	55	49	52
Retention of specifically qualified personnel	24	44	28	30	31
Intensive sales and service efforts	56	69	49	48	54

1. The figures in this table are percentage shares of firms with the values 4 (“high“) or 5 (“very high“) on a five-point Likert scale.

Table 9. **Characteristics of clusters for knowledge sources**

Cluster 1 (24.8% of firms, 13.5% of employment)	
Knowledge pattern: Firms with a rather high intensity of using external information primarily from customers, competitors, fairs and expositions, professional conferences and journals (market-oriented knowledge).	
R&D co-operation intensity	Low
Appropriability	Medium effectiveness primarily of informal protection mechanisms
Human capital intensity	Average
Firm size	Small
Industry	Food, clothing, plastics, and, to a somewhat lesser extent, metal working, machinery, transport equipment and other manufacturing
Export orientation	Average
Economic performance	Average
Cluster 2 (23.8% of firms, 45.1% of employment)	
Knowledge pattern: Firms with a very high intensity of using information from practically every external source, relying heavily on information from universities, technical colleges, other research institutions as well as government technology programs and technology transfer agencies (science-based knowledge).	
R&D co-operation intensity	Very high (domestic as well as foreign partners)
Appropriability	High effectiveness of legal as well as informal protection mechanisms
Human capital intensity	High
Firm size	Large/medium
Industry	Chemicals/pharmaceuticals, non-metallic mineral products, metal production, electrical machinery, transport equipment and, to a somewhat lesser extent, paper, plastics, machinery as well as electronics/instruments
Export orientation	High
Economic performance	Average
Cluster 3 (23.4% of firms, 15.6% of employment)	
Knowledge pattern: Firms with a very high intensity of use of information from suppliers of materials/ components and equipment as well as through purchase of capital goods, but rather low information use of other knowledge sources (supplier-oriented knowledge).	
R&D co-operation Intensity	Medium
Appropriability	Low effectiveness of all protection mechanisms
Human capital intensity	Low
Firm size	Small
Industry	Textiles, wood products, paper, printing/publishing, metal working as well as other manufacturing and, to a lesser extent, food and clothing
Export orientation	Low
Economic performance	Average
Cluster 4 (28.0% of firms, 25.8% of employment)	
Knowledge pattern: Firms with a high intensity of using information primarily from science-oriented institutions as well as from patent disclosures and specialised experts (knowledge for specialised producers).	
R&D co-operation intensity	High (primarily domestic partners)
Appropriability	Medium effectiveness of most appropriability mechanisms, to some extent also legal ones
Human capital intensity	High
Firm size	Large/small
Industry	Machinery, electronics/instruments, watch-making and, to a lesser extent, textiles as well as non-metallic mineral products
Export orientation	Very high
Economic performance	Average

Table 10. **Joint consideration of innovation clusters and clusters for knowledge sources**[1]

Innovation clusters	Innovative Cluster 3 Activities		Clusters for knowledge sources					
				Cluster 1 (supplier)	Cluster 4 (market)	Cluster 2 (science)	(science and all other)	
	Intensity	Orientation		Row percentages[2]				N
				(1)	(2)	(3)	(4)	
Cluster 3:	low	process	(1)	49	14	23	14	43
Cluster 2	low	product	(2)	21	29	32	18	154
Cluster 1	medium	product/ process	(3)	28	23	21	28	181
Cluster 5	high	product	(4)	9	32	45	14	22
Cluster 4	high	product/ process	(5)	10	25	33	32	95
Final data set				23	25	28	24	495

1. The innovation clusters are reordered in terms of innovation intensity and direction of innovative activity, the knowledge clusters according to type and intensity of use of external sources (see text).
2. The figures in this table are percentage shares of firms of a certain innovation cluster belonging also to a certain cluster for knowledge sources (row percentages).

Annex

RESULTS OF THE FACTOR ANALYSIS

Innovation indicators

The variables used in the factor analysis of innovation indicators correspond basically to those listed in Table 1, but for technical reasons some are analysed in a transformed way. Thus, in the case of each input-oriented measure, we included the sum of the scores for product and process innovations. Similarly, we first added the scores of the four types of assessments of the importance of an innovation (*i.e.* product/process and technological/economic assessment). In both cases, we considered the product-share of the overall scores as additional variables.

The factor analysis with these innovation measures led to satisfactory results, as can be seen from the statistical information presented in the lower part of Annex Table A1. According to Kaiser's MSA, the original variables are quite strongly correlated; hence, a basic requirement for a factor analysis to be sensible is fulfilled. Furthermore, the RMSE of the residual is low enough, and the variance accounted for by the first four principal components is quite high. Finally, the factor pattern identified in this analysis seems plausible in economic terms (see main text).

Table A1. **Factor analysis with innovation indicators**

Variable	Rotated factor pattern[1]			
Total research				.89
Total development			.48	.66
Total engineering/design			.77	
Total follow-up investment			.79	
Innovation assessment			.67	
Product share of research/development	.77			
Product share of engineering/design	.78			
Product share of follow-up investment	.77			
Product share of the innovation assessment score	.82			
Sales share of world novelties		.82		
Sales share of highly improved or new products		.89		
Sales share of all types of improved/new products		.72		
Number of observations				516
Kaiser's overall measure of sampling adequacy (MSA)				.764
Variance accounted for by the first four components (%)				67.6
Root mean square off-diagonal residuals (RMSE)				.072
Variance accounted for by each factor	2.52	2.11	1.99	1.48
Final communality estimate (total)				8.10

1. The table shows only factor loadings above 0.4.

Knowledge sources

The variables used in the factor analysis of knowledge sources are those listed in Table 1. Again, the results are satisfactory from the statistical point of view. Kaiser's MSA is even higher compared to Annex Table A1. The RMSE of the residual is satisfactory in this case too, and the variance accounted for by the first four principal components, although somewhat lower than for the innovation indicators, is high enough. Finally, the factor pattern seems plausible in economic terms (see main text).

Table A2. **Factor analysis with knowledge source variables**

Variable	Rotated factor pattern[1]			
Customers/users of products			.65	
Suppliers of materials/components				.65
Suppliers of equipment				.83
Competitors			.58	
Subsidiaries/mother firms		.69		
Universities/technical schools	.72			
Other government research institutions	.64			
Private scientific laboratories, consulting firms	.54			
Government technology programmes	.80			
Technoparks/other technology transfer agencies	.73			
Patent disclosures	.48			
Fairs, expositions			.77	
Professional conferences/journals			.48	
Recruitment of experts		.59		
Acquisition of licenses		.54		
Acquisition of capital goods				.64
Acquisition of other firms		.65		
Number of observations				495
Kaiser's overall measure of sampling adequacy				.823
Variance accounted for by the first four components (%)				51.8
Root mean square off-diagonal residuals				.075
Variance accounted for by each factor	3.10	2.03	1.91	1.76
Final communality estimate (total)				8.81

1. The tables shows only factor loadings above 0.4.

NOTES

1. The latter approach has been explored in Hollenstein (1996) for product as well as process innovations based on a factor analysis of a large number of indicators.

2. This procedure involves partitioning of the sample with observations being allowed to move in and out of groups at different stages of the analysis. At the beginning some more or less arbitrary group centres are chosen and individual observations allocated to the nearest one. An observation is then moved to another group if it is closer to that group's centre than to the centre of the present group. This process during which close groups are merged and distant ones split is continued until stability is achieved with a predetermined number of clusters (Manly, 1986, p. 101). We used the FASTCLUS procedure of the statistical package SAS to perform the analysis.

3 The intensity of price and non-price competition as well as the medium-term development of the market potential are ordinal variables measured on a five-point Likert scale; for details see Arvanitis *et al.*, 1998.

4. High intramural innovative activities foster the absorption of external knowledge due to the higher information and learning capacity (Cohen and Levinthal, 1989).

5. It is, however, quite natural that Pavitt, in looking for a general typology, stressed the differences between industries more than those within them (see also Arundel *et al.*, 1995, p. 87).

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Chapter 4

INNOVATION MODES IN THE SWISS SERVICE SECTOR: A CLUSTER ANALYSIS BASED ON FIRM-LEVEL DATA

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Introduction

The innovation process is a complex phenomenon characterised by several stages, ranging from basic research to the penetration of the market with new products and the introduction of new production techniques within the firm. A whole series of indicators is needed to describe and measure a firm's innovative activities, each of which stresses specific aspects but also contains measurement errors. Using the information contained in such a system of indicators, we developed in earlier work a composite measure of innovation intensity and used it for ranking manufacturing and service firms and industries according to their innovativeness (Hollenstein, 1996; Arvanitis *et al*., 1998, Chapter 3).

Implicitly, this ranking assumes that an industry is a (more or less) homogeneous entity with respect to the innovativeness of its firms – an assumption which contradicts a basic hypothesis of the evolutionary view of technological change. The latter framework considers groups of firms characterised by similar innovation patterns which are conceptualised as unordered categories ("innovation modes"). Such a purely classificatory procedure allows for the (presumed) heterogeneity of an industry with respect to the innovation strategies pursued by its firms. This approach permits the co-existence of different innovation modes which – at least for a certain time period – may turn out to be equivalent in terms of economic performance. Which of these innovation strategies are sustainable in the long run is decided in the course of a market-driven selection process whose outcome is not predictable (see, for example, Metcalfe, 1995).

We explored this classificatory approach in an earlier study for the Swiss manufacturing sector using firm-level data (Arvanitis and Hollenstein, 1998). The analysis yielded five innovation modes which showed similarities to those identified by other authors (Pavitt, 1984; Cesaratto and Mangano, 1993; Arundel *et al*., 1995). The specificities of our classification could be explained to a large extent by the structural characteristics of the Swiss economy. In the present chapter, we look for innovation patterns in Swiss service industries by using the same methodology as that applied in our study on manufacturing which had been inspired by the work of Cesaratto and Mangano (1993).

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Despite the high and growing importance of the service sector, empirical work related to services is still quite scarce in empirical economics in general, and in innovation research in particular.[1] This unsatisfactory situation is partly due to conceptual problems ("what makes service innovations different?"),[2] partly to a lack of data.[3] It is thus not surprising that, to our knowledge, there is only one study which looks for innovation patterns in the service sector in a similar way as the present chapter does (Evangelista, 2000).[4] By applying cluster analysis to data for 19 service industries in Italy, this author succeeds in identifying four "patterns of innovation", two of which show some similarities to innovation types in manufacturing identified by Pavitt (1984) and the other authors cited above.

The aim of the present chapter is two-fold. First, our goal is to contribute to a better understanding of the patterns of innovation in the service sector which covers a broad range of activities with very different kinds of innovations. Second, we shall explore the relative merits of the classification and the ranking approach as a means of analysing the innovation process; in this way, we hope to define the range of application of the two ways of looking at the issue.

The set-up of the chapter is as follows: The procedure and the variables used to identify innovation modes, as well as the variables used to characterise such patterns, are described in the next section. The third section provides information on the data used in this exercise. The empirical results of the search for innovation modes and their main characteristics are presented in the fourth section. The following section looks at the relationship between the identified innovation modes and i*)* their industrial structure; and *i)* the (average) economic performance of the firms in the cluster. Based on these results we go on to discuss whether (or to what extent) service industries are heterogeneous or homogeneous in terms of innovation modes. Finally, we summarise the main results and draw some conclusions.

Procedure

In contrast to Evangelista (2000), who uses industry data, the present analysis seeks to identify innovation modes based on firm-level information. In a first step of analysis, we try to group firms into homogeneous categories, which can be interpreted as innovation modes, by use of cluster analysis. To group the firms, we consider their characteristics with respect to a large number of innovation indicators. However, cluster analysis is not directly applied to these variables. We began by synthesising (and standardising) the information contained in these measures into a small number of variables ("principal components") using a (principal component) factor analysis.[5] The components then are used in a (non-hierarchical) cluster analysis to group the firms into a number of categories which are, with respect to the variables under investigation, as homogenous as possible (small within-cluster variance) and at the same time as different as possible from each other (large between-cluster variance).[6] In a second step, the identified clusters are interpreted in terms of the innovation indicators used in the cluster analysis itself, as well as according to a large number of additional variables which cover the firms' position in knowledge networks, the environment with respect to a number of supply- and demand-side determinants of innovative activity, some structural characteristics of firms such as size, age, industry, etc., and the firms' economic performance.

The identification of the clusters (innovation modes) is based on the information contained in the 17 innovation indicators listed in Table 1. These measures cover all stages of the innovation process, *i.e.* the input and the output side of the generation of innovations as well as the degree of novelty of newly introduced products and the cost-reducing potential of new processes. On the input side, in addition to the classical aspects of research and development which for several service industries are of minor importance, we take account of the expenditures for IT (hardware as well as software) and the level and composition of innovation-related follow-up investments (innovative machinery,

acquisition of external knowledge such as licences, trademarks, etc., human capital investments, marketing outlays). The output side of innovative activity is captured, first, by the firms' assessments with respect to the technical and economic significance of the innovations; in addition, we include a variable which measures the IT content of innovation output, again evaluated by the firms themselves. Moreover, we use two indicators representing a firm's innovation output in terms of patent applications and licences granted. Finally, the sales share of innovative products and cost reductions induced by process innovations, both representing innovation-related improvements of the firms' market position, are used as market-oriented innovation indicators.

Table 1. **Innovation indicators used in the cluster analysis**

Innovation indicator	Measurement scale	Value range
1. Input-oriented measures		
Expenditures for:		
• Research	Ordinal	1, 5
• Development	Ordinal	1, 5
• IT (hardware, software)	Ordinal	1, 5
Follow-up investments:		
• Total	Ordinal	1, 5
• By type		
- Machinery and equipment	Ordinal	1, 5
- Acquisition of external knowledge (licences, trademarks, etc.)	Ordinal	1, 5
- Training	Ordinal	1, 5
- Market introduction of innovations	Ordinal	1, 5
2. Output-oriented measures		
• Significance of the innovations in technical terms		
- Product	Ordinal	1, 5
- Process	Ordinal	1, 5
• Significance of the innovations in economic terms		
- Product	Ordinal	1, 5
- Process	Ordinal	1, 5
• IT content of innovations	Ordinal	1, 5
• Patent application (yes/no)	Nominal	1, 0
• Licences granted to other firms (yes/no)	Nominal	1, 0
3. Market-oriented measures		
• Sales share of new or highly improved services (%)	Metric	0, 100
• Cost reduction generated by process innovations (yes/no)	Nominal	1, 0

The 17 innovation variables used to identify innovation modes cover as many aspects of service innovations as possible. The measurement scales and the corresponding value ranges of these variables are shown in Table 1. Most are qualitative in nature, *i.e.* either dichotomous (yes/no) or polychotomous, with five response levels ranging from "very low" (value 1) to "very high" (value 5). In contrast to prejudices held by many researchers, the information content of such subjective measures is high, as has been shown in earlier econometric work devoted to the explanation of the innovativeness of firms measured both by quantitative and qualitative indicators of R&D inputs (Arvantis and Hollenstein, 1994, 1996).

Step 2 of the analysis is devoted to the description and interpretation of the clusters identified in step 1. To this end, we used the variables listed in Table 2:

- A first group of indicators contains the innovation measures used in the clustering procedure and some additional indicators characterising a firm's innovative activities. The latter set is made up, first, of quantitative measures of R&D and innovation expenditures as well as of cost reductions directly linked to process innovations; these variables are already included as qualitative measures in the clustering procedure. In addition, we take account of the relative importance of product and process innovations, or combinations of the two, which in most instances indicate more complex innovations. The "degree of novelty" pertains to information indicating whether the innovation is "new for the industry" or just "new for the firm" (reflecting adoption rather than innovation in the narrow sense) or whether it is an improvement to an existing product/service (incremental innovation).

- A second group of variables deals with the knowledge network to which the firms belong. Under this heading, we take account of the intensity of use of 14 external knowledge sources: clients/customers, three categories of suppliers (material/components, equipment, software), competitors/firms of the same industry, firms of the same enterprise group, universities, other research institutions, consultancy firms, technology transfer institutions, patent disclosures, professional conferences/journals, fairs/exhibitions and computer-based networks. Moreover, we include variables representing R&D out-contracting as well as institutionalised R&D co-operations; for both types of arrangements, we distinguish between domestic and foreign relationships with different types of partners. There are good reasons for drawing on such detailed information with respect to the use of external knowledge. First, the importance of co-operation and networking for the generation of innovations has grown significantly over time (Haagedoorn, 1996; for Switzerland, see Arvanitis *et al.*, 1998, Chapter 6). Second, the structure of use of external knowledge is one of the most important features of the patterns of innovations identified in the studies mentioned above which deal with the manufacturing sector.

- A third group of variables used in characterising innovation modes represents the main factors determining innovative activity as identified in earlier work related to Swiss manufacturing (*e.g.* Arvanitis and Hollenstein, 1996) and services (Arvanitis, 2000).[7] On the demand side, we take account of the medium-run demand perspectives as well as the intensity of price and non-price competition on the relevant product markets. On the supply side, we include a variable representing a firm's assessment of the potential for generating novelties in or around the fields of its activities as a proxy for innovation opportunities, as well as a measure for the appropriability of knowledge (which is important as an incentive to exploit such innovation potential). Human capital is added to this third group of variables because firms well-endowed with skills are in a good position to absorb knowledge from other sources (Cohen and Levinthal, 1989).

- The fourth group of variables refers to some of the structural characteristics of a firm (such as industry, size, age and export orientation).

- Finally, the description of clusters pertains to firm performance measured by value added per employee as well as the change of sales and employment over time.[8]

Table 2. **Indicators used to characterise innovation modes**

	Measurement scale	Value range
1. Innovative activities		
• Innovation indicators as shown in Table 1	see Table 1	see Table 1
• Other innovation indicators		
- Sales share of R&D (%)	metric	0, 100
- Sales share of innovation expenditures (%)	metric	0, 100
- Cost reduction generated by process innovations (%)	metric	0, 100
- Degree of novelty (three dummies: new for the industry, new for the firm, (significant) improvements	nominal	1, 0
2. Knowledge networks		
• Use of 14 types of external knowledge sources (see text)	ordinal	1, 5
• Out-contracting of R&D		
- In Switzerland (yes/no)	nominal	1, 0
- Abroad (yes/no)	nominal	1, 0
• R&D co-operation:		
- Number of domestic partners (3 and more *vs*. 0-2 partners)	nominal	1, 0
- Number of foreign partners (3 and more *vs.* 0-2 partners)	nominal	1, 0
3. Determinants of innovative activity		
• Demand side		
- Medium-run demand perspectives on the product market	ordinal	1, 5
- Intensity of price competition on the product market	ordinal	1, 5
- Intensity of non-price competition on the product market	ordinal	1, 5
• Supply side		
- Opportunities for innovation in the fields relevant for the firm's activities	ordinal	1, 5
- Appropriability of knowledge	ordinal	1, 5
- Employment share (%) of highly qualified labour (tertiary level)	metric	0, 100
4. Structural characteristics of the firm		
• Share of firms (%) by 9 industries (see appendix, table A1)	metric	0, 100
• Employment share (%) by 5 size classes (5-19, 20-49, 50-199, 200-499, 500+)	metric	0, 100
• Share of firms (%) by start-up year: 3 classes (up to1988, 1989/94, 1995/99)	metric	0, 100
• Share of firms (%) by export to sales ratio: 3 classes (up to 1, 2-19, 20+)	metric	0, 100
5. Economic performance		
• Value added per employee (1000 sFr.)	metric	> 0
• Share of firms (%) with increasing sales in the period 1996/98	metric	0, 100
• Share of firms (%) with increasing employment in the period 1996/98	metric	0, 100

Note: The ordinally scaled variables reflect the firms' assessments on a five-point Likert scale; the response levels range from "very low" (value of 1) to "very high" (value of 5). We used the share of firms (%) with a value of 4 or 5 to characterise the clusters in the case of ordinal scales; similarly, the share of firms (%) with a value of 1 (yes) is used in the case of nominal scales.

To evaluate the relative merits of ranking and classification, we investigate the relationship between innovation modes and their structure by industry. If the clusters are composed of several industries, *i.e*. not concentrated on a few industries, or – a less restrictive condition – if the industry composition of the clusters is similar to that of the service sector as a whole, the heterogeneity hypothesis is confirmed; in this case, classification is a more sensible procedure than ranking. The

same holds if the (average) economic performance of the firms of the various innovation modes does not significantly differ.

Data

The data used in this study are taken from the Swiss Innovation Survey 1999 which in its core questions is comparable to the Community Innovation Surveys (CIS2) conducted in most European countries. The survey was based on a (disproportionally) stratified random sample (28 industries and – within each industry – three firm size classes based on industry-specific employment thresholds with full coverage of the class of large firms). The firms were asked to fill in a questionnaire[9] on their innovative activities and a large set of other variables relevant to the description of the innovation process and the explanation of innovative activity and economic performance during the period 1997-99.

The present analysis is confined to the sub-sample of services (2 731 firms; nine industries). We received valid answers from 880 firms, *i.e.* 32.2% of the underlying sample. The response rates are not too different across industries and size classes (with a few exceptions as can be seen from Annex Table A1). Nevertheless, in view of the rather low (overall) response rate, it was necessary to conduct a survey among a sample of non-respondents using a few core questions related to innovative activity (response rate 90%). The non-response analysis did not indicate a serious selectivity bias with respect to the structure of the basic sample. By imputing missing values in case of item non-response,[10] we could avoid a loss of observations which might have led to a biased sample. In sum, the data set may be considered as representative of the underlying sample. For obvious reasons, the search for innovation modes is based on the sub-sample of innovative firms only; that is, 54% of the respondents (see Annex Table A1, which shows the share of innovating firms by industry and firm size classes).

Innovation modes: identification and characteristics

Identification

As mentioned above, to identify innovation modes, we used principal component factor analysis to standardise the underlying variables and synthesise their information content in a number of uncorrelated variables (*i.e.* "principal components" or "factors"); we then used cluster analysis to group the firms into a predetermined number of clusters which, if the procedure yields satisfactory results, may be interpreted as innovation modes.

The preliminary step of factor analysis yielded statistically satisfactory results (detailed results are shown in Annex Table A2). The five factors extracted in the analysis account for 56% of total variance. The factor solution is convincing in economic terms as can be seen from the factor pattern depicted in Annex Table A1. The first factor accounts for 20% of total variance and gives high weights to innovation-related follow-up investments (level and various components such as training, marketing-related outlays, etc.). The second factor, which captures 11% of the variance, shows high loadings on R&D inputs and science-oriented innovation output (patent applications, licences granted). The third factor, explaining 10% of total variance, refers to the technological and IT dimension of service innovations. Whereas the first three factors do not differentiate between product and process innovations, the last two do, with both stressing the economic side of innovation. The fourth factor focuses heavily on (product) market-orientation, the last one on cost reductions related to process innovations.

We then performed a non-hierarchical cluster analysis of the five principal components identified in the first step. According to the usual statistical criteria (approximate expected overall R^2, cubic clustering criterion, etc.), groupings with four, five or six clusters were more or less of equal quality. In order to choose the appropriate number of clusters, we took account of three criteria:, *i)* the statistical properties in terms of the relationship of within-cluster as compared to between-cluster variance; *ii)* the plausibility of the clusters in economic terms ("can the clusters convincingly be interpreted as innovation modes"?); and *iii)* the need to have a minimum number of firms within each cluster. According to criterion *iii)*, the version with six clusters was not attractive, while the solution with four clusters was inferior to that with five groups in terms of criteria *i)* and *ii)*. We thus chose a five-cluster solution which is satisfactory in statistical terms (the approximate expected overall R^2 of 0.45 points to an acceptable fit of the data to the underlying clustering model) and yields a set of innovation modes which have straightforward interpretation.[11]

The basic characteristics of the five innovation modes

The five innovation modes identified are described in detail in Annex Table A3, based on the variables listed in Table 2. The five categories are summarised below.

Mode 1: "Science-based fully-network-integrated high-tech firms"

This cluster consists of 21 firms endowed with highly qualified staff conducting large amounts of R&D in a highly conducive environment in terms of technological opportunities and market perspectives. Own R&D is supported by intensive use of science-related external knowledge sources as well as many institutionalised R&D co-operations (and research contracts) with domestic and foreign universities as the main partners. The innovation output often consists of products/processes which are new for the industry and are protected by patents (accompanied by the granting of licences). The sales share of new products is high (partly due to a significant number of young firms), although sales are realised in a highly competitive environment. This cluster contains an above-average share of export-oriented, medium-sized and some very large firms heavily concentrated in IT/R&D services, business services (altogether 70% of firms), and banking/insurance/other financial services (15%). Labour productivity is distinctly below average; however, growth performance is more favourable (about average in terms of sales and very strong with respect to employment).

Mode 2: "IT-oriented network-integrated developers"

This cluster contains 19 firms, which – although innovation opportunities are no more than average – dispose of favourable preconditions to be highly innovative in view of very promising market conditions and a highly qualified labour force. Based on sizeable investments in development and IT (but not in research), the firms of this cluster generate product and process innovation which are of high technical standard and, in many instances, new to the industry. The innovations, often patented and licensed to other firms, are technology-oriented and characterised by a high IT content and a strong potential for cost reductions. These firms are intensive users of manifold sources of external knowledge (suppliers of software and investment goods, universities, competitors and other firms of the same enterprise group). Among the more formal knowledge links out-contracting of R&D (at home as well as abroad) and the use of licences are of higher importance than more far-reaching R&D co-operations. Medium-sized and export-oriented firms are distinctly more frequent in this cluster than in services as a whole. Compared to the sector average IT/R&D services as well as banking/insurance/other financial services are represented over proportionally, while the opposite

holds for retail trade, hotels/restaurants and real estate, which are characterised on average by a rather low innovation intensity. Value added per employee is on average distinctly higher than in the other four categories of firms; growth of sales and employment, however, is lower than in services as a whole.

Mode 3: "Market-oriented incremental innovators with loose external links"

The innovative activities of the 99 firms belonging to this cluster benefit from very favourable market perspectives, although the supply-side conditions for the generation of novelties are only average. The firms of this cluster generate product and process innovations with a high IT-content which are primarily incremental in nature (which comes no surprise in view of the rather low innovation input). Nevertheless, innovation output is of high value in economic and technological terms and is successfully brought to the marketplace. In general, networking is rather weak; only market-oriented (users, software suppliers) and easily accessible knowledge sources (fairs/exhibitions, computer-based networks) are of some importance. Compared to the sector average, this cluster contains a large proportion of (very) small firms with average export orientation. The firms are distributed across industries in a similar pattern as for services as a whole, with some over-representation of business services and wholesale trade and only a few firms in transport/telecommunication. Labour productivity of this innovation mode is high, but growth of sales is no more than average with even weaker employment growth.

Mode 4: "Cost-oriented process innovators with strong external links along the value chain"

This cluster, with its 229 firms, is by far the largest one. In view of strong price competition and only slightly above-average market growth, it is not surprising that cost-reducing process innovations, which are predominantly incremental, are the most prominent feature of innovative activity. Innovation input concentrates on IT expenditures and innovation-related follow-up investments, among which all components are highly relevant (machinery, external knowledge, training, marketing). The technological and economic significance of innovation output is high although, as mentioned, it is frequently based on further developments to existing products/processes. The firms' own innovative activity strongly benefits from a wide (primarily informal) network which is spanned along the value chain from suppliers (of software in particular) at the one end to users at the other, with strong links to different partners in between (consultancy firms, competitors/firms of the same industry, computer-based networks, professional conferences, fairs/exhibitions). Institutionalised co-operation (R&D contracts, R&D co-operation) is only of average importance. Large firms are somewhat over-represented, very small ones distinctly under-represented in this cluster, and export orientation is rather low. In view of the large number of firms in this cluster, it is not surprising that the industry structure is close to the sector average. The same holds for labour productivity; growth of sales, however, is much higher than in any other clusters and employment growth is also above average.

Mode 5: "Low-profile innovators without external network"

The (process) innovations of the 107 firms belonging to this cluster seem to be quite marginal which comes as no surprise given the unfavourable demand- and supply-side factors determining innovative activity: weak demand perspectives, strong price competition, low appropriability and innovation opportunities and relatively poor human capital endowment. This cluster shows the weakest performance with respect to most of the variables used to characterise the various innovation

modes. The adoption of novelties generated elsewhere is the primary form of innovation. Correspondingly, innovation input is mainly restricted to buying machinery/equipment. The use of external knowledge, which is distinctly below average for almost all sources, is concentrated on suppliers and competitors. This clusters comprises an over proportional share of small firms, most of which produce for domestic markets, and of firms belonging to industries such as personal services, real estate, hotels/restaurants, retail trade and transport, whose innovation intensity is low or only moderate. Not surprisingly, the (average) economic performance (level, growth) of the firms belonging to this cluster is low.

From this characterisation of the five clusters, it follows that they clearly differ from each other in terms of characteristics of high relevance for innovative activity. This holds true not only for the description in terms of the 17 innovation indicators underlying the cluster analysis (Table 1) but also – and most importantly – in terms of the large number of "external criteria" which are not used in the clustering process (see Table 2). In view of the consistent and economically plausible pattern, the five clusters can be safely interpreted as modes of innovation.

Are innovation modes equivalent in economic terms?

It is common practice to rank industries according to their innovativeness with the objective, for example, of assessing their competitiveness or predicting their opportunities and risks in structural change (see, for example, European Commission, 1997). As mentioned above, ranking is sensible if industries are sufficiently homogeneous with respect to innovation intensity. This assumption holds only if innovation modes, which are homogeneous groups by construction, and industries closely correspond. In addition, to infer competitiveness (and the like) from innovation rankings by industry requires – as a necessary although not sufficient condition – systematic differences between innovation modes in terms of economic performance. It is precisely this hypothesis which is denied by advocates of the classificatory approach to innovation. In the following, we shall discuss the first of these conditions, before moving on to the second one.

Relationship between innovation modes and industries

Table 3 shows the industry composition of the five innovation modes (columns 1 to 5) and of the service sector as a whole (column 6). Industries are ordered by decreasing innovation intensity, the latter being measured by an indicator which aggregates the information contained in the 17 innovation measures listed in Table 1 by means of a factor analysis.[12] Although the five innovation modes are primarily regarded as unordered classes, they could also be ranked – at least by tendency – according to innovation intensity, with mode 1 ("science-based fully-network-integrated high-tech firms") at the top and mode 5 ("low-profile innovators without external network") at the bottom of the scale.

A first look at Table 3 shows that the firms in four out of the five innovation modes (with the exception of mode 1) are distributed to many industries, a fact which contradicts the "homogeneity assumption". However, at least three innovation modes are strongly concentrated in a few industries. This holds most clearly for mode 1 ("science-based fully-network-integrated high-tech firms") containing mainly firms from the two most innovative industries. The industry composition of mode 2 ("IT-oriented network-integrated developers") – although somewhat less pronounced – is also biased towards the most innovative industries. Just the opposite is true for mode 5 ("low-profile innovators without external network") which, in comparison with the sector average, is mainly present in industries with low or intermediate innovation intensity. Less pronounced is the concentration of mode 3 ("market-oriented incremental innovators with loose external links"), while the firms of

mode 4 ("cost-oriented process innovators with strong external links along the value chain") are distributed across industries almost in the same way as for the service sector as a whole (which is not very surprising, given the fact that almost half of the firms of our sample belong to this group). In sum, we find, on the one hand, a clear correspondence between industries and innovation modes, if ranked by innovation intensity;[13] on the other hand, four out of the five innovation modes are distributed quite widely across industries.[14]

In concordance with the "heterogeneity hypothesis", firms thus seem to have a certain degree of freedom in choosing an innovation strategy within technologically and economically similar environments (proxied by industry). However, given the statistically significant positive correlation between industries and innovation modes (see note 12), the ranking of industries by innovation intensity seems to be a sensible procedure if innovativeness is appropriately measured and interpreted with caution.

Table 3. **Industrial structure, by innovation mode**

Industry	Innovation mode					
	1	2	3	4	5	Total
	Distribution of firms by industry (%)					
Innovation intensity above average	***95.0***	***83.2***	***73.8***	***72.6***	***67.5***	***73.0***
IT and R&D services	30.0	16.7	5.1	3.9	2.8	5.5
(Other) business services	40.0	16.7	23.2	18.3	15.7	19.6
Banking/insurance/financial services	15.0	22.1	16.2	17.0	15.7	16.4
Wholesale trade	5.0	22.1	24.2	22.5	15.7	20.5
Transport/telecommunication	5.0	5.6	5.1	10.9	17.6	11.0
Innovation intensity below average	***5.0***	***16.8***	***26.2***	***27.4***	***32.5***	***27.0***
Retail trade	0.0	5.6	14.1	13.0	16.7	13.3
Hotels, restaurants	5.0	5.6	9.1	12.2	11.1	10.7
Real estate	0.0	0.0	1.0	0.9	1.9	1.1
Personal services	0.0	5.6	2.0	1.3	2.8	1.9
	100	100	100	100	100	100

Note: If for a cluster the industry share of firms (%) is higher by more than 10% than the share of the industry total in the grand total (column 6), the corresponding cell is shaded. For the definition of the five innovation modes, see text and Annex Table A3.

Innovation modes and economic performance

To assess the validity of the "homogeneity hypothesis," we need to investigate whether there are significant differences between the innovation modes with respect to average firm performance. A negative result would support the "heterogeneity hypothesis", according to which there is – at least temporarily – more than one economically feasible innovation strategy. To evaluate the two conflicting propositions, we consider labour productivity (value added per employee; full-time equivalents) as a measure of firm performance, and sales and employment growth as indicators of the performance change over time.

As can be seen from Table 4, labour productivity differs strongly across the five innovation modes; it is 44% higher in mode 2 (cluster with the highest productivity) than in mode 1 (cluster with the lowest productivity). We find even more pronounced differences with respect to the growth of sales and employment. These data seem to be at variance with the "heterogeneity hypothesis". However, this view of the matter is too simple because firm performance is determined not only by the

"innovation mode" variable, but also by several other factors such as those listed in the lower part of Table 4. For example, it is obvious that a firm which uses intensively physical capital exhibits higher labour productivity than a company producing in a more labour-intensive way. This example is clearly relevant in comparing average labour productivity of innovation mode 3 (high value added, high capital intensity) with that of mode 1 (low value added, low capital intensity).

Table 4. **Economic performance, by mode of innovation**

Indicator	Innovation mode					
	1	2	3	4	5	Total
	Cluster means					
Performance indicators						
Value added per employee (CHF thousands)	153	221	196	171	172	178
Share of firms (%) with increasing sales 1996/98	65	39	63	70	57	64
Share of firms (%) with increasing employment 1996/98	50	28	34	43	32	38
Factors determining firm performance						
Gross capital income per employee (CHF thousands)	56	67	87	86	72	81
Employment share of highly qualified labour (%)	50	32	27	22	19	24
Share of R&D performing firms (%)	100	89	31	45	36	44

Note: For each indicator, the cell with the highest (lowest) cluster mean is shaded in dark (light) colour. For the definition of the five innovation modes, see text and Annex Table A3.

To control for such differences with respect to the use of various input factors, we performed a cross-section regression analysis of firm performance in a production-theoretic setting. More specifically, we estimated a production function with the following arguments: *i)* physical, human and knowledge capital measured by gross capital income per employee, the employment share of personnel holding tertiary level degrees and the share of firms with R&D activities respectively;[15] *ii)* dummy variables for the innovation modes (cluster 1 as reference group); and *iii)* industry dummies (as variables to control for unspecified factors; personal services as reference group). To explain sales and employment growth, we used the same variables, complemented by two dummies to control for changes in the firms' structure (selling-off, splitting or closure of parts of the firm and mergers). Sales growth and the average wage level have been used as additional variables in explaining employment change. The growth of sales and employment has been measured on an ordinal scale or as a percentage change.

The estimation results may be summarised as follows:

- *Labour productivity*: We find a statistically significant impact (positive sign) on firm performance only in the case of innovation mode 2 ("IT-oriented network-integrated developers"). The other four modes are equivalent in terms of labour productivity. The differences with respect to value added per employee, as shown in Table 4, are explained primarily by physical as well as human and/or knowledge capital intensity (positive signs). In addition, we obtain statistically significant signs for some industry dummies which are negative in the case of two less-innovative industries (retail trade, hotels/restaurants) and positive for the highly innovative banking/insurance industry.

- *Sales growth*: Two of the dummies measuring a firm's innovation mode exert a statistically significant influence on sales growth: innovation mode 2 ("IT-oriented network-integrated developers") a negative one, mode 4 ("cost-oriented process innovators with strong external links along the value chain") a positive one. We find a positive, although not in all

specifications statistically significant, influence of knowledge capital intensity, whereas human and physical capital variables yielded no significant results. The two dummies controlling for changes over time of the firms' boundaries showed the expected sign and were statistically significant. In addition, two industry dummies (wholesale trade, banking/insurance/other financial services) are positively related to the growth of sales.

- *Employment growth*: The effects of particular interest are again those pertaining to the innovation modes. However, none of the corresponding dummy variables is statistically significant. The most important variable in explaining employment change is, not surprisingly, the growth of sales. Moreover, the wage level exerts the expected negative influence on employment growth. The two variables controlling for changes in the firms' structure show the right signs and were statistically significant. A positive impact is found for the industry dummy IT/R&D services. The intensity of use of the various input factors is important (human capital in particular), but the effects are not very stable across different specifications of the variable "employment growth".

In sum, the estimates of the relationship between innovation mode (with mode 1 as reference) and firm performance, lead to the conclusion that – with one exception (mode 2) – a firm's labour productivity is independent of its innovation mode. The same holds (without exception) for the growth of employment, whereas for sales growth we get a significant negative impact of innovation mode 2 and a positive one for mode 4. The differences between the innovation modes with respect to the three performance measures are thus only in (some of the) "extreme cases" (shaded areas in the upper half of Table 4) systematic in nature. These results are more or less in concordance with the "heterogeneity hypothesis", which states that firms dispose of a certain freedom in choosing (economically viable) innovation strategies. On the other hand, an assessment has to take into account that the intensity of use of human and/or knowledge capital, as well as some of the industry dummies systematically related to innovativeness, exert a statistically significant influence on productivity. In view of this result, we conclude that the choice of an innovation strategy depends quite strongly on structural characteristics which are closely related to the hierarchy of industries in terms of innovation intensity.

Summary and conclusions

By applying cluster analysis to a large set of innovation indicators (which also capture non-technical aspects of innovation that are far more important in services than in manufacturing), we identified five clusters. In a second step, the latter were characterised by using five groups of variables: *i)* innovation indicators (partly already used for clustering); *ii)* the firms' position in knowledge networks (use of external knowledge sources, R&D out-contracting and R&D co-operation); *iii)* demand- and supply-side determinants of innovative activity (market perspectives, competitive environment, innovation opportunities, appropriability, human capital endowment); *iv)* some general characteristics of firms (size, export orientation, industry, etc.); and *v)* measures of firm performance.

The descriptions of the five clusters showed that they can be interpreted as specific "modes of innovation" which have an economically plausible interpretation:

- Science-based fully-network-integrated high-tech firms.
- IT-oriented network-integrated developers.
- Market-oriented incremental innovators with loose external links.

- Cost-oriented process innovators with strong external links along the value chain.

- Low-profile innovators without external network.

According to the evolutionary view of technical change, such a classificatory procedure ("innovation modes") is preferable to an approach which seeks to rank industries according to their innovativeness. Whereas the starting point of classification is the heterogeneity of firms with respect to innovation strategies, the ranking approach assumes that an industry is rather homogeneous in terms of the innovativeness of its firms. To evaluate the relative merits of the two approaches and the underlying assumptions, we investigated in a first step the relationship between innovation modes and industries. We found that the firms of most innovation modes are distributed over several industries; however, compared to the service sector average, three out of five innovation modes are concentrated on specific industries, and we find a statistically significant positive correspondence between innovation modes and industries ranked according to innovation intensity. In a second step, we analysed the relationship between innovation modes and firm performance as well as its change. We found that a firm's labour productivity is independent of its innovation mode (except in one case), with a somewhat stronger relationship between innovation strategies and the change of sales, but no correlation with the growth of employment. On the other hand, there is strong evidence that variables related to innovativeness, such as human and knowledge capital intensity, as well as some dummy variables representing industries with an above-average (below-average) innovation performance, exert a positive (negative) influence on firm performance.

In view of these results, neither the "classical" ranking of industries according to their innovativeness nor the classification of firms into (unordered) categories representing innovation modes of equal "economic value", captures the whole reality. This ambiguous result can be interpreted as follows. In accordance with the heterogeneity hypothesis, firms dispose of a certain degree of freedom in selecting an economically viable innovation strategy (innovation mode) even in similar economic and technological environments. However, the room of manoeuvre is restricted by structural characteristics which are closely related to the hierarchy of industries in terms of innovation intensity, factor endowment, etc.; the ranking approach is thus relevant too. In view of the latter result, it also makes sense to rank industries according to their innovativeness, for example, in order to assess their competitiveness, growth potential, etc. In this framework, however, the measurement of innovation intensity must be broadly based and cover also non-technological indicators; only in this way can one take account of the diversity of innovation modes within an industry. This aspect rarely gets the attention it deserves: most rankings are based on a single indicator which is easy to collect, such as R&D or patent intensity, but these indicators, as shown, are irrelevant for the innovative activities of three out of five innovation modes. The aggregate innovation measure used to rank industries according to their innovation intensity in Table 3 seems to be a useful instrument to take account of the heterogeneity aspect because it contains information provided by 17 innovation indicators covering many different aspects of "innovativeness", only some of which are technology-oriented.[16]

The interesting question of whether there are similar innovation modes across countries is difficult to answer at this stage of research. Evangelista (2000), to our knowledge the only study which is more or less comparable to the present one (although based on industry-level data), identified four groups of clusters constructed from nine clusters of the basic analysis. Excluding his fourth group which covers just one industry (technical consultancy) we get the following picture: one group of clusters found for Italy ("S&T-based") is more or less identical to our first innovation mode ("science-based fully-network-integrated high-tech firms") and the two others ("interactive and IT-based" and "technology users", respectively) show some similarities to our modes 4 and 5 ("cost-oriented process innovators with strong external links along the value chain" and "low-profile innovators without external network"). However, there is no correspondence to our innovation modes 2 and 3. This

difference between the Italian and the Swiss case is perhaps the result of a specific feature of the procedure used by Evangelista (2000). For technical reasons (see p. 211), at a certain stage of his analysis, this author dropped the indicators representing the market-orientation of innovations; therefore, it would have been surprising if he had identified a cluster similar to our innovation mode 3 ("market-oriented incremental innovators with loose external links").

In sum, there is some (preliminary) evidence of similarities in innovation modes across countries. This hypothesis should be tested in further work using the same type of data and method of analysis for several countries. In view of the harmonisation of innovation surveys in Europe, such a research strategy appears feasible. It should thus become possible to identify common as well as country-specific modes of innovation. From the few studies looking at innovation patterns in manufacturing mentioned in this chapter, we know that, in this sector, innovation modes are quite similar across countries, with some important exceptions. In the Swiss case, for example, there is no "scale-intensive mode of innovation" as has been identified for the United Kingdom, Italy and the largest European firms. This result, however, is not surprising given the small size of the Swiss economy and its particularly high proportion of SMEs (OECD, 1994). Therefore, although similarities between countries with respect to innovation patterns are probably more important than differences, the identification of country-specific innovation modes can contribute to characterising national innovation systems.

At this stage of research, one has exercise caution in drawing policy conclusions. Nevertheless, the results of this study have some implications for policy makers. First, in assessing and shaping policy measures, decision makers need to account of the variety of innovation patterns identified. The network characteristics of the five innovation modes are very different, ranging from "science-based fully-network-integrated high-tech firms" to "low-profile innovators without external network". The various innovation modes also differ in other aspects, such as type and intensity of use of innovation inputs or the orientation of innovative activity towards products, production techniques or combined novelties. In view of such differences, innovation policy has to be based on a comprehensive set of measures which cover the specific needs of all types of firms. For example, firms belonging to the innovation mode "IT-oriented network-integrated developers" would presumably benefit most from programmes facilitating the diffusion of IT and measures contributing to enlarging and improving the supply of IT professionals. "Science-based fully-network-integrated high-tech firms" should be supported, in the first place, by strengthening the production of (basic) scientific knowledge as well as by measures facilitating the transfer of knowledge to the business sector. Second, in view of the poor economic performance of "low-profile innovators without external network", measures aimed at strengthening outside links could contribute to improving the innovativeness of this type of firm. Third, to the extent that innovation modes are country-specific (although, as shown above, there is also evidence of similarities across countries), they are important elements of national innovation systems. We conclude from this result that there are limitations to designing best policy practices at the international or supranational level;[17] therefore, one should at least consider country-specific modifications to such policy recommendations. Finally, because the overlap between industry structure and innovation modes is only partial, and in view of rather small differences between the various modes with respect to economic performance, it may be advisable to direct policy measures towards specific innovation modes rather than towards sectors (as "classical" industrial policy would do) or types of firms (such as, for example, highly R&D-intensive ones).

Annex

Table A1. **Structure of the sample and the final data set**

	Sample		Respondents			Innovators		
Industry	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	N	%	N	%	(3)/(1)	N	%	(6)/(3)
Wholesale trade	596	21.8	207	23.5	34.7	101	21.2	48.8
Retail trade	516	18.9	132	15.0	25.6	63	13.3	47.7
Hotels, restaurants	403	14.8	84	9.6	20.8	50	10.6	59.5
Transport/communication	378	13.8	133	15.1	35.2	52	11.0	39.1
Banking/insurance	266	9.7	99	11.2	37.2	77	16.2	77.8
Real estate	38	1.4	14	1.6	36.8	5	1.1	35.7
IT/R&D-services	100	3.7	36	4.1	36.0	26	5.4	72.2
Business services	384	14.1	155	17.6	40.4	92	19.3	59.4
Personal services	50	1.8	20	2.3	32.2	9	1.9	45.0
	2 731	100	880	100	32.2	475	100	54.0
Firm size (no. of employees)								
Small	1 487	54.4	465	52.8	31.3	218	46.0	46.9
Medium	1 021	37.4	330	37.5	32.3	194	40.7	58.8
Large	223	8.2	85	9.7	38.1	63	13.3	74.1
	2 731	100	880	100	32.2	475	100	54.0

Note: Column 5 shows the response rate by industry and size class, column 8 the share of innovating firms. Under-represented industries/size classes are lightly shaded, while over-represented ones are darkly shaded; criterion: deviation of more than 15% of the total.

Results of the factor analysis with innovation indicators

The factor analysis with the innovation variables listed in Table 1 gave satisfactory results, as can be seen from: *i)* the factor pattern which seems sensible in economic terms (see upper part of Annex Table A2 and main text; and *ii)* the statistical information presented in the lower part of Annex Table A2. According to Kaiser's measure of sampling adequacy (MSA), the original variables are fairly strongly correlated; hence, a basic requirement for a factor analysis to be sensible is fulfilled. Moreover, the root mean square (RMSE) of the residual is low enough, and the variance accounted for by the first five principal components is sufficiently high.

Table A2. **Factor analysis with the innovation indicators used in cluster analysis**

Innovation indicator	Rotated factor pattern (factor loadings)				
Follow-up investments: total	.77				
Follow-up investments: training	.75				
Follow-up investments: machinery and equipment	.67				
Follow-up investments: market introduction of innovations	.66				
Follow-up investments: acquisition of external knowledge	.54				
Development expenditures		.74			
Patent application		.73			
Research expenditures		.68			
Granting of licences		.61			
IT-content of innovations			.80		
IT expenditures (hardware, software)			.68		
Significance of product innovations in technical terms			.57		
Significance of process innovations in technical terms			.57		
Sales share of new or highly improved products				.76	
Significance of product innovations in economic terms				.73	
Cost reduction related to process innovations					.78
Significance of process innovations in economic terms					.59
Number of observations					475
Kaiser's overall measure of sampling adequacy (MSA)					.720
Variance accounted for by the first five components					.557
Root mean square off-diagonal residuals (RMSE)					.079
Variance accounted for by each factor	3.32	1.94	1.68	1.46	1.06
Final communality estimate (total)					9.46

Note: For the definition of the innovation indicators see Table 1. Only factor loadings above 0.5 are shown. We used equamax as rotation method.

Table A3. **Description of the five innovation modes identified for the service sector**

Mode 1: "Science-based fully-network-integrated high-tech firm" *(4.4% of firms, 18.1 % of employment)*	
Innovation activities and innovativeness	Extraordinarily high innovation performance, in particular combined product/process innovations:
	Based on very high R&D expenditures (also at foreign locations), these firms generate basic novelties often protected by patents (with much granting of licences); the innovations, which in many cases are "new for the industry", are successfully introduced in the market.
Knowledge network	Intensive use of (primarily) science-related external knowledge sources (universities, other research centres, patent disclosures, licences, journals); high importance of institutionalised relationships with domestic and foreign partners (R&D co-operations and contracts) which are very effective in terms of the generation of publications, patents, prototypes and new products.
Innovation determinants	
- Demand side	Very good market perspectives in a highly competitive environment.
- Supply side	Extremely good innovation opportunities, which – favoured by strong appropriability of knowledge – are realised by an excellently qualified labour force (very high share of academics).
Firm characteristics	
- Industry	Pronounced concentration in the most innovative industries (IT/R&D services, business services).
- Size, age, export orientation	Besides some very large enterprises, primarily medium-sized firms (with a considerable share of rather young ones) with very strong export orientation.
Firm performance	Low labour productivity (combined with very low physical capital intensity); average growth of sales and very strong employment growth.
Mode 2: "IT-oriented network-integrated developers" *(4.0% of firms, 1.7% of employment)*	
Innovation activities and innovativeness	High innovation performance (products, processes, combined innovations):
	Based on high investments in IT and development (but not research) also at foreign locations, these firms generate innovations which very often are industry novelties protected by patents and licensed to other firms. The innovations are technology-oriented and characterised by a high IT content and a strong cost-reducing potential, whereas the sales share of new products is low.
Knowledge network	Intensive use of manifold sources of external knowledge (universities, suppliers of software and investment goods, licences, competitors, firms of the same group); institutionalised knowledge relationships (at home and abroad) which primarily take the form of R&D out-contracting, in second instance also R&D co-operations (with a high output of patents and new processes).
Innovation determinants	
- Demand side	Favourable market perspectives with below-average competitive pressure.
- Supply side	Innovation opportunities are below average; however, firms can fully use this potential, given strong knowledge protection and a highly qualified workforce.
Firm characteristics	
- Industry	Some concentration on IT/R&D services, banking/insurance/other financial services, whereas retail trade and hotels/restaurants are represented less than in the service sector as a whole.
- Size, age, export orientation	Highly export-oriented, primarily medium-sized firms (with a non-negligible share of rather young firms).
Firm performance	Very high labour productivity (combined with low physical capital intensity), but very weak growth of sales and employment.

Mode 3: "Market-oriented incremental innovators with loose external links"	
(20.9% of firms, 9.1% of employment)	
Innovation activities and innovativeness	Average innovation performance for new products and processes: These firms successfully generate and introduce innovations which are primarily developments of existing products/processes. These incremental innovations, which often contain IT components, are of high value in both technological and economic terms, although innovation inputs (R&D as well as innovation-related follow-up investments) are rather low.
Knowledge network	These firms are only loosely embedded in knowledge networks. Among the external knowledge sources, only a few easily accessible ones (fairs, computer-based networks) and some market-oriented sources (suppliers of software, users) are of some importance. Institutionalised knowledge transfer through co-operations and R&D out-contracting is weak.
Innovation determinants	
- Demand side	Bright demand perspectives on markets where competition is not very intensive.
- Supply side	Innovation opportunities, appropriability and human capital endowment are about average.
Firm characteristics	
- Industry	The firms are distributed across industries in the same way as for the service sector as a whole; there is some over-representation of wholesale trade and business services whereas transport/communication is under-represented.
- Size, age, export orientation	High proportion of (very) small firms (some of them rather young) with average export orientation.
Firm performance	Labour productivity (and physical capital intensity) are significantly higher than for services as a whole; growth of sales is about average whereas employment growth is weaker than in the service sector as a whole.
Mode 4: "Cost-oriented process innovators with strong external links along the value chain"	
(48.2% of firms, 62.9% of employment)	
Innovation activities and innovativeness	High innovation performance concentrated on new processes: These firms generate strongly cost-reducing process innovations which are primarily developments of existing processes, based on high innovation-related investments in machinery, training and marketing.
Knowledge network	These firms are intensively connected to many types of external knowledge sources which form an (informal) network along the value chain: from suppliers (primarily of software) to users with many partners in between (consultancy firms, competitors, fairs/exhibitions, computer-based networks, professional conferences). Institutionalised knowledge transfer through co-operations and R&D out-contracting which is of average importance leads primarily to new processes.
Innovation determinants	
- Demand side	Slightly above-average demand perspectives combined with strong price competition.
- Supply side	Innovation opportunities are slightly higher than for services as a whole; appropriability and skill endowment are somewhat below average.
Firm characteristics	
- Industry	Industrial structure is almost identical to that of the service sector as a whole.
- Size, age, export orientation	Large firms are somewhat over represented; export orientation is rather low.
Firm performance	Labour productivity is below average (with very high physical capital intensity); very strong sales growth with above-average employment growth.

Mode 5: "Low-profile innovators without external network" (22.5% of firms, 8.2% of employment)	
Innovation activities and innovativeness	Very weak innovation performance (primarily process innovations): Innovations, which in first instance are only "new to the firm" (adoption!), are of quite marginal significance with respect to innovation inputs (buying machinery only), both innovation output in terms of its technological and economic content and the impact of innovative activity on sales and costs are low.
Knowledge network	The use of external knowledge is modest; only suppliers and competitors play a certain role as sources of know-how.
Innovation determinants	
- Demand side	Demand perspectives are weak; price competition is intensive and far more relevant than non-price competition.
- Supply side	Innovation opportunities, appropriability and human capital endowment are all below average.
Firm characteristics	
- Industry	Industries with (rather) low innovation intensity such as real estate, personal services, retail trade and transport/communication, are over-represented, whereas firms producing business services and – particularly – IT/R&D services are rare.
- Size, age, export orientation	The share of small firms is high; firms serve primarily domestic markets.
Firm performance	Labour productivity is below average(with physical capital intensity also below average); growth of sales and employment are weak.

NOTES

1. It is very revealing that the *Handbook of the Economics of Innovation and Technological Change* published in 1995 (Stoneman, 1995) does not treat the service sector at all. Metcalfe and Miles (2000) may serve as a survey on many aspects of innovation in services.

2. See, for example, Gallouj and Weinstein (1997) and several contributions in Metcalfe and Miles (2000) for a discussion of these matters.

3. Although the Community Innovation Survey 1996 (CIS2) and similar surveys conducted in non-EU countries such as Canada and Switzerland now cover the service sector as well, there are still rather few econometric investigations pertaining to this part of the economy. Worth mention are, for example, a study for the Netherlands (Brouwer and Kleinknecht, 1996), some work at the European Center for Economic Research (ZEW), Mannheim (Ebling and Janz, 1999), a few studies at Statistics Canada (Gellatly, 1999), as well as some analyses for Switzerland (Arvanitis *et al*., 1998; Donzé and Lenz, 1999; Arvanitis, 2000).

4. Also worthy of mention is an explorative taxonomy of service industries proposed by Antonelli *et al*. (2000) which is based on criteria other than those used in Evangelista (2000) and the present study: tradability, productivity, network interaction, internal/external impact of innovations.

5. This procedure produces linear combinations of the original variables (principal components). The latter are standardised variables which are uncorrelated and contain the information common to the underlying variables. The choice of the number of principal components depends on statistical criteria (variance accounted for by the factors, root mean square off-diagonal residuals, etc.) as well as on the plausibility and interpretability of the resulting factor pattern in economic terms; see Manly (1986) for an introduction and Ost (1984) for an in-depth treatment of principal component factor analysis.

6. This procedure involves partitioning the sample, with observations being allowed to move in and out of groups at different stages of the analysis. At the beginning, some more or less arbitrary group centres ("cluster seeds") are chosen and individual observations allocated to the nearest one. An observation is then moved to another group if it is closer to that group's centre than to the centre of the initial group. This process during which close groups are merged and distant ones split is continued until stability is achieved with a predetermined number of clusters (Manly, 1986, p. 101); for a more detailed discussion of cluster analysis, see, for example, Kaufmann and Pape (1984).

7. See Cohen (1995) for detailed survey of the empirical literature.

8. We do not have any information on the *change* in value added.

9. The questionnaire exists in German, French and Italian versions and is available on request or can be downloaded from www.kof.ethz.ch.

10. The method used is "multiple imputation" (Donzé, 2000), primarily developed by Rubin (1987).

11. As stressed in Kaufmann and Pape (1984), there is no such thing as a "natural" or "correct" classification; statistical criteria are mainly helpful in narrowing down the range of possible solutions within which a satisfactory one has to be identified.

12. For details of the procedure, see Hollenstein (1996).

13. This finding is supported by a statistically significant value of Goodman-Kruskal γ, which is an appropriate measure of association in case of ordinary scaled variables ($\gamma = 0.19$).

14. It cannot be excluded that the wide distribution by industry is to some extent the result of too much heterogeneity in the underlying industry classification.

15. As an alternative measure of knowledge capital, we used the employment share of R&D personnel.

16. The same argument is put forward by Baldwin and Gellatly (1998), who constructed an overall index of innovativeness which takes account of non-technological indicators.

17. See OECD (1998) for an attempt at formulating best policy practices in innovation and technology.

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Chapter 5

TECHNOLOGICAL COLLABORATION, FIRM SIZE AND INNOVATION: A STUDY OF UK MANUFACTURING FIRMS

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Introduction

The central aim of this contribution is to explore the relationship between technological collaboration[1] and innovation, presenting an empirical analysis of around 1 600 business enterprises in the United Kingdom who responded to the UK part of the second Community Innovation Survey (CIS2).[2] We are primarily interested in three research questions: What are the factors that influence the propensity of a firm to collaborate on innovation projects? What is the relationship between formal and informal external linkages and innovation intensity, and how is this relationship affected by firm size? What is the relationship between formal and informal external linkages and innovation performance, and how is this relationship affected by firm size?

We argue that there is a strong positive relationship between firm size and the propensity to collaborate. Furthermore, that this relationship has important implications for our understanding of the way collaboration is used by firms of different sizes, and the economic effects that such collaborations have. We argue that the positive correlation between firm size and the propensity to collaborate is not only a strong empirical finding, but that it has strong theoretical foundations.[3]

From an empirical point of view, technological collaboration has been seen as an increasingly important phenomenon ever since the rapid increase in different types of co-operation agreements especially in high-technology sectors since the early 1980s.[4] From a theoretical point of view, notions of complementary assets and interconnectivity within the national system of innovation have come to the fore in the burgeoning literature on innovation and competitiveness. Such literature has had a significant impact on public policy both at the national and international level, with an increasing number of industrial policies including major collaborative elements.[5] This is especially the case in technology and innovation policy (broadly defined).

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Nevertheless, with a few notable exceptions, there is a lack of large-scale empirical evidence on the determinants of collaboration as well as the effects of those collaborations on innovation intensity and innovation performance. At the theoretical level as well, collaboration as an organisational form has been dealt with by different but nevertheless overlapping bodies of literature. These include neo-classical economics (in particular, industrial organisation), the resource/competence-based view of the firm, as well as transaction-cost economics.

Each broad area of literature has a slightly different focus of analysis and is represented by its own community of academics with different languages and "sets of codes". This often leads to apparently irreconcilable differences on particular issues, *e.g.* rationality, the role of technology. However, we argue that, with specific reference to the three research questions cited at the beginning of this chapter, the differences between some of these bodies of literature are not irreconcilable. In particular, in many cases, several theories predict the same thing (large firms will collaborate more than small firms) using different languages and with differing starting assumptions.

The approach of this chapter is to use the research questions as a starting point, then to make predictions based on the most relevant theories. On the basis of these predictions, testable hypotheses are drawn and form the basis of the subsequent empirical sections.

The second Community Innovation Survey (CIS2), implemented in 1997, is an attempt to gather up-to-date information on the extent and characteristics of technological innovation activity in enterprises both in the United Kingdom and in other European countries.[6] The survey was centrally co-ordinated by Eurostat, who produced a core questionnaire based on the *Oslo Manual* (OECD and Eurostat, 1997). This core questionnaire was then adapted and administered by agencies in the participating countries.

The UK part of the CIS2 was conducted by the Office of National Statistics (ONS) on behalf of the DTI in the summer/autumn of 1997. The sample included enterprises in most production and service sectors with more than ten employees (micro-enterprises were excluded). These enterprises accounted for 57% of all non-agricultural business employment in the United Kingdom. The remaining 43% of the economy is made up of, in the first instance, micro-enterprises of less than ten employees; some industrial sectors were omitted from the survey.

The CIS2 survey provides a unique opportunity to examine these types of question. It represents the most systematic large-scale attempt to collect both quantitative and qualitative information about firms' innovation characteristics across a wide range of industrial sectors and firm sizes. In particular, it allows us to assign profiles to firms in terms of traditional indicators of innovative activity such as R&D along with non-R&D inputs to innovation. These non-R&D inputs to innovation, which have increasingly been recognised as playing a crucial role, can be anything from the amount of money spent on non-R&D innovation-related expenditures to the extent to which firms use external organisations as a source of technological knowledge.

As a final introductory point of clarification, it is worth noting the level of aggregation at which the innovation survey samples firms. The unit of analysis for the purposes of the innovation survey is the "enterprise unit".[7] However, there is no "theory of the enterprise unit"! The enterprise unit is the level at which most statistical collection agencies deem it necessary and most useful to conduct surveys of economic activity. In the literature, we talk about the "firm" without necessarily defining precisely what we mean. There is a theory (or even several theories) of "the firm" but it is not always apparent whether we mean a corporation (comprised of a number of enterprises, or an enterprise, or even a plant). Suffice it to say that we work with what we have. The theoretical discussion in the chapter often refers to "firms" in the (badly defined) sense of the literature. The CIS2 data were

collected on the basis of enterprise units defined by the ONS. For simplicity's sake we refer to "firms" throughout most of the chapter, although it should be remembered that the enterprises covered by the survey may not always correspond to what we mean by "a firm" in other contexts.[8]

What drives collaboration?

In this section, we present our first research question; namely, what are the factors that influence the propensity of firms to have formal collaborations on technological innovation projects? In particular, we focus our analysis on the relationship between firm size and collaboration.

Theoretical background

Both those that view firms as information processors (*e.g.* neo-classical economists) and the resource-based (competence-based or evolutionary) perspectives, predict that larger firms are more likely to collaborate than smaller firms. However, although the empirical prediction is the same, the underlying rationales are different:

- Under the *neo-classical framework*, collaboration may come about because of pressures to internalise a number of different types of externality. However, such collaboration would mostly be a second-best solution to mergers and acquisitions, which may be prevented by (competition) regulation. Firms choose to collaborate, assuming that the benefits of internalising the externality exceed the bargaining and administration costs of setting up and running the collaboration.

- The *competence-based approach*, which sees firms as repositories of knowledge, views the principle aim of collaboration as a way of combining complementary but dissimilar assets (including intangible assets such as knowledge) with those of other firms and institutions in order to protect and reinforce existing competitive advantages and to create new ones through learning. The same caveat applies to the transaction costs discussed above.

So, why should larger firms be more likely to collaborate than smaller firms? Although this question has not been dealt with very intensively in the literature, Colombo argues forcefully a similar point drawing on similar bodies of literature (Colombo, 1995, 1998).[9] Broadly speaking, we can divide the theoretical arguments supporting the view that large firms are more likely to collaborate than smaller firms into two groups: one based on market power [which one could also consider the neo-classical (IO) bit]; the other on efficiency arguments (broadly the resource/competence-based view).

The main point of the market-power view is that large firms can have more gains from collusion than smaller firms. If larger firms have more to gain from collusion, it follows that they will also have more co-operative agreements since they "may be a vehicle for the co-ordination of partners' conduct, information sharing and side payments, thus facilitating collusion". An extension to this is the theoretical work that has pointed out that in equity arrangements such as equity joint ventures, the linking of profits leads to a reduction in the partner firms' incentives to compete effectively, resulting in the standard collusive outcome of an overall reduction in output and an increase in prices (Reynolds and Snapp, 1986; Jacquemin and Slade, 1989). (Colombo, 1995) argues that "all things being equal, linkages involving larger firms are expected to produce bigger output contractions than those with smaller firms".

The view that efficiency gains from collaboration as an organisational alternative to markets or hierarchies would be greater for larger firms than for smaller ones is based around a number of different approaches that are briefly outlined below.

First, the resource-based approach sees the view of the firm as a collection of tangible and intangible, often tacit and certainly firm-specific assets. These assets are often specialised (Richardson, 1972), have accumulated over time through learning and are difficult to replicate by other firms. These assets (and very importantly capabilities) are what contributes to creating competitive advantages for the firm. An important part of the resource-based theory of the growth of the firm is that as a firm grows it creates new resources (Penrose, 1959). Two key points arise from this. First, large firms are more likely to have more specialised assets (in more areas) that are attractive to potential partners. Second, larger firms are also more likely to have created assets or resources that they could put to more productive use elsewhere and as such could afford to experiment with them in collaborations.

Game theory provides another efficiency-based argument to support the view that large firms are more likely than smaller firms to collaborate. The co-operative solution to a standard prisoner's dilemma model will only come about after an infinite number of iterations. As such, it has been shown that the incentives to co-operate depend on two factors. First, the probability that the partners will co-operate again. Second, the ability of the firm to deter opportunistic behaviour from the other party by credibly threatening retaliation.

In both cases, large firms come out on top. On the first point, it is reasonable to assume that probability of repeat co-operation increases with the probability of survival, which almost certainly increases with firm size. On the second, larger firms' greater "bargaining power", in terms of influence over suppliers of components and capital equipment, distributors and also competitors, means that opportunism by others is very expensive. These two factors (survival and bargaining power) imply that large firms are more likely to meet the two conditions set out above. Also, since larger firms are more active in more areas, the potential for retaliation is greater.

The final "efficiency argument" comes partly from transaction-cost economics (TCE). According to TCE, large firms are more likely to collaborate than smaller ones because the potential benefits are greater and the costs lower. Williamson puts great emphasis on the fact that large firms (hierarchies) become difficult to co-ordinate (in terms of, for example, the monitoring of opportunistic behaviour) from a managerial point of view (Williamson, 1987). This "bureaucratisation", in a sense sets a limit to the growth of the firm.

In addition to the above, we also argue that, since the Schumpeterian hypothesis of R&D increasing with firm size is almost unanimously confirmed by most empirical studies (Cohen, 1995), there is a further extension to the neo-classical-based approach worth mentioning. Since, from this point of view, one of the most important motives for collaboration is the internalisation of negative technological externalities, by virtue of the fact that larger firms do more R&D, they must also be more open to the sorts of externalities that may lead to collaboration.[10]

Logistic regression analysis

This section presents the first part of our empirical analysis. In particular we present the results of a firm-level analysis of the propensity to collaborate using CIS2 data for the United Kingdom. We use a logistic regression to explore the relationships between our variables of interest. We briefly describe the rationale for using logistic regressions as opposed to other types of regressions.

Unfortunately, we do not have any information on the relative importance of each collaboration to each firm. We do not know how many collaborations each firm has or how integral those collaborations are to the overall strategy of the firm. All we have is a dichotomous (binary) variable, the results of the question; do you collaborate or not (represented in the data as either a 1 or a 0)?

There is a range of econometric models that have been developed to get around this problem. These are called discrete-choice models. The logistic regression model is a commonly used discrete-choice model. Such models work in very similar ways to their conventional counterparts (OLS, etc.); however, they allow the use of dichotomous (or even sometimes multi-chotomous dependent variables). The logistic regression model works on the principal of logarithmic transformation of the variables. In simple terms, the logistic regression estimates the effect that independent variables have on the odds of the dependent variable being either a 1 or a 0 (in this case, if a firm is a collaborator or not).

Specification of the regression

Our dependent variable is the binary variable, collaboration. Our independent variables are as follows; turnover in 1996 (to proxy firm size), government programme participation (a binary variable), nationality (a binary variable indicating whether the firm is foreign or domestic), sources of information (binary variables for all those sources of information found in Table 7)**,** and sector dummy variables. The dummy variable for the transport sector (variable LD8) is left out since it has the median proportion of collaborations, The logistic regression model takes the form of equation [1] where Z is represented by equation [2] and X_1 to X_N are the independent variables.

$$prob(collab) = \frac{1}{1+e^{-Z}} \qquad [1]$$

$$Z = \beta_0 + \beta_1 X_1 + ...\beta_N X_N \qquad [2]$$

The Z term is analogous to the standard multiple linear OLS regression model.

Results of the logistic regression analysis

In this section, we present the results of the logistic regression analysis described above. As with all regressions, getting the right specifications is a bit of an art. We present results from three different specifications of a model of the propensity to collaborate. Our main focus of interest is in the interactions between the effect of firm size and the effect of sectoral differences on the likelihood that a firm will collaborate. In the first specification, we present estimates of the relationship between firm size (proxied by turnover) with a constant, and collaboration. The second specification controls for sectoral differences by the inclusion of dummy variables. Finally, we include other variables of interest, including a proxy for firm growth, nationality and a range of more informal external linkages. In this final set of variables all are binary, for instance for firm growth, rather than a proportion: the variable takes the value of 1 if the firm grew (in terms of turnover) between 1994-96, and takes the value 0 if turnover fell over the period. For each specification, the same binary collaboration variable is on the left-hand side of the equation as the dependent variable.

Specification 1: constant + firm size

In this first specification, we have only a constant and turnover (or proxy for firm size) on the right-hand side.[11]

Log likelihood statistic with just constant	1 923.7241
Log likelihood statistic with full model	1 690.334
Model chi squared	233.390
Sig value	0.0000

Classification table for LCOOP

The cut value is .50

			Predicted		Percent correct
			.00	.69	
			1	2	
Observed	.00	1	1 055	80	92.95%
	.69	2	336	127	27.43%
				Overall	73.97%

The classification table above describes the proportion of cases correctly predicted by the regression as being either collaborating or not. In this case, 74% of the sample are correctly classified. Table 1 gives values of the coefficient on firm size and the constant with the corresponding statistics used to evaluate significance.

Table 1. **Logistic regression; specification 1**

Variable	B	S.E.	Wald	df	Sig	R
LTRN96	.4694	.0340	191.0630	1	.0000	.3135
Constant	-5.1955	.3247	256.0666	1	.0000	

The sig values indicate that the coefficient on firm size is highly significant. As described above, the coefficients produced in the logistic regression give the change in logit which is the change in the natural logarithm of the odds of collaborating. In this form, the size of the coefficient is not easy to interpret and for this reason the exponent of the coefficient is given in Table 2.

Table 2. **Specification 1; exponents**

	95% CI for Exp(B)		
Variable	Exp(B)	Lower	Upper
LTRN96	1.5990	1.4960	1.7090

This effectively tells us that firm size appears to have a more than proportionate effect on the likelihood of collaborating.

Specification 2: constant + firm size + sector dummies

In this second specification, we re-examine the effect of size on the propensity to collaborate, this time controlling for differences between sectors by means of dummy variables. We exclude the dummy variable for instruments (variable LD7) since with 32.1% collaboration, instruments has the median proportion collaboration of the group of sectors (Torbett, 2001).

Log likelihood statistic with just constant	1 923.7241
Log likelihood statistic with full model	1 633.316
Model chi squared	290.409
Sig value	.0000

Classification table for LCOOP

The cut value is .50

			Predicted		Percent correct
			.00	.69	
			1	2	
Observed	.00	1	1 047	88	92.25%
	.69	2	309	154	33.26%
				Overall	75.16%

With the inclusion of industry dummy variables, the proportion of cases correctly classified in terms of collaboration or non-collaboration has increased slightly to just over 75%, as shown in the above classification table. The coefficient on firm size remains positive and highly significant. None of the coefficients on industry dummy variables are significant. The information from the excluded dummy variable (for the instruments sector) goes into the constant, which we find to be significant as expected. In effect, each sector dummy variable tests the hypothesis that the sector in question is significantly different from the excluded sector. Since all of our sector dummies are non-significant, we can conclude that none of the sectors are significantly different from the sector with the median proportion of collaborators, *i.e.* instruments. The strong positive effect of firm size on the propensity to collaborate is robust across sectors. Again, for clarity of interpretation, we report the exponents of the coefficients below. The coefficient on firm size has marginally increased in size.

Table 3. **Logistic regression; specification 2**

Variable	B	S.E.	Wald	Df	Sig	R
LTRN96	.5024	.0363	191.6383	1	.0000	.3140
LD1	-1.0470	.4363	5.7579	1	.0164	-.0442
LD2	.4720	.4442	1.1292	1	.2879	.0000
LD3	.1415	.3882	.1329	1	.7154	.0000
LD4	.0565	.3826	.0218	1	.8827	.0000
LD5	.6422	.4020	2.5521	1	.1101	.0169
LD6	.5114	.3711	1.8985	1	.1683	.0000
LD7	1.1393	.4466	6.5082	1	.0107	.0484
LD9	-.8562	.3322	6.6427	1	.0100	-.0491
Constant	-5.4497	.3951	190.2780	1	.0000	

Table 4. **Specification 2; exponents**

	95% CI for Exp(B)		
Variable	Exp(B)	Lower	Upper
LTRN96	1.6527	1.5392	1.7745
LD1	.3510	.1492	.8255
LD2	1.6032	.6713	3.8289
LD3	1.1520	.5383	2.4654
LD4	1.0581	.4998	2.2398
LD5	1.9007	.8644	4.1792
LD6	1.6676	.8057	3.4514
LD7	3.1247	1.3021	7.4984
LD9	.4248	.2215	.8146

Specification 3: constant + firm size + sector dummies + other managerial variables

Finally, we include some additional variables of interest to see what effect they have on the propensity to collaborate. These include government programme participation, firm growth, informal external linkages (sources of information for innovation), nationality.

Log likelihood statistic with just constant	1 923.7241
Log likelihood statistic with full model	1 185.317
Model chi squared	482.628
Sig value	.0000

Classification table for LCOOP

The cut value is .50

			Predicted		Percent correct
			.00	.69	
			1	2	
Observed	.00	1	857	104	89.18%
	.69	2	180	228	55.88%
				Overall	79.25%

These additional explanatory variables clearly have some value as we see the largest decrease in log likelihood statistic as well as the largest proportion of correctly predicted cases. As with the first two specifications, the overall significance of the regression is confirmed by the model chi-squared. As we can see in Table 5, the coefficient on firm size is still positive and highly significant. The coefficient on government programme participation is also positive and significant, as we would expect since many public innovation programmes are, themselves, collaborative. We find a significant negative coefficient on our nationality variable. This variable is coded 1 if the enterprise unit is from the United Kingdom, and 0 if the firm is a foreign-owned subsidiary. This negative coefficient means that foreign-owned subsidiaries are statistically more likely to have formal collaborations than domestic firms. There are no significant negative coefficients on the variables indicating the more informal external linkages (sources of information for innovation). There is a significant positive relationship between collaboration and the use of universities, RTOs and “other external sources”.

Table 5. **Logistic regression, specification 3**

Variable	B	S.E.	Wald	df	Sig	R
LTRN96	.3591	.0462	60.4989	1	.0000	.1873
LD1	-.7929	.5234	2.2946	1	.1298	-.0133
LD2	.1021	.5026	.0412	1	.8391	.0000
LD3	.1971	.4458	.1955	1	.6584	.0000
LD4	.4838	.4495	1.1585	1	.2818	.0000
LD5	.3208	.4700	.4659	1	.4949	.0000
LD6	-.0047	.4290	.0001	1	.9913	.0000
LD7	1.0485	.5281	3.9415	1	.0471	.0341
LD9	-.5126	.3905	1.7230	1	.1893	.0000
LTRNNC	-.1260	.2065	.3721	1	.5419	.0000
LGPP	1.4496	.2251	41.4699	1	.0000	.1538
LRSENT	.8520	.4618	3.4033	1	.0651	.0290
LRSCOM	.0267	.3869	.0048	1	.9450	.0000
LRCLI	-.2358	.5250	.2017	1	.6534	.0000
LRSSUP	-.2922	.4309	.4597	1	.4977	.0000
LRSUNI	1.0204	.2488	16.8196	1	.0000	.0943
LRSRTO	.5903	.2436	5.8741	1	.0154	.0482
LROEXT	4.9333	1.5663	9.9197	1	.0016	.0689
LFORDOM	-.5568	.2631	4.4788	1	.0343	-.0386
Constant	-8.2216	1.1253	53.3812	1	.0000	

Table 6. **Specification 3; exponents**

		95% CI for Exp(B)	
Variable	Exp(B)	Lower	Upper
LTRN96	1.4320	1.3081	1.5677
LD1	.4525	.1622	1.2624
LD2	1.1074	.4136	2.9656
LD3	1.2179	.5083	2.9178
LD4	1.6222	.6722	3.9145
LD5	1.3782	.5486	3.4625
LD6	.9953	.4294	2.3073
LD7	2.8533	1.0135	8.0328
LD9	.5989	.2786	1.2876
LTRNNC	.8816	.5882	1.3215
LGPP	4.2613	2.7412	6.6245
LRSENT	2.3443	.9482	5.7960
LRSCOM	1.0271	.4811	2.1925
LRCLI	.7900	.2823	2.2105
LRSSUP	.7466	.3209	1.7373
LRSUNI	2.7743	1.7036	4.5179
LRSRTO	1.8046	1.1196	2.9087
LROEXT	138.8345	6.4450	2 990.6810
LFORDOM	.5730	.3422	.9597

"External activities", innovation intensity and absorptive capacity

As mentioned above, we argue that the results on the relationship between firm size and collaboration are of crucial importance for the way we examine the *effects* of collaboration. In particular, we argue that firm size could potentially bias an analysis of the effects of collaboration on *i)* innovation intensity; and *ii)* innovation performance (this corresponds to our second and third central research questions). The following sections describe our analysis of innovation intensity and innovation performance, in some way controlling for this bias by estimating firm-level regressions at different employment size bands.

Theoretical background

Neo-classical and resource/competence-based approaches make the same prediction about the effect of collaboration (and external linkages more generally) on innovation intensity.

At first glance, a stylised view of neo-classical economics would imply that collaboration is used as a cost-cutting substitute to in-house technological activities. This is often set against the competence-based approach, which stresses the importance of complementary assets. One would assume, then, that innovation intensity would be lower for collaborators in the neo-classical case and higher in the competence-based case. We argue however, that this interpretation of the literature is slightly misleading. In fact, there is much evidence in the neo-classical literature to suggest that innovation intensity would increase for collaborating firms. As discussed above, the work of Kamien *et al.* (1992) is a case in point. In the language of neo-classical economics, externalities cause a gap between private and social returns to R&D. Collaboration internalises these externalities and thus increases the amount of R&D done nearer to the (higher) socially optimal level. From a competence-based perspective, firms are unlikely to be able to use collaboration as a cheap way of gaining knowledge or technology from outside without having to spend money on innovation internally. This is largely because of the absorptive capacity argument (Cohen and Levinthal, 1989; Cohen and Levinthal, 1990).

Regression analysis of innovation intensity

In the following section, we present the results of a firm-level regression analysis of the determinants of innovation intensity. In particular, we are interested in the effect of collaboration and other external linkages on innovation intensity for firms in different size bands.

Innovation intensity has generally been defined in the literature as R&D divided by sales and has been examined from a number of different perspectives (Cohen and Levinthal, 1989; Cohen and Levinthal, 1990; Colombo and Paola ,1996; Kleinknecht and Brouwer, 1996). The CIS provides a unique set of information about the innovation-related expenditures of firms that responded to the survey. In this chapter, we experiment with an alternative indicator of innovation intensity; namely, "total innovation intensity".

R&D vs. "innovation expenditure"

One of the most traditional measures of innovation intensity uses R&D statistics as the numerator (Mowery and Rosernberg, 1989; Freeman and Soete, 1997). However, we have to ask ourselves whether this is really the most appropriate indicator to best represent *innovation* intensity. Much has

been written on the uses and abuses of R&D statistics (Patel and Pavitt, 1995). It is generally accepted that R&D statistics measure technological activities in science-based sectors such as chemicals and electronics much better than for other, more production-based sectors such as mechanical and especially software. Production-based technological activities are less well represented by R&D statistics for two reasons. First, much innovative activity in those sectors is just not classified as R&D. Activities that might be classified as R&D in one firm may be considered as being "just part of the core business in another". This is especially the case when there is no specific "R&D department" in the firm. Second, even when R&D departments exist, they are almost certainly not the only, or even main, source of technological innovation for firms in production-based sectors. Activities such as design, assembly, building and operation of advanced capital equipment can be as important, if not more important, to the overall innovation performance of the firm as the R&D department.

Perhaps the most critical drawback in the context of the CIS is the fact that R&D statistics do not adequately capture the technological activities of small firms. Firms with less than 1 000 employees are significantly less likely to have an R&D department than larger firms. It has been shown that R&D is a function of specialisation and firm size (Patel and Pavitt, 1995). It has also been shown that the top 100 firms in terms of R&D accounted for about 90% of total R&D. This is not to say that those firms accounted for 90% of *innovation*. Patel and Pavitt have shown that those same firms only accounted for 60% of US patents (Patel and Pavitt, 1987). Since the CIS data are strongly biased towards small firms, it may not be so useful to compare them on the basis of R&D but rather on the basis of a more inclusive indicator of "innovation expenditure".

Table 7. **Dependent variable = Total innovation expenditure intensity**

Standard and log model estimates

	B for log model	Std. error	Sig	B for model without logs	Std. error	Sig
Constant	0.06646**	0.031	0.032	0.07197*	0.037	0.051
Government programmes	0.02082**	0.007	0.005	0.01584**	0.006	0.01
Collaboration	**-0.00251**	**0.007**	**0.731**	**-0.00306**	**0.006**	**0.614**
Sources of information for innovation:						
Internal	-0.02695*	0.015	0.07	-0.02546**	0.012	0.039
Competitors	-0.02135	0.013	0.109	-0.0184*	0.011	0.096
Clients/customers	-0.00534	0.017	0.759	-0.00994	0.014	0.489
Suppliers	0.01158	0.014	0.412	0.01049	0.012	0.37
Universities	-0.00238	0.008	0.775	-0.00097	0.007	0.888
RTOs	-0.02054**	0.008	0.012	-0.01647**	0.007	0.015
Other external	0.05072	0.046	0.267	0.0482	0.038	0.203
Foreign/domestic	0.000192	0.009	0.982	0.000918	0.007	0.897
Dummy: Food, beverages and tobacco	-0.04758**	0.015	0.002	-0.03612**	0.012	0.004
Dummy: Chemicals	-0.02193*	0.015	0.15	-0.01609	0.013	0.203
Dummy: Chemical related	-0.0275**	0.014	0.046	-0.02036*	0.011	0.075
Dummy: Metals and metal products	-0.02196	0.014	0.114	-0.01682	0.011	0.143
Dummy: Machinery and equipment	-0.01947	0.014	0.175	-0.0149	0.012	0.21
Dummy: Electrical, electronics	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
Dummy: Instruments	0.0415**	0.016	0.01	0.03389**	0.013	0.012
Dummy: Transport	-0.03395**	0.014	0.015	-0.02565**	0.012	0.026
Dummy: Other	-0.02201*	0.012	0.057	-0.01484	0.01	0.122

Note: ** denotes significance at p<0.005 and * denotes significance at p<0.05.
R-squared for model without logs = .068.
R-squared for model with logs =.073.

In this first model, we estimate innovation intensity as described above on the basis of "total innovation expenditure". That is to say, the dependent variable is total innovation expenditure, R&D plus other innovative expenditures such as the acquisition of machinery and equipment, training, industrial design, etc., as a proportion of turnover. The rationale behind this is to obtain a broader picture of innovation expenditure than just R&D. Since R&D is more relevant in some sectors than others, including other types of expenditures may give us a better overall picture of innovation intensity.

Table 7 shows the estimated coefficients, their standard errors and p-values for two versions of the model; one with the raw, untransformed variables and the other being exactly the same model but with log transformed variables.

The two models are broadly consistent with one another in terms of the direction of the relationships analysed. However, the log model is likely to give more reasonable estimates since it has gone some way in improving the normality of the variables concerned.

As with other models that attempt to predict innovation intensity, the explanatory power of the model is quite weak with an R-square of only 0.073 for the model with logs.

It is interesting to note the signs of most of the coefficients. Only participating in innovation-related government programmes comes out as having a significant positive influence on innovation intensity. Other positive coefficients are: firm growth, suppliers as an important source of information, other external sources of information and nationality (meaning that foreign firms are likely to have a higher R&D intensity than domestic ones). However, these coefficients are not statistically significant. Sources of information within the enterprise, competitors and RTOs have a statistically significant negative impact on innovation intensity. All other coefficients are negative but not significant, including collaboration.

Several industry dummy variables are significant. This is expected and is in keeping with the literature, and should only be interpreted in that there are significant differences between sectors in their determinants of innovation intensity.

Estimating the same total innovation intensity model by three size bands yields interesting results (see Table 8). Since splitting the data has effectively reduced the number of firms in each estimation, there are, in general, fewer significant coefficients than in the full sample model. This would be expected since reducing the number of firms reduces the number of degrees of freedom. However, by splitting the sample in this way, we have increased the explanatory power of each model in that the R-squares have almost doubled to around 0.12.

We have already identified an overwhelming influence of firm size on the propensity to collaborate. However, these regressions indicate that firm size has a much more pervasive effect that just the likelihood that firms will collaborate. There are interesting differences between size bands in the split sample model and differences between the split sample and full sample model. As in the full sample model, many of the coefficients are negative which has important implications for the evaluations of our hypotheses discussed earlier.

Table 8. **Total innovation expenditure intensity model, by size band**

	Large			Medium			Small		
	B	Std. error	Sig	B	Std. error	Sig	B	Std. error	Sig
Constant	0.032	0.020	0.109	-0.003	0.070	0.966	0.051	0.047	0.281
Firm growth	0.003	0.009	0.750	-0.020	0.014	0.148	0.001	0.014	0.931
Government progs	0.008	0.008	0.282	0.033*	0.017	0.057	0.027*	0.015	0.078
Collaboration	**0.015***	**0.008**	**0.052**	**0.007**	**0.016**	**0.647**	**-0.024**	**0.016**	**0.121**
Sources of information for innovation:									
Internal	0.019	0.022	0.406	-0.052	0.040	0.192	-0.021	0.024	0.390
Competitors	-0.016	0.014	0.226	-0.022	0.029	0.449	-0.040	0.029	0.171
Clients/customers	0.008	0.018	0.629	0.092**	0.042	0.030	-0.105**	0.038	0.006
Suppliers	-0.003	0.015	0.821	0.063*	0.037	0.092	0.024	0.026	0.372
Universities	-0.018*	0.009	0.055	-0.015	0.018	0.382	0.032*	0.017	0.067
RTOs	-0.002	0.009	0.786	-0.013	0.018	0.486	-0.037**	0.016	0.024
Other external	Excluded	Excluded	Excluded	0.037	0.106	0.730	0.166**	0.072	0.021
Foreign/domestic	-0.010	0.008	0.219	-0.011	0.019	0.569	0.016	0.021	0.436
Dummy: Food/bev./tobacco	Excluded	Excluded	Excluded	0.002	0.043	0.968	-0.041	0.042	0.338
Dummy: Chemicals	0.028	0.015	0.073	-0.001	0.033	0.975	-0.059*	0.033	0.076
Dummy: Chemical related	0.020	0.014	0.158	-0.048	0.029	0.100	-0.025	0.028	0.361
Dummy: Metals/metal prod.	0.020	0.016	0.202	-0.031	0.028	0.265	-0.024	0.027	0.371
Dummy: Machin./equip.	0.024	0.016	0.134	-0.043	0.030	0.151	-0.015	0.028	0.576
Dummy: Electrical/electron.	0.045**	0.014	0.002	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded
Dummy: Instruments	0.054**	0.019	0.005	0.021	0.045	0.647	0.048*	0.028	0.095
Dummy: Transport	0.024	0.015	0.111	-0.018	0.026	0.489	-0.066**	0.030	0.025
Dummy: Other	0.009	0.012	0.446	-0.009	0.024	0.709	-0.013	0.024	0.568

Note: ** denotes significance at p<0.005 and * denotes significance at p<0.05.
R-squared for large firms model = 0.112746.
R-squared for large medium model = 0.129998.
R-squared for large small model = 0.123302.

The first, and most interesting, result to note is the prediction of the effect of collaboration on innovation intensity. In the full sample model, we noted that the coefficient was negative but non-significant. By splitting the sample, we get an impression of why this might be the case. For small firms, the coefficient is negative and almost (but not quite) significant. For medium-sized firms, the sign of the coefficient has changed to positive; however, it is not significant. For large firms, the coefficient on collaboration is positive and significant. So not only does firm size increase the likelihood that a firm will collaborate, the larger the firm, the more positive the effect collaboration has on its innovation intensity.

The coefficient for internal sources of information is also negative for small firms and positive for large firms, although neither of these coefficients are significant. None of the coefficients are significant for competitors, all are negative. Customers as a source of information have a positive non-significant coefficient for large firms, a highly significant positive coefficient for medium-sized firms but a highly significant negative coefficient for small firms. Suppliers as a source of information have positive coefficients for small and medium-sized firms and a negative coefficient for large firms, although the result is only significant for medium-sized firms.

Universities as a source of information have a significant positive impact on innovation intensity for small firms but a significant negative impact on the innovation intensity of large firms. The use of

RTOs seems to have a negative impact on innovation intensity for small medium and large firms (it is particularly significant for small firms). Other external sources of information have a highly significant positive effect on the innovation intensity of small firms. None of the coefficients on nationality are significant for the split sample regressions.

Collaboration, external activities and innovation performance

We now turn to our final research question on the relationship between collaboration and innovation performance. Innovation performance is a rather strange measure. The CIS asked firms to report the proportion of their turnover between 1994-96 that was due to innovative products. These products may have been, "technologically improved", new to the firm, or new to the industry (novel innovation).

Theoretical background

In contrast to our two previous research questions, we argue that in terms of predicting the likely relationship between collaboration and innovation performance, there are more important differences between neo-classical and competence-based perspectives

Strictly speaking, the neo-classical perspective does not offer any predictions about the success of collaborations, to say nothing of the fact that it rarely discusses any sort of innovation. Firms made up of completely rational individuals will always have an optimal structure. Since the theory is static, it cannot adequately deal with dynamic effects. In other words, it has nothing to say about the adjustment process from a state of not being in a collaboration to being in a collaboration. The fact that a collaborating firm may have higher performance than a non-collaborating firm is irrelevant in this framework since we assume general equilibrium and that all firms have their optimal structure.

The resource-based/competence approach is inherently more dynamic and has more to say about innovation generally and the likely outcomes of collaboration. Competence-based motives for collaborating are, by definition, based on the attempt by the firms involved to improve their capabilities through learning with other institutions. While innovation is not seen as linear or predictable, effective use of collaboration at least gives firms the possibility of monitoring and learning other technical fields with a view to potentially combining them with existing capabilities in house to bring about innovation. On the other hand, the competence-based approach does not assume that everyone is rational and that firms never get it wrong. Collaborations can be costly (in terms of general transactions, bargaining, contracting, etc.) as well as beneficial in terms of learning. If transaction costs are not effectively evaluated, in a way either defined by traditional transaction-cost economics or by more recent dynamic transaction-cost approaches, *vis à vis* the learning benefits, the net result of the collaboration could be negative for the firm.

In general terms, however, we hypothesise that collaborating firms are likely to have greater innovation performance, measured by share of innovative products in turnover, than non-collaborating firms.

Regression analysis of innovation performance

Simple OLS regressions are used to estimate the relationship between a range of variables relating to external sources of knowledge, firm growth and sector characteristics to three different measures of innovation performance, measured by the proportion of turnover in innovative products. Three different types of "innovative product" are identified by the CIS: improved, new or novel. All

represent some sort of "innovation", although in principal these three different categories enable us to distinguish between types of innovation, *i.e.* incremental *vs.* radical innovation. For the purposes of this section we focus on the most inclusive of these; namely, "improved products".

The above sections have shown how firm size affects not only the propensity to collaborate but also the patterns of expenditure inputs to innovation, *i.e.* innovation intensity. Including a proxy for firm size in the present model of innovation performance would cause a co-linearity problem with the collaboration variable, our central concern. For this reason, firm size has been left out of the specification. Instead, we re-estimate the model on different employment size bands in a similar way to that described above.

Table 9 shows the coefficients of the regression estimated on the entire data set in both standard and log forms with turnover in improved products as the dependent variable. The rationale behind doing a log transformation is the same as discussed previously. The log transformed variables improve the normality of the distribution and improve the explanatory power of the regressions.

According to this regression, collaboration has a significant positive effect on innovation. Most of the other coefficients on sources of information also have positive coefficients, although suppliers as a source of information is singled out as being very significant. Using competitors and "other external" sources of information have a significant positive effect on innovation performance. Significant coefficients on the sector dummy variables indicate that there are important differences between sectors in terms of the relationship between these explanatory variables and innovation performance. It is interesting to note the significant negative coefficient on nationality: foreign firms seem to have more turnover in improved products than domestic firms.

Table 9. **Innovation performance based on turnover in improved products**

	B	Std. error	Sig.
Constant	0.125	0.032	0.000
Government programmes	0.001	0.016	0.957
Collaboration:	**0.050**	**0.016**	**0.002**
Internal	0.018	0.026	0.490
Competitors	0.050	0.025	0.044
Clients/customers	0.034	0.031	0.287
Suppliers	0.085	0.029	0.003
Universities	0.002	0.017	0.892
RTOs	-0.010	0.017	0.542
Other external	-0.108	0.047	0.021
Foreign/domestic	-0.044	0.018	0.017
Dummy: Food, beverages and tobacco	-0.076	0.034	0.026
Dummy: Chemicals	-0.083	0.035	0.018
Dummy: Chemical related	-0.060	0.031	0.057
Dummy: Transport	Reference	Reference	Reference
Dummy: Machinery and equipment	-0.052	0.032	0.106
Dummy: Electrical, electronics	0.022	0.029	0.444
Dummy: Instruments	0.072	0.036	0.043
Dummy: Metals and metal products	-0.007	0.032	0.831
Dummy: Other	-0.061	0.025	0.017

Note: ** denotes significance at p<0.005 and * denotes significance at p<0.05.
R-square = 0.075.

Innovation performance by size band

Our innovation performance model is re-estimated by size band. As above, we confine ourselves , to the analysis of turnover in the "improved products" variable.

Table 10 shows the coefficients for all three size bands. The first point to note is that we have far more significant results for small firms than for large ones. Part of this could stem from having more degrees of freedom for small firms, but it may have analytical implications. Could it be the case that, although large firms are more likely to use collaboration and external sources as a matter of course, the management of external sources of knowledge is even more critical in small firms because they can less easily take advantage of economies of scale and scope?

Collaboration has a positive effect on innovation performance but this result is even more significant for firms in the small size band. This is interesting if we compare our findings on collaboration in our previous section. Collaboration had a negative coefficient on innovation intensity for firms in the small size band and a positive significant coefficient for firms in the large size band. This might imply that small firms are using collaboration more as a substitute for spending money internally, while large firms are using collaboration more as a complement. However, when we look at the relationship between collaboration and innovation performance in Table 10, we see that the positive relationship is only very significant in small firms and not significant at all in large firms.

Table 10. **Innovation performance based on turnover in improved products**

	Large			**Medium**			**Small**		
	B	Std. error	Sig.	B	Std. error	Sig.	B	Std. error	Sig.
Constant	-0.057	0.126	0.654	0.110	0.106	0.301	0.164	0.038	0.000
Government progs	0.016	0.026	0.538	-0.026	0.041	0.528	0.001	0.024	0.954
Collaboration	**0.013**	**0.026**	**0.613**	**0.059**	**0.039**	**0.132**	**0.090**	**0.025**	**0.000**
Internal	0.104	0.065	0.110	0.142	0.076	0.063	-0.013	0.030	0.672
Competitors	0.012	0.043	0.774	-0.031	0.063	0.622	0.101	0.034	0.003
Clients/customers	-0.004	0.058	0.943	-0.066	0.092	0.478	0.091	0.041	0.028
Suppliers	0.029	0.052	0.573	0.098	0.085	0.248	0.086	0.038	0.022
Universities	0.041	0.031	0.181	0.024	0.041	0.554	-0.033	0.025	0.184
RTOs	-0.019	0.029	0.520	0.008	0.042	0.857	-0.004	0.024	0.862
Other external	0.054	0.192	0.778	-0.076	0.173	0.663	-0.153	0.051	0.003
Foreign/domestic	-0.004	0.027	0.897	-0.043	0.044	0.328	-0.081	0.032	0.012
Dummy: Food/bev/tobacco	0.004	0.054	0.944	-0.008	0.109	0.940	-0.117	0.059	0.048
Dummy: Chemicals	0.034	0.058	0.557	-0.016	0.096	0.871	-0.148	0.051	0.004
Dummy: Chemical related	0.024	0.057	0.677	-0.018	0.079	0.816	-0.118	0.043	0.006
Dummy: Transport	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Dummy: Machin/equipment	0.080	0.059	0.173	-0.085	0.081	0.296	-0.112	0.044	0.011
Dummy: Electrical/electronics	0.178	0.056	0.002	0.050	0.069	0.471	-0.080	0.040	0.046
Dummy: Instruments	0.230	0.071	0.001	0.043	0.094	0.648	0.008	0.045	0.858
Dummy: Metals/metal prods.	0.137	0.058	0.019	-0.126	0.074	0.088	-0.004	0.046	0.924
Dummy: Other	0.039	0.049	0.417	-0.015	0.067	0.825	-0.120	0.033	0.000

R-squares for innovation performance regressions by firm size

Large	0.10
Medium	0.09
Small	0.15

We also discussed the negative coefficient on foreign firms for the innovation performance model on the whole data set We see that this result is also found within size bands, although is only very significant in the small size band. Only in the small size band do we find significant coefficients on the use of external sources of information. These coefficients are positive for competitors, clients and suppliers, and negative for universities, RTOs and other external sources of information.

Analysis and conclusions

In this section, we provide a brief analytical overview of the main econometric results as well as offering some conclusions with a particular emphasis on possible policy implications.

In the first instance, according to the empirical analysis presented here, there is a strong positive relationship between firm size and the propensity to collaborate. This effect is more than proportionate and is independent of differences between industrial sectors. Results of a logistic regression analysis indicate that government programme participants, foreign-owned subsidiaries as well as those that cite universities and "other external" sources of information as being important to the innovation process are more likely to have had formal collaborations.

We have argued that, because of the strong relationship between firm size and the propensity to collaborate, it is necessary to take firm size into consideration when assessing the impact of collaboration on innovation intensity and performance. An OLS regression was estimated at three different size bands to examine the influence of collaboration and other factors on innovation intensity. Interestingly, we found that the sign of the coefficients would often change according to size band. For example, collaboration seems to have a negative impact on innovation intensity for small firms but a significant positive impact for larger firms.

This is interesting because it suggests that not only does firm size affect whether or not a firm is likely to have formal collaborations, it also affects how those collaborations influence the innovation process internal to the firm. In this case, smaller firms that collaborate seem to spend less on innovation that those that do not (*i.e.* they use the collaboration as a substitute for internal activities). For larger firms, collaborators seem to spend more on innovation than non-collaborators (supporting the view that collaborations for large firms are more of a complement to internal activities). This is completely consistent with the notion of absorptive capacity. Whereas, often in the literature, a "false dichotomy" is cited between those who believe that collaboration is a complement and those who believe that it is a substitute to internal activities, this chapter suggests that both points of view are relevant but at different levels of firm size (with, in a sense, absorptive capacity becoming more relevant the larger the firm).

Similarly, an OLS regression was estimated at the same size bands to explore the relationships between these factors and innovation performance measured by turnover in "innovative products". It should be emphasised that this is not an "overall performance measure" and as such only captures product innovations that have been commercialised within the time span of the questionnaire.

Again, we find different results for different size bands. We do not find any significant relationship between collaboration and innovation performance for large firms. In fact, for firms in the large size band, we do not find any significant results at all. The finding is similar for firms in the medium size band, although we do find a significant positive coefficient on collaboration here. For firms in the small size band, however, there are many significant results, in particular a highly significant positive coefficient on collaboration. The same goes for foreign subsidiaries and those that cite customers, suppliers and competitors as an important source of information for innovation *for firms in the small size band*. At first glance, we might say that it seems that collaborating large firms are failing since turnover in innovative products is not higher, while the opposite is true for small firms. However, we should guard against such a rash conclusion and argue that it may well be that large firms are using collaborations for different strategic reasons than small firms. As such, the effect of these (large firm) collaborations may be more difficult to identify with cross-sectional data of this kind. For example, large firms may be using collaborations more as an exploratory tool to monitor new technologies and scientific developments. As such, learning from failure may be a crucial part of their innovation strategy. Smaller firms, on the other hand, may not be able to afford to "explore" in such a potentially expensive way, simply because of the comparative lack of internally generated funds.

Several findings of this chapter have important implications specifically for a policy audience. It is clear that collaboration occurs for many and various reasons. It is a very broad, at best inclusive (at worst, perhaps nebulous) concept. As such, there is not going to be "one theory" that explains all. Perhaps, then, we should not look for one, but rather be more inclusive and open minded about what theories can help to respond to what questions under what circumstances. Clearly, this needs to be reflected in the type of advice given to industrial policy makers.

In terms of targeting specific policies to specific needs, the contribution of this work on the role of firm size, especially when compared to sectoral differences in the determination of the propensity to collaborate, is particularly striking. Sweeping "one-size-fits-all" statements about the value of collaboration should be replaced with a more subtle understanding of what goes on at different levels of size.

In particular, several "theories", such as absorptive capacity, should reflect more critically on firms' size as a structural variable and understand that the competitive and economic environment of firms differs between levels of size. As such, the rationales for collaborating, and indeed the rationales for public support for such collaborations, may be different for firms at different levels of size, regardless of sector.

The section on the relationship between collaboration and innovation intensity sheds new light on our understanding of the implications of complementary assets for the structure of firms' relationships with other organisations. Significant relationships are found for large firms indicating that the extent of their external linkages, be they formal or informal collaborations, has an important impact on their innovation expenditure compared with the results for the small firms.

In the section on performance, interestingly, no significant findings resulted from our regressions on large firms. This might imply that firms' use of external linkages, be they formal or informal collaborations with others, does not have much of an impact on innovation performance (in terms of product innovation in the same period) for large firms. Why then would they do it? Plausible ideas that have been put forward in the literature include: monitoring new technologies, internationally collaborating to adapt products to local markets (although in this case we might expect to find "new products"). Large firms may simply have a broader financial base, allowing them to do more "exploratory" work. (Large firms are also more likely to be involved in process innovation). A further

exploration of these ideas would have important implications for policy, particularly for the evaluation of collaborative programmes. Evaluating the success or failure of a collaborative programme may not be simply a case of measuring direct performance increases. Collaborative activity may well have longer-term benefits to the organisations involved in terms of learning about new technologies or modes of organisation from their partners.

For small firms, on the other hand, their external environment, in terms of their formal and informal relationships with other organisations, is extremely important in the short term for bringing about technological innovation.

We stress that we are still at a relatively early stage of developing ways of measuring "inter-firm activity" generally. The many different types of inter-firm arrangement, collaboration, alliance, etc., mean that constructing meaningful measures that are relatively easy to collect and tell us something useful is an extremely difficult task, but one that should not be overlooked. The CIS2 provides a unique source of information that is complementary to other data sources. However, the CIS (and innovation surveys more generally), too, is in the relative early stages of development. The benefits of further refinement of such innovation surveys are highlighted by this work. Both the questions asked and the sample design could be improved, possibly including some measure of "collaboration intensity", rather than the current (and fairly limited) binary variable. However, in asking simple questions of a large number of firms of different sizes and in different sectors (as we have done in this chapter), we often see statistical regularities or broad structural effects that might otherwise have gone unnoticed. Policy makers should give priority to further work that combines quantitative information about firms with more qualitative information about their innovation characteristics. This would ultimately lead to a richer set of innovation indicators from which to inform policy.

Finally, and in conclusion, in recent years much innovation policy, and industrial policy more generally, has been founded on the notion that "bringing" people and firms together in collaborative activities is a good thing for learning, innovation and economic growth. Such policy thinking has been heavily influenced by academic discussions of globalisation and the national system of innovation. Increasing connectivity between the elements of the national system of innovation through collaborations is seen as being a key policy tool for improving the competitiveness and prosperity of firms and nations.

This chapter stresses that, on the one hand, there is an increasing amount of evidence to support the view that the most innovative firms are almost certainly collaborative. However, there is still much that we do not know about collaboration. We are not clear about the motives or the effects that these collaborations have on the internal workings of participant organisations or on their performance.

By simply comparing firms at different size levels across sectors we have shown that there seem to be systematic differences in the way that these collaborations are used by firms and in their outcomes.

NOTES

1. Technological collaboration in this chapter refers to some sort of "formal collaboration". We are largely considering a binary variable derived from responses to question 13 of the UK Community Innovation Survey, *i.e.* we do not consider type or location of partner, simply whether or not the firm has had some sort of formal collaboration.

2. The UK CIS was implemented in 1997. Responses refer to the three-year period 1994-96, inclusive.

3. The chapter aims to present the results of the central firm-level analysis for each of the three research questions and to draw out the key conclusions. The "summary" nature of this document clearly limits the amount of theoretical discussion and empirical detail that can be included. Interested readers should consult (Torbett, 2001) for further detail.

4. For example, work using the CATI database at MERIT (Hagedoorn and Schakenraad, 1990; Hagedoorn and Schakenraad, 1992) has been the one of the most important sources of empirical evidence in support of this.

5. For example, the LINK programme in the United Kingdom and the EC Framework Programmes.

6. Participating countries were as follows: Belgium, Germany, Spain, France, Ireland, the Netherlands, Austria, Finland, Sweden, the United Kingdom and Norway.

7. "The *enterprise* is the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision making, especially for the allocation of its current resources. An *enterprise* carries out one or more activities at one or more locations. An *enterprise* may be a sole legal unit" (ONS, 1992).

8. Finally, it should be noted that all data presented in this chapter are in unweighted form. Although the CIS was designed as a size- and sector-stratified sample, the sampling ratios achieved were too large to make weighting the data a reasonable proposition for analysis. For example, in many cases, one firm would have represented several hundred firms under the weighting system. Nevertheless, the results presented represent a larger-scale survey of innovation than has hitherto been available in the United Kingdom.

9. Indeed, the overall theoretical approach of this work has very much been inspired by Colombo's original (and pragmatic) approach to drawing on different and overlapping bodies of economic literature.

10. Clearly, the Schumpeterian-inspired empirical work also supports the resource-based view to a certain degree. In particular, larger firms (having grown to be large) are more involved with the creation of the new assets and resources that make them desirable collaboration partners.

11. Full versions of the statistical outputs are available on request.

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Chapter 6

EXCHANGE OF EMPLOYEES, PROTOTYPES AND USE OF ELECTRONIC MEDIA IN PRODUCT DEVELOPMENT COLLABORATION: RESULTS FROM A DANISH STUDY

by

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Introduction

It is generally recognised that, in the current economic context, product development is of crucial importance in securing competitive advantage for the individual firm, the nation and the world economy as a whole. Several studies have dealt with product innovations and, even though they are based on different approaches at different levels, it is emphasised that development of product innovations is a result of feedback loops between knowledge-producing and knowledge-using agents where a varying degree of interaction within and among firms takes place.

Much of the literature on collaboration, co-operation and networking in innovation has focused on the types and patterns of collaboration, *i.e.* dyads in value chains (Von Hippel, 1988), value chains (Miller and Blais, 1992), networks (Håkansson, 1987) and virtual organisations (Grenier and Metes, 1995), on the difficulties involved in assimilating and exploiting the information where one of the most comprehensive contributions to this issue is the concept of absorptive capacity (Cohen and Levinthal, 1990) and on the integrative capabilities of the firm (Verona, 1999). In the words of Tidd *et al.*, "the capability to manage such [development] networks can itself be a source of competitive advantage" (1997, p. 250). A less investigated element in this respect is the way two parties – the firm and its collaboration partner – transfer knowledge to one another.

The increased importance of external knowledge sources in stimulating the development of product innovations and the growing amount and complexity of knowledge will thus highlight the

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importance of the effective transformation of knowledge. Despite the importance of knowledge transfers between firms, the literature has mainly focused on transfers within the firm (Bolisani and Scarso, 2000), and Lynskey (1999) argues that there is little systematic evidence of knowledge transfer between firms. Hence, the lack of studies and the growing importance of the knowledge transfer mechanism call for analysis which provides a better understanding of the "relatedness" of these mechanisms in order to promote more focused, fine-grained and subtle policies.

This objective of this chapter is to shed light on knowledge transfers using quantitative techniques on a survey on inter-firm collaboration and product development, and to examine the importance of three types of knowledge transfer: *i)* exchange of employees; *ii)* exchange of prototypes; and *iii)* use of electronic media. Thus, both the tacit and codified dimension of knowledge are touched upon and each of the dyads are analysed according to a number of characteristics related to the focal firm, the project and the partner. Following the framework presented by Albino *et al.* (1999), knowledge transfer has four core components: actors, context, content and media. For the purposes of the present chapter:

- The *actors* are Danish manufacturing firms and their collaboration partners of all types.
- The *context* is product development projects.
- The *content* of the transfer is the competence of the parties.
- Finally, the survey covers three *media:* exchange of employees, exchange of physical prototypes, and electronic exchange.

The next section describes the study while the following one reports the results of the three media in relation to the focal firm, the project and the partner. A logistic regression is then carried out in order to clarify the inter-relatedness of the variables. The chapter concludes with a discussion of the complementarity of the three media.

The study

Danish manufacturing firms were identified in a Danish database (KO) covering 5 923 firms with more than ten employees listed under the heading Manufacturing (NACE 15-36). A total of 1 500 firms were randomly selected and contacted; the first part of the interview was undertaken with 1 022 of these. Of these, 294 firms were surveyed for the second part of the interview, which comprised questions on media of exchange. A Danish research institute, specialised in adaptive computer-assisted telephone interviewing, conducted the interviews during 1997-98.

Analysis of the incidence of non-contact and non-response show (Kristensen *et al.*, 1998, Tables 1 and 2) that the bias between the firms in the survey population and the interviewed firms, distributed according to firm size and industry, is so small as to be of no importance.

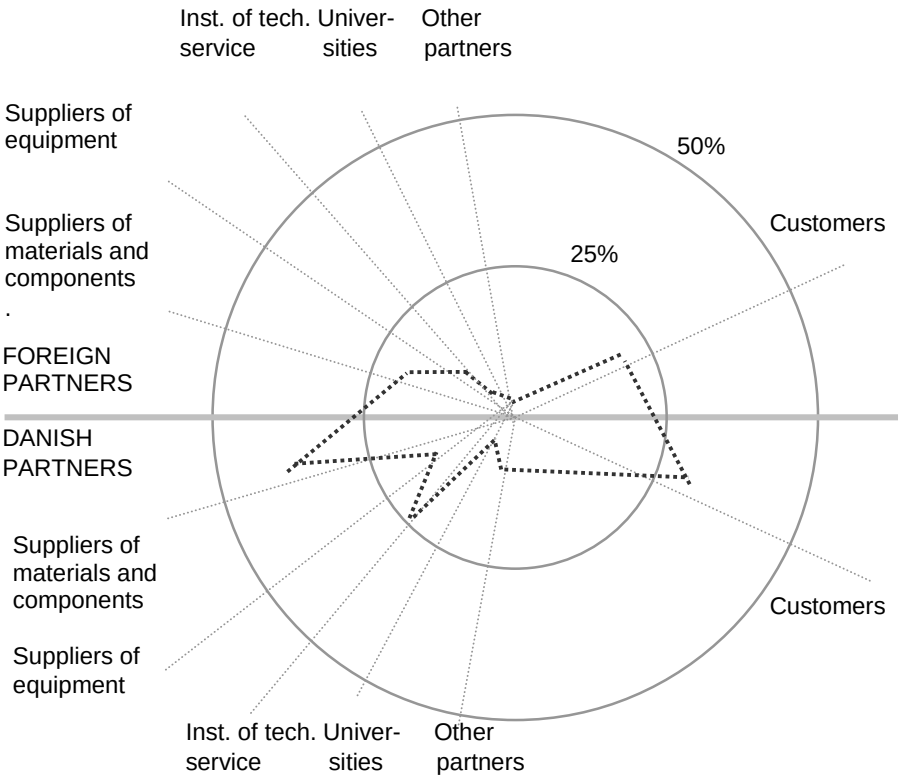
Each of the firms surveyed was asked whether or not it had developed one or more new products within the last two years. The 548 firms which had developed new products were then asked whether this had taken place in collaboration with partners external to the firm. The 531 firms in which collaboration took place were asked to describe the specific type of partners the firm had collaborated with. Among the 294 firms with which the second part of the interviews was completed, 283 replied to the questions about their (555) collaboration partners in sufficient detail. The informants were asked a number of questions on the exchange of *physical prototypes* and the use of *electronic media* in the exchange. The 294 firms had already answered questions on *exchange of employees* in the first part of

the interview. The questions can be seen in context in the complete questionnaire in Kristensen *et al.* (1998).

Results and discussion

The pattern of collaboration between the 283 focal firms and their 555 partners – irrespective of the media used – is shown in Figure 1 where "Universities" include sectoral research institutes, "Inst. of tech. service" include institutes of certification, tests, etc., and "Other partners" comprise competitors, management, marketing and legal consultants.

Figure 1. **Pattern of collaboration partners on the most important projects**



Exchange of employees

In the two dimensional (impersonal-personal)/(dynamic-static) media typology derived by Hoffman and Novak (1996), exchange of employees is, of course, personal and, as the exchange takes place face-to-face, it is a highly dynamic medium.

Informed employees can capture tacit knowledge through socialisation, observation and imitation (Nonaka, 1991; Nonaka and Takeuchi, 1995; Von Hippel *et al*., 1999; Albino *et al.*, 1999) and transfer much rich information (Draft and Lengel, 1986; Davenport *et al.*, 1998). Besides functioning as a

medium for catching and carrying knowledge, exchange of employees can further increase the absorptive capabilities (Cohen and Levinthal, 1990). By allowing immediate feedback on questions in face-to-face communication (Hartley *et al.,* 1997) and by taking part in a group innovation process on the receiver's premises (Leonard and Sensiper, 1998), a shared set of experiences develops that is crucial for the exchange of tacit knowledge (Sivadas and Dwyer, 2000).

Following the framework of Blumentritt and Johnston (1999), exchanged employees may also carry knowledge that enables the receiver of information to widen his interpretative competence so that it can match the new information and transform it into knowledge of his own. In their study of supplier involvement in product design, Wasti and Liker (1997) use the number of working days supplier engineers spent with customers as part of an index named communication.

In the present study, the firms were asked whether employees from the collaboration partner had worked in the firm and whether employees from the firm had spent time on the premises of the collaboration partners during the development.

In more than half of the cases, the work lasted for more than one week. In 11 cases, employees from partners worked more than one month in the firm, and in seven cases, employees from the firm worked more than one month on the project on the partner's premises. In general, however, there is no major difference between the distribution of working time in and out of the firm.

The distinction between light and heavy exchangers is determined by whether the total number of days spent on a project is below or above the median value.

Firms exchanging employees

Firms exchanging employees as part of their most important product development project do not differ significantly from other firms in terms of number of employees, years of establishment or geography. On the other hand, there are clear differences when the NACE codes of the firm are pooled into Pavitt's taxonomy (Pavitt, 1984). Compared to firms in the scale-intensive and supplier-dominated sectors, firms in the science-based sector and specialised suppliers distinguish themselves by a higher percentage of firms exchanging employees. Furthermore, the exchanges taking place in projects in the science-based sector are of longer duration than exchanges in other sectors.

Table 1a. **Exchange of employees by Pavitt sector**

Pavitt sector	Exchange of employees during project			Total
	Yes, heavy	Yes, light	No	
Scale-intensive	11 (11%)	8 (8%)	82 (81%)	101 (100%)
Supplier-dominated	2 (2%)	8 (10%)	73 (88%)	83 (100%)
Science-based	7 (21%)	2 (6%)	24 (73%)	33 (100%)
Specialised suppliers	12 (16%)	13 (17%)	52 (68%)	77 (100%)
	32	31	231	294

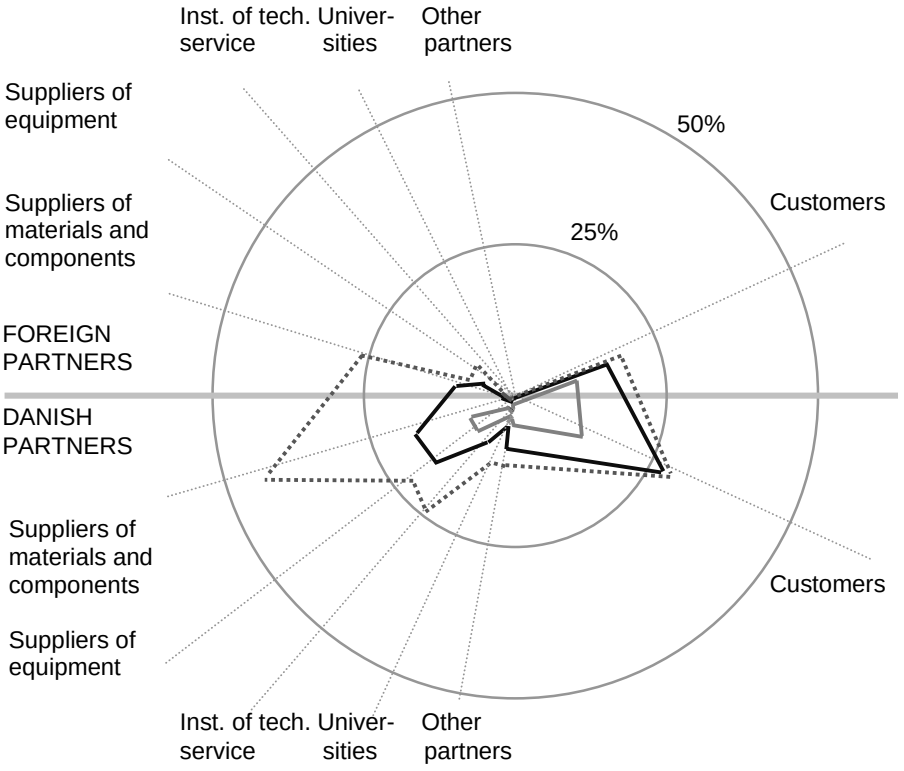
Note: Chi-square test of independence: p = .01.

When this is broken down into industries (as in Annex 3), it can be seen that most employees are exchanged in the machinery industry, while electrical and optical equipment have the highest number of exchanges relative to the size of their respective industries.

Partners of exchange

The pattern of partners with which the firms exchanged employees is shown in Figure 2. The figure shows that, among firms that exchange employees, collaboration with customers almost always involves exchange of employees, while such exchanges only take place in half of the cases of collaboration with other partners.

Figure 2. **Exchange of employees in collaborative product development**



Percentage of the 63 firms with heavy exchange of employees with this type of partner
Percentage of the 63 firms exchanging employees with this type of partner
Percentage of the 63 firms collaborating (with or without exchange of employees) with this type of partner on the project

For each collaboration partner, the firms were asked what expertise from this partner was exploited in the project. The responses were recorded by the interviewer and grouped by one of the authors in such a way that the answer concerning each partner was coded as to which of the competencies used in the project was thought most likely to be supplemented by the partner's competence. The coding was done according to Miyazaki (1995) typology of five competencies: marketing, technological, financial, organisational and production. Reliability was evaluated on the basis of a revision of the coding undertaken by the other author and by a colleague specialised in the study of competence. In order not to base the analysis on the unavoidably unreliable coding of answers that were ambiguous, the following is based on the reliable discrimination between partners where it is

beyond any doubt that an answer relates to a specific competence *vs.* all other answers. The competencies most often referred to are marketing and technological competence. Accordingly, the partners were sorted depending on: *i)* whether or not the partner contributed to the marketing competence used in the project; and *ii)* whether or not the partner contributed to the technological competence used in the project (two answers referring to marketing and technological competence were coded as "not marketing" and "not technological", respectively).

The expertise of the parties with whom employees were exchanged is consistent with the pattern that can be expected from the role of the partner in the value chain. On the demand side, half of the customers contribute to the marketing competence and very few to the technological competence. On the supply side, more than half of the suppliers contribute to the technological competence, and very few to the marketing competence used in the project.

Projects where employees are exchanged

Projects where exchange of employees takes place differ significantly from other projects; costs are not kept within the project's original budget.

Table 1b. **Employees exchanged by project cost kept within the budget**

Cost kept within project	Employees exchanged during project			Total
	Yes, heavy	Yes, light	No	
Yes, kept within budget	14 (9%)	16 (11%)	123 (80%)	53 (100%)
No, overrun on the budget	16 (22%)	7 (9%)	51 (69%)	74 (100%)
	30	23	174	227*

Note: Chi-square test of independence: $p < .05$.
* The 227 projects where the specific questions on budgets were answered.

The exchange of employees is significantly correlated with the answer to the question: "Are you still developing the product?" If this is interpreted positively, it may point to those firms which practice continuous improvement. However, taken together with the result above, it may also reflect an over-representation of projects which have overrun the budget yet remain unfinished.

Table 1c. **Employees exchanged by products still under development**

Still developing the product	Employees exchanged during project			Total
	Yes, heavy	Yes, light	No	
Yes	25 (16%)	17 (11%)	113 (73%)	155 (100%)
No	7 (5%)	14 (10%)	118 (85%)	139 (100%)
	32	31	231	294

Note: Chi-square test of independence: $p < .01$.

There is also a significant – but maybe tautological – correlation with the number of man-years invested in the project. However, contrary to expectations based on the results from Blenkhorn and Noori (1990) who identified exchange of employees as a factor connected with the successful development of products, there is no significant correlation with the market success of the eventual product. Finally, there is no correlation with the duration of the development project until the interview was done.

Model

Exchange of employees takes place in dyads characterised by a number of features of the focal firm, the project and the partner. On the basis of earlier analysis of which variables could be of importance (Kristensen and Vinding, 2001), a number of characteristics were taken into account. In the present analysis, use of prototype and electronic exchange were added. The characteristics were built into a logistic model as independent variables, whereas exchange of employees was treated as a dependent variable. When dealing with logistic regression, the estimates of each variable in the model shall be interpreted according to its reference category, hence the relative differences. The full model and the reference categories are illustrated in Annex 1.

The model shows that if employees are exchanged in a dyad, the dyad will also more often use either electronic or prototype exchange. If the focal firm uses either one of the variables, the focal firm is almost twice as likely to also use exchange of employees as a means of knowledge transfer. Moreover, it is not surprising that firms with more than 50 employees are more than 2.5 times more likely to exchange employees than firms with less than 20 employees. Finally, the firms are almost twice as likely to exchange employees with those partners which have been rated as being of great or crucial importance to the project compared to partners rated of little/some importance.

Exchange of prototypes

Exchange of physical prototypes is often described as a medium conveying extremely rich information to the knowledgeable receiver (Kristensen, 1992, Von Hippel, 1994, Bailetti and Litva, 1995, Mascitelli, 2000). All firms were asked whether they had exchanged prototypes, and how many times this happened in the most important project.

Placed in the typology of Hoffman and Novak (1996), prototypes are always impersonal, but are static *vs.* dynamic to varying degrees, depending on whether they are exchanged once carrying information one way, or exchanged and carrying information both ways (Kristensen, 1992). Here, the distinction between light and heavy exchangers is drawn between those firms where a prototype was moved once (light) and those where a prototype was moved two or more times during the project (heavy).

Firms exchanging prototypes

Among the 294 firms, 60 had exchanged prototypes with one or more partners during their most important product development project. As shown in Table 2a, these firms differ significantly from other firms by having a larger number of employees.

Table 2a. **Exchange of prototypes by number of employees in firms**

Number of employees	Exchange of prototypes during project			Total
	Yes, heavy	Yes, light	No	
10-19	5 (5%)	7 (7%)	84 (88%)	96 (100%)
20-49	6 (6%)	15 (15%)	80 (79%)	101 (100%)
50-	13 (13%)	14 (14%)	70 (72%)	97 (100%)
	24	36	234	294

Note: Chi-square test of independence: $p < .10$.

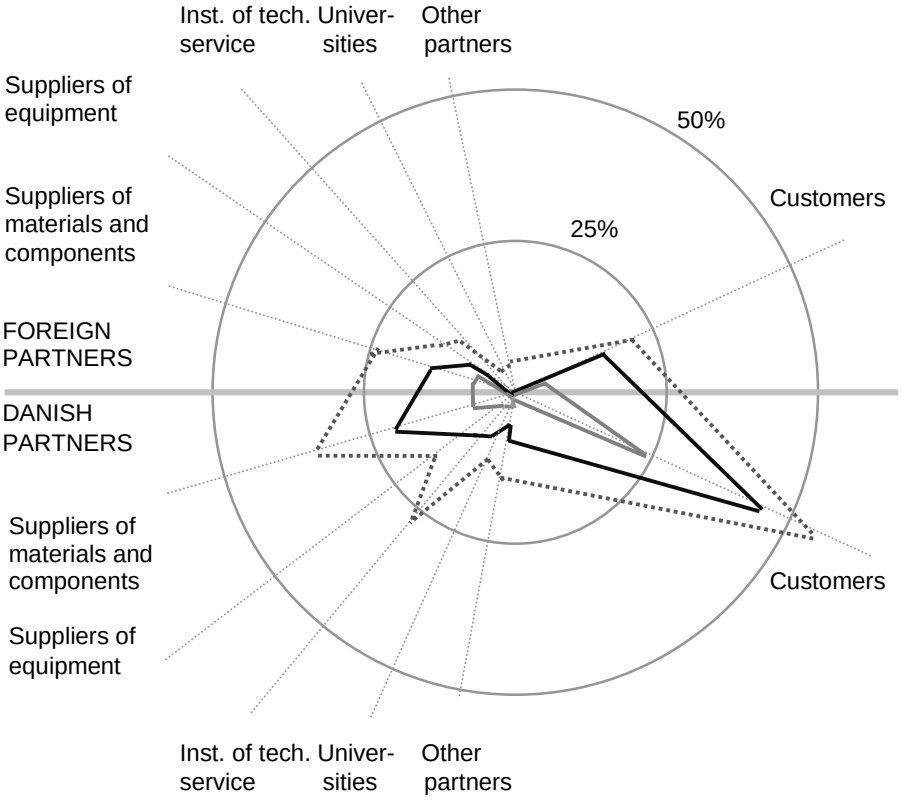
On the other hand, the firms do not differ concerning year of establishment, geography or according to Pavitt sectors. At the industry level, shown in Annex 3, machinery and electrical and optical equipment seems both absolutely and relatively to exchange prototypes more often than do other industries.

Partners of exchange

From Figure 3, it can be seen that exchange of prototypes very often takes place in dyads between firms and domestic customers. Consequently, when the overall pattern of collaboration for the 60 firms who exchanged prototypes in Figure 3 is compared with the pattern for all firms in Figure 1, it can be noted that firms exchanging prototypes collaborate with domestic customers nearly twice as often as other firms.

The suppliers with whom prototypes are exchanged differ from other partners among suppliers in that they less often (43% compared to 59%) contribute with technological competence. On the other hand, the partners among customers more often (60% as opposed to 50%) contribute with marketing competence.

Figure 3. **Exchange of prototypes in collaborative product development**



Percentage of the 60 firms with heavy exchange of prototypes with this type of partner
Percentage of the 60 firms exchanging prototypes with this type of partner
Percentage of the 60 firms collaborating (with or without exchange of prototypes) with this type of partner on the project

Projects where prototypes are exchanged

Projects where physical prototypes are exchanged differ significantly from other projects concerning budget overruns (Table 2b). Furthermore, the projects have not been able to stick to the planned timetable (Table 2c). A picture of long and costly projects emerges. On the other hand, this may be balanced by the fact that a significantly higher proportion of the products did better than expected when introduced to the market (Table 2d).

Table 2b. **Exchange of prototypes by project cost kept within the budget**

Cost kept within project	Prototype exchange during project			Total
	Yes, heavy	Yes, light	No	
Yes, kept within budget	13 (9%)	15 (10%)	125 (81%)	153 (100%)
No, overrun on the budget	10 (14%)	15 (20%)	49 (66%)	74 (100%)
	23	30	174	227

Note: Chi-square test of independence: $p < .05$.

Table 2c. **Exchange of prototypes by development time kept within the timetable**

Development time kept within the timetable	Prototype exchange during project			Total
	Yes, heavy	Yes, light	No	
Yes	9 (7%)	11 (9%)	110 (84%)	130 (100%)
No	14 (11%)	20 (16%)	90 (72%)	124 (100%)
	23	31	200	254

Note: Chi-square test of independence: $p < .10$.

Table 2d. **Exchange of prototypes by market success of the eventual product**

Market success	Prototype exchanged during project			Total
	Yes, heavy	Yes, light	No	
Better	11 (17%)	5 (8%)	49 (75%)	65 (100%)
As expected	4 (5%)	13 (15%)	68 (80%)	85 (100%)
Worse	4 (10%)	9 (21%)	29 (69%)	42 (100%)
	19	27	146	192*

Note: Chi-square test of independence: $p < .05$.
* Excl. “don’t know”.

Finally, projects in which prototypes are exchanged do not differ from other projects concerning project duration or whether or not the firm is still developing the project.

Model

Following the method used above and in Annex 1, exchange of prototypes in a dyad is associated with the same variables as exchange of employees, *i.e*. use of the other two media, size of the focal firm, and the rated importance of the partner.

Firms using exchange of employees are almost twice as likely to use prototypes, and those using electronic exchange are four times more likely to also use exchange of prototypes as a means of knowledge transfer. Small firms with less than 20 employees are nearly four times less likely to use exchange of prototypes as a means of knowledge transfer compared to firms with more than 50 employees. Furthermore, exchange of prototypes is almost three times more likely in dyads where the partner is a customer compared to dyads involving suppliers or partners outside the value chain.

Finally, as in the case of exchange of employees, firms are almost twice as likely to exchange prototypes with those partners which have been rated as being of great or crucial importance to the project compared to partners rated of little/some importance.

Electronic media

The firms were asked if they had exchanged models, drawings, data files or similar in electronic form with any of their development partners. Of the 294 firms, 60 stated that they had exchanged information in electronic form. As discussed by Bolisani and Scarso (1999), different electronic media are able to transfer different kinds of information. The questionnaire took this into account by asking questions concerning several electronic media. Using Hoffman and Novak's (1996) typology, the movable media are static as opposed to dynamic electronic media. Therefore, those firms which used only disks, magnetic tape or another movable medium were classified as light users of electronic exchange. Heavy users were the firms who answered used online connection and/or Electronic Data Interchange.

Firms using electronic media

Firms in the science-based sector use electronic exchange more often, as can be seen from Table 3a.

Table 3a. **Use of electronic media by Pavitt sector**

Pavitt sector	Use of electronic media during project			Total
	Yes, heavy	Yes, light	No	
Scale-intensive	5 (5%)	10 (10%)	86 (85%)	101 (100%)
Supplier-dominated	8 (10%)	5 (6%)	70 (84%)	83 (100%)
Science-based	9 (27%)	5 (15%)	19 (58%)	33 (100%)
Specialised suppliers	9 (12%)	9 (12%)	59 (76%)	77 (100%)
	31	29	234	294

Note: Chi-square test of independence: $p < .01$.

When the material is divided according to industries (Annex 3), a high frequency of electronic exchange can be seen in the electronics and printing industries. In electronics, this finding is not

surprising, and in the case of printing, the result no doubt relates to the widespread transfer of composition in the same electronic form as in the firm's internal production processes.

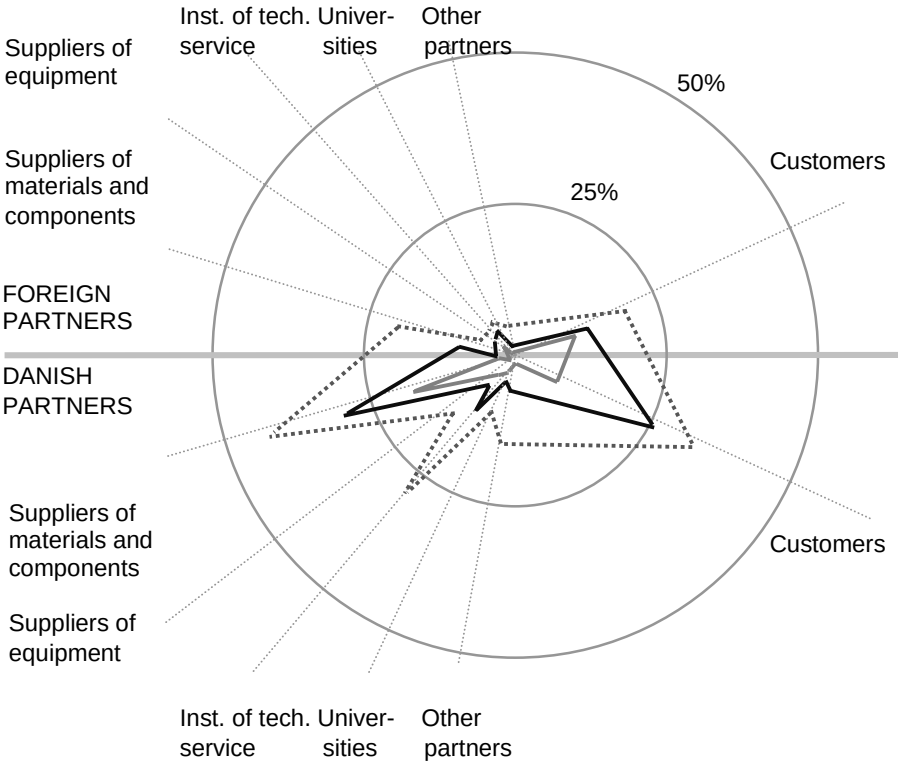
Partners

Those firms which had used electronic exchange were asked: "With which of the collaboration partners did such exchange occur?" The pattern of partners in electronic exchange is presented in Figure 4, which shows that use of electronic media is most common in collaboration with domestic customers and suppliers of materials and components. The competencies of the collaboration partners with whom electronic exchange takes place do not differ from the pattern for all partners.

Projects where electronic media are used

As was the case for projects using the two other media of exchange – employees and prototypes – projects using electronic media differ significantly (Table 3b) from projects which do not use the media, by overrunning the budget. The use of electronic media is also correlated with the number of man-years invested in the project (Table 3c). Such products are more often still under development (Table 3d) and, finally, they are more likely to do better than expected in the market (Table 3e).

Figure 4. **Use of electronic media in collective product development**



Percentage of the 60 firms with heavy electronic exchange with this type of partner
Percentage of the 60 firms using electronic exchange with this type of partner
Percentage of the 60 firms collaborating (with or without electronic exchange) with this type of partner on the project

Table 3b. **Use of electronic media by project cost kept within the budget**

Cost kept within project budget	Use of electronic media during project			Total
	Yes, heavy	Yes, light	No	
Yes, kept within budget	15 (10%)	13 (9%)	125 (82%)	153 (100%)
No, overrun on the budget	13 (18%)	12 (16%)	49 (66%)	74 (100%)
	28	25	174	227

Note: Chi-square test of independence: $p < .05$.

Table 3c. **Electronic exchange by number of man-years invested in the project**

Man-years invested	Use of electronic media during project			Total
	Yes, heavy	Yes, light	No	
1-12 months	6 (5%)	15 (12%)	105 (83%)	126 (100%)
13 months	21 (18%)	12 (11%)	80 (71%)	113 (100%)
	27	27	185	239

Note: Chi-square test of independence: $p < .01$.

Table 3d. **Electronic exchange by products still under development**

Still developing the product	Use of electronic media during project			Total
	Yes, heavy	Yes, light	No	
Yes	23 (15%)	12 (8%)	120 (77%)	155 (100%)
No	8 (6%)	17 (12%)	114 (82%)	139 (100%)
	31	29	234	294

Note: Chi-square test of independence: $p < .05$.

Table 3e. **Electronic exchange by market success of the eventual product**

Market success	Use of electronic media during project			Total
	Yes, heavy	Yes, light	No	
Better	12 (19%)	4 (6%)	49 (75%)	65 (100%)
As expected	7 (8%)	12 (14%)	66 (78%)	85 (100%)
Worse	1 (2%)	4 (10%)	37 (88%)	42 (100%)
	20	20	152	192

Note: Chi-square test of independence: $p < .05$.

Model

As in the former logistic regressions, use of the two other media is correlated with the use of the present medium. Thus, if either employees or prototypes are exchanged in the dyad, the likelihood that

electronic exchange is also used is significantly larger, *i.e.* 1.7 and 3.6 times more. The same holds for the rated importance of the partners, *i.e.* 1.7 times more.

Compared to the two former models, the difference is in the characteristics of the focal firm. Use of electronic media is not significantly more common in dyads where firms have more than 50 employees. On the other hand, the industry variable – which only had minor significant relation to the use of the other two media – shows that dyads where the focal firms are in the science-based sector are more than twice as likely to use electronic exchange than dyads comprising other firms. Annex 3 indicates that this may be a result of the categorisation of the electronics industry as science-based. In this industry, electronic media is often the only medium capable of carrying the kind of information to be exchanged, irrespective of its science base.

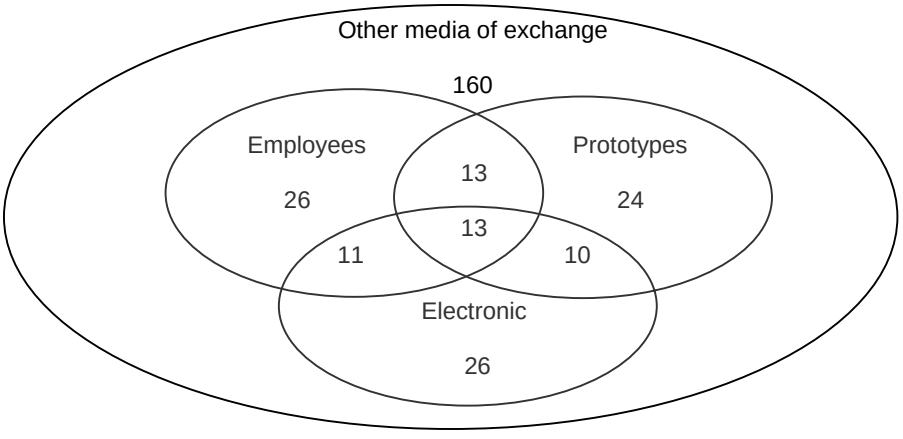
Use of more media in the same project

In their study of Internet use, Boyle and Alwitt (1999, Table 8), found that within the American plastics industry, firms which communicate with their suppliers and processors by Internet also communicated more frequently with the same parties through face-to-face meetings and through several other media. Stated more generally, some firms seem to have higher communication activity across a broader spectrum of types of communication. A similar pattern is found in the present study where there is significant positive correlation:

- Between exchange of employees and use of electronic media.
- Between use of electronic media and exchange of physical prototypes.
- Between exchange of physical prototypes and exchange of employees.

Overlaps are depicted in Figure 5 and the significant relations from Annex 1 are shown in Figure 6.

Figure 5. **Firms using one or more media in their single most important collaborative project**
Absolute number of focal firms (n=283)



Complementary media?

One explanation as to why there is a coincidence between the use of the three kinds of media in the same dyads is that they can be assumed to complement each other. As pointed out by Davenport *et al*. (1998) and Blumentritt and Johnston (1999), the media have different abilities to convey information and to contribute to the process of transforming explicit and tacit information into knowledge.

When the above cases of exchange of employees are broken down (Annex 2) to show whether the employee came from the firm and worked on the partner's premises or *vice versa*, an interesting pattern can be observed:

- Exchange of employees from the firm to the partner has a significant correlation with the exchange of prototypes, and no correlation with use of electronic media.

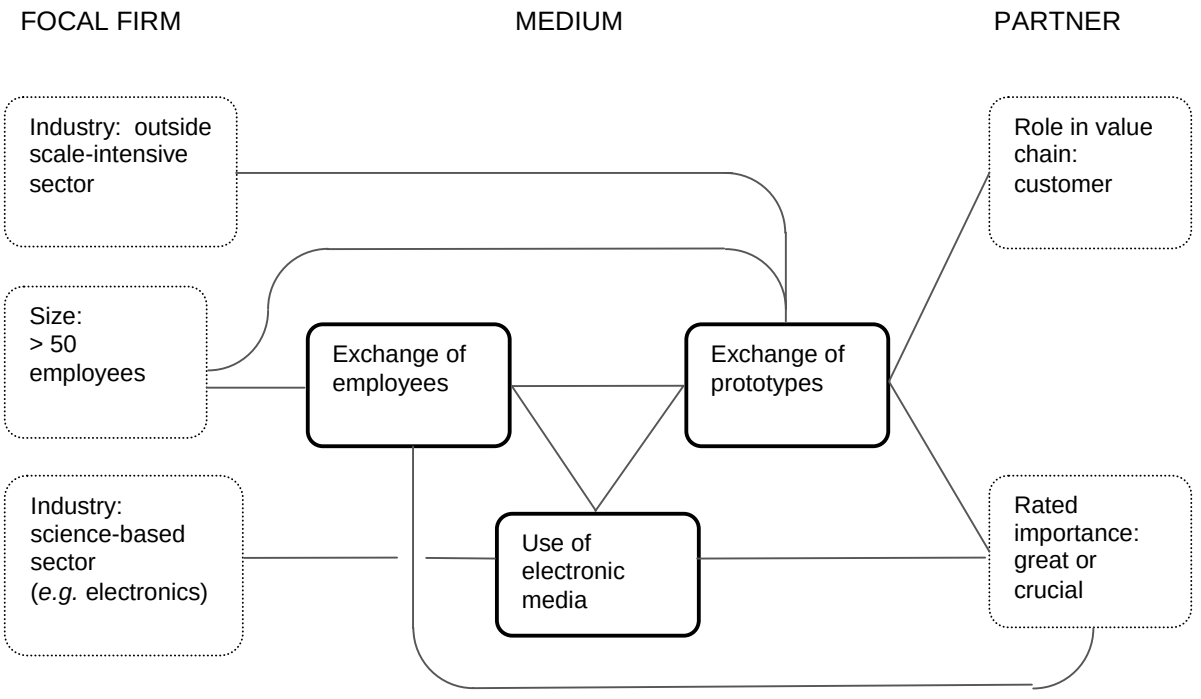
- Exchange of employees from the partner to the firm shows the reverse picture. It has no correlation with the exchange of prototypes, but shows significant correlation with use of electronic media.

This may reflect that exchange of employees can be complementary to use of other media in two ways: *i)* in the coding during the capture (Nonaka and Takeuchi, 1995); and *ii)* in the decoding during the interpretation of exchanged information (Sivadas and Dwyer, 2000). As pointed out by Cowan and Foray (1997), some tacit knowledge is needed in order to understand codified knowledge.

The role of employees who work on the partner's premises when a prototype is exchanged may be to capture and bring home to the firm information produced during observation of the partner's use of the prototype. The role of employees from a partner working on the premises of the focal firm may be to provide tacit knowledge that complements codified information exchanged electronically.

However, this may be a phenomenon that is losing importance. A continuous and rapid widening of the richness of the information that can be transmitted through electronic media is taking place. In general, the survey results may overestimate the role of the traditional media. In the ongoing transition from the use of personal and physical media towards electronic communication, the traditional media can be expected to serve as a back-up to the electronic media for the next few years. This back-up may be mistaken for complementarity and thus, the role of the more traditional media of exchange in product development interaction may be overestimated and blur the picture, as may be the case in this survey.

Figure 6. **Relationships between characteristics in dyads**



Significant relationship (Annex 1).

Annex 1

ESTIMATION RESULTS OF LOGISTIC REGRESSION: REDUCED MODEL

Dependent variable	**Exchange of prototypes**			**Electronic media exchange**			**Employee exchange**		
	Estimates	Std. Error	Odds ratio	Estimates	Std. Error	Odds ratio	Estimates	Std. Error	Odds ratio
Independent variables									
Constant	-1.318***	0.191	0.268	1.150***	0.181	0.317	-1.53***	0.184	0.216
Media:									
Electronic exchange, reference=no	1.340***	0.299	3.818				0.589*	0.309	1.802
Employee exchange, reference=no	0.609*	0.315	1.839	0.572*	0.310	1.772			
Prototype exchange, reference=no				1.294***	0.298	3.649	0.563*	0.311	1.755
Firm									
10-19 employees	-1.344***	0.374	0.261	0.151	0.323	1.163	-0.968***	0.357	0.380
20-49 employees	-0.505*	0.294	0.604	-0.257	0.305	0.773	-0.119	0.278	0.887
reference category, 50 or more employees									
Supplier dominated	-0.526	0.430	0.591	-0.554	0.389	0.575	0.088	0.418	1.092
Scale intensive	-0.759*	0.397	0.468	-0.730**	0.344	0.482	0.342	0.374	1.408
Specialized supplier	0.437	0.383	1.548	-1.03***	0.381	0.356	-0.032	0.409	0.968
reference category, science-based									
Partner:									
Suppliers	-0.979***	0.303	0.376	-0.131	0.307	0.877	-0.141	0.303	0.869
Partners outside the value chain	-1.028***	0.343	0.358	-0.132	0.335	0.877	-0.023	0.331	0.977
reference category, customers									
Import. of partn. - great/crucial, ref.=little/some	0.669**	0.287	1.953	0.547*	0.281	1.729	0.536*	0.274	1.709
Log likelihood	387.79			415.68			425.68		
Correct predicted	84.1%			84.5%			84.1%		
N	555			555			555		

Note: There is no sign of multicolinearity between the independent variables. The multicolinearity is estimated by using the predicted probabilities in the logistic estimation as weights in an ordinary regression. A tolerance is computer by regressing each variable on all the other explanatory variables.

*** = level of significance of less than 0.01.

** = level of significance of less than 0.05.

* = level of significance of less than 0.1.

Annex 2

ESTIMATION RESULTS OF LOGISTIC REGRESSION: REDUCED MODEL

Dependent variable	Employee from partner to firm			Employee from firm to partner		
	Estimates	Std. Error	Odds ratio	Estimates	Std. Error	Odds ratio
Independent variables						
Constant	-1.416***	0.255	0.243	-1.224***	0.247	0.294
Media:						
Electronic exchange, reference=no	1.131***	0.413	3.099	-0.127	0.443	0.880
Prototype exchange, reference=no	-0.036	0.447	0.965	0.718*	0.413	2.051
Employee exchange from firm to partner, reference=no	3.083***	0.393	21.821			
Employee exchange from partner to firm, reference=no				3.073***	0.390	21.606
Firm						
10-19 employees	-0.893*	0.513	0.410	-0.487	0.465	0.615
20-49 employees	0.646*	0.371	1.909	-0.696*	0.393	0.499
reference category, 50 or more employees						
Supplier dominated	0.937	0.637	2.552	-0.653	0.560	0.521
Scale intensive	1.577***	0.588	4.839	-0.853*	0.503	0.426
Specialized supplier	0.973	0.622	2.645	-0.502	0.512	0.605
reference category, science-based						
Partner:						
Suppliers	0.380	0.425	1.463	-0.484	0.409	0.616
Partners outside the value chain	0.698	0.455	2.010	-0.714	0.460	0.490
reference category, customers						
Importance of partner - great/crucial, reference=little/some	0.645*	0.375	1.906	-0.003	0.368	0.997
Log likelihood	260.126			254.351		
Correct predicted	90.7%			91.9%		
N	555			555		

Note: There is no sign of multicolinearity between the independent variables. The multicolinearity is estimated by using the predicted probabilities in the logistic estimation as weights in an ordinary regression. A tolerance is computer by regressing each variable on all the other explanatory variables.

*** = level of significance of less than 0.01.

** = level of significance of less than 0.05.

* = level of significance of less than 0.1.

Annex 3

EXCHANGE OF EMPLOYEES BY INDUSTRY

Industry	Exchange of employees during project			Total
	Yes, heavy	Yes, light	No	
Food, beverages, etc. (NACE 15-16)	4 (14%)	2 (7%)	23 (79%)	29 (100%)
Textiles, etc. (NACE 17-19)	1 (6%)	2 (13%)	13 (81%)	16 (100%)
Wood, etc. (NACE 20)	0 (-%)	1 (-%)	10 (-%)	11 (100%)
Paper, printing, etc. (NACE 21-22)	1 (6%)	2 (13%)	13 (81%)	16 (100%)
Petroleum, chem. etc. (NACE 23-24)	1 (-%)	2 (-%)	11 (-%)	14 (100%)
Rubber, plastic, etc. (NACE 25-26)	1 (4%)	1 (4%)	23 (92%)	25 (100%)
Processing of metals NACE 27-28	6 (12%)	3 (6%)	43 (82%)	52 (100%)
Machinery (NACE 29)	9 (13%)	12 (17%)	48 (70%)	69 (100%)
Electrical, optical equip. (NACE 30-33)	9 (28%)	3 (9%)	20 (63%)	32 (100%)
Transport equipment (NACE 34-35)	0 (-%)	1 (-%)	3 (-%)	4 (100%)
Furniture, manuf. n.e.c. (NACE 36)	0 (0%)	2 (8%)	24 (92%)	26 (100%)
	32	31	231	294

EXCHANGE OF PROTOTYPES BY INDUSTRY

Industry	Exchange of prototypes during project			Total
	Yes, heavy	Yes, light	No	
Food, beverages, etc. (NACE 15-16)	1 (3%)	1 (3%)	27 (79%)	29 (100%)
Textiles, etc. (NACE 17-19)	1 (6%)	4 (25%)	11 (69%)	16 (100%)
Wood, etc. (NACE 20)	1 (-%)	0 (-%)	10 (-%)	11 (100%)
Paper, printing, etc. (NACE 21-22)	1 (6%)	0 (0%)	15 (94%)	16 (100%)
Petroleum, chem. etc. (NACE 23-24)	0 (-%)	3 (-%)	11 (-%)	14 (100%)
Rubber, plastic, etc. (NACE 25-26)	2 (8%)	3 (12%)	20 (80%)	25 (100%)
Processing of metals NACE 27-28	3 (6%)	6 (12%)	43 (82%)	52 (100%)
Machinery (NACE 29)	8 (12%)	10 (14%)	51 (74%)	69 (100%)
Electrical, optical equip. (NACE 30-33)	4 (13%)	7 (22%)	21 (65%)	32 (100%)
Transport equipment (NACE 34-35)	1 (-%)	0 (-%)	3 (-%)	4 (100%)
Furniture, manuf. n.e.c. (NACE 36)	2 (8%)	2 (8%)	22 (84%)	26 (100%)
	24	36	234	294

USE OF ELECTRONIC MEDIA BY INDUSTRY

Industry	Exchange of prototypes during project			Total
	Yes, heavy	Yes, light	No	
Food, beverages, etc. (NACE 15-16)	0 (0%)	1 (3%)	28 (97%)	29 (100%)
Textiles, etc. (NACE 17-19)	0 (0%)	2 (13%)	14 (87%)	16 (100%)
Wood, etc. (NACE 20)	0 (-%)	0 (-%)	11 (-%)	11 (100%)
Paper, printing, etc. (NACE 21-22)	6 (38%)	0 (0%)	10 (63%)	16 (100%)
Petroleum, chem. etc. (NACE 23-24)	1 (-%)	1 (-%)	12 (-%)	14 (100%)
Rubber, plastic, etc. (NACE 25-26)	2 (8%)	3 (12%)	20 (80%)	25 (100%)
Processing of metals NACE 27-28	2 (4%)	5 (10%)	45 (86%)	52 (100%)
Machinery (NACE 29)	6 (9%)	7 (10%)	56 (81%)	69 (100%)
Electrical, optical equip. (NACE 30-33)	12 (38%)	5 (16%)	15 (46%)	32 (100%)
Transport equipment (NACE 34-35)	0 (-%)	3 (-%)	1 (-%)	4 (100%)
Furniture, manuf. n.e.c. (NACE 36)	2 (8%)	2 (8%)	22 (84%)	26 (100%)
	31	29	234	294

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Chapter 7

INTER-FIRM TECHNOLOGICAL COLLABORATION IN AUSTRALIA IN AN INTERNATIONAL CONTEXT: IMPLICATIONS FOR INNOVATION PERFORMANCE AND PUBLIC POLICY

by

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Introduction

When firms innovate, do they create change on the basis of their own individual resources, internal to the firm, or do they combine their own resources with those of other firms and institutions? This simple question is important for the design of innovation policy. Many forms of policy incentive for innovation, such as R&D tax credits or R&D subsidies, in effect assume that the primary problem in innovation is to strengthen the knowledge-creating capabilities of individual firms. Such approaches tend to see firms as individual actors in the market, operating via arm's-length market transactions with other firms. The firms themselves may be complex organisations, with many internal divisions or components, but they are nonetheless seen as entities that are clearly separated from other firms. But what if firms acquire knowledge or other capabilities from outside the boundaries of the firm as they seek to innovate? In this case, policy makers might want to consider the general shape of the "innovation environment" as it affects knowledge flows, and particularly as it is affected by public policy decisions. These issues turn in large part on the extent and importance of innovative collaboration among firms. For example, if such collaboration is of negligible extent, and is transient and temporary in nature, then we could argue that policies based on the individual-firm are appropriate. If, however, collaboration is pervasive, and if it persists over long periods, then arm's-length market models of inter-firm relationships are likely to be inappropriate, and we may need a more "system-oriented" approach to knowledge creation and thus to innovation policy instruments.

This chapter explores patterns of collaboration between Australian firms in the process of technological innovation. It forms part of a wider international effort to gather empirical data on inter-firm collaboration, in a research effort co-ordinated by the OECD. The background to this is the development of large-scale surveys of innovation activity implemented in many countries in 1992 and again in 1996-97. In the early 1990s, the OECD sponsored work on the development of direct indicators of innovation conditions, and innovation inputs and outputs. Prior to this work, most innovation data consisted either of a rather restricted input indicator, namely R&D, and a very limited

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output indicator, namely patent data. The OECD sought to measure innovation much more directly, by collecting data on sales from new and modified products, and sought also to measure a wider range of innovation inputs (such as expenditures on design, training, engineering development, acquisition of capital goods, etc.) (OECD, 1992). The Community Innovation Survey, based on this approach, was implemented throughout the European Union and the European Economic Area in 1993 and 1997, co-ordinated by EUROSTAT, and in many other countries including Canada, Australia and China (for overviews of the surveys, see Grünewald and Smith, 1993; Smith, 1997).

The Community Innovation Survey produced an intriguing result concerning collaboration. Firms were asked whether or not they collaborated with external partners, and if so what types of partners were involved in collaboration. The result was that a substantial majority of firms that reported innovation activity (in the form of new product or process development), also reported collaboration. This result was found in all countries and appeared to be so robust that it encouraged researchers to explore the collaboration process more deeply. In 1997, the Danish delegate to an OECD meeting suggested that other countries could adopt the method developed at the University of Aalborg. The Danish DISKO survey involved a telephone interview instrument to gather data from firms on collaborative activity around their most important recent innovation. An informal international network of researchers emerged around this project, and others began to develop, elaborate and apply the Danish methodology. In the end, versions of the approach were implemented in Australia, Austria, Denmark, Norway, Spain and Sweden.

The OECD played an important role in this, via the Directorate for Science, Technology and Industry (DSTI). In 1995, DSTI began to co-ordinate a large project on the empirical analysis of national innovation systems. This involved analyses of clusters, of labour mobility, of institutional set-ups, catch-up problems, the innovative firm, and of inter-firm collaboration. Within this overall OECD work, the inter-firm collaboration project is based on the sharing and analysis of data from the DISKO-based telephone surveys mentioned above.

The results reported below are from the Australian version of the survey, which follows the Danish approach and is comparable with it. The survey focuses on the extent, character and location of collaborative behaviour by firms in the innovation process. The following sections describe first the theoretical and empirical background to this research, and then the specific methodology adopted, before turning to the results and their implications.

Theoretical background

The past 20 years have seen a substantial increase in research on innovation. Much of this research has been empirical in character, and theory has often reflected the results of empirical research. One of the most important aspects of these results has been the insight that innovation usually has a collective character and is best understood as a collective phenomenon. The broad theoretical notion expressing the collective view of innovation is often referred to as the "systems" approach: it focuses not on individual innovations or individual innovators, but at the broad socio-technical or socio-economic frameworks within which innovation occurs. Smith remarks that:

> "Innovation by firms cannot be understood purely in terms of independent decision making at the level of the firm. Rather, innovation involves complex interactions between a firm and its environment." (Smith, 2000, p. 73)

These systems approaches did not emerge from any specific programme of empirical work but were based in the first instance on the results of a wide range of studies of technological linkages

between firms. From the early 1980s, these links began to be closely studied, and quickly moved from a focus on strictly technological linkages to studies of the nature, organisation and content of collaboration and "interactive learning" between firms. We can distinguish three broad sets of studies:

- Historical studies of technological interdependence, either in statistical form or in the form of industrial histories of firms or entrepreneurs.

- Studies of network behaviour and interactive learning by firms in the course of innovation.

- Studies of national innovation systems.

The first source of systems insights was an essentially historical literature on technological interdependence, which showed that many major technological advances in fact consisted of interconnected technical changes. In a study looking at the development of railways, electric light, shipping and a wide range of other technologies, Rosenberg argued that:

> "The social payoff of an innovation can rarely be identified in isolation. The growing productivity of industrial economies is the complex outcome of large numbers of interlocking, mutually reinforcing technologies, the individual components of which are of very limited economic consequences by themselves. The smallest relevant unit of observation, therefore, is seldom a single innovation but, more typically, an interrelated cluster of innovations." (Rosenberg, 1982, pp. 58-59)

In part, this insight has been studied via a statistical approach, using input-output and patent data to study flows of products and knowledge among firms. Scherer showed that patented information is widely used outside the industry producing the patent, and linked industries of use with input-output and R&D data to demonstrate complex inter-industry flows of knowledge in the US economy. He concluded that there are "complex interdependencies among industries in the process of technological change" (Scherer, 1984, p. 57). On the other hand, there have been many historians of technology who have studied major individual technologies and shown that they require a study of technical interdependencies and system effects. Thomas Hughes, for example, showed that the development of technologies for the production, distribution and use of electricity, for example, involve complex engineering, economic, managerial and socio-political interactions, and cited similar studies in other industries; he concluded that "the history of all large-scale technology – not only power systems – can be studied effectively as a history of systems" (Hughes, 1988, p. 7).

The second broad area of study has been networking and clustering behaviour by firms. Some years ago, Håkansson explored a large sample of Swedish firms and showed that there was substantial networking behaviour among them, that these networking links were persistent over time and involved sharing both the development and use of knowledge (Håkansson, 1989). In a series of case studies, von Hippel showed the existence of significant inter-firm interactions in innovative learning, and the widespread existence of what he called "informal know-how trading" among engineers working on unrelated innovation projects across firms (von Hippel, 1989). A different type of company-based approach looked at more formal strategic partnering (Mytelka, 1991). A well-known example was the project on "Inter-company collaboration and technological development" conducted by MERIT at the University of Maastricht: this mapped formal technology-related co-operation agreements between firms, building up a database of over 7 000 such agreements. Research using this database showed a sharp increase in agreements related to the core technologies of material, biotechnology and ICT during the 1980s (Hagedoorn and Schakenraad, 1990, pp. 26-27).

Finally, a third area of study is the literature on national innovation systems. The pioneering work in this field was reported in Nelson (1993) and Lundvall (1992); Nelson's book was essentially a study of knowledge creation systems across countries, while Lundvall's was a deeper case study focusing mainly on Denmark. His definition of a system is as follows:

> "A system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new and economically useful, knowledge ... a national system encompasses elements and relationships, either located within or rooted inside the borders of a national state." (Lundvall, 1992, p. 2)

Within this framework, knowledge creation is seen almost entirely in a collective and collaborative framework. The emphasis is on the ways in which interactive learning occurs, on the institutional framework and on the ways in which markets are organised. In the Lundvall book, much of the emphasis is on the Danish agro-industrial complex as a case study, or on Danish industries generally, and the case for taking an interactive view of knowledge creation in that economy is strongly argued. There were a wide range of prior and parallel studies along similar lines, both within the national innovation systems approach, and in related areas (such as the work of Michael Porter on industrial clustering).

Methods and methodology

The literature discussed above has for the most part relied on case-study approaches. As with most case studies, it is reasonable to ask whether these cases are generalisable to the economy as a whole? Or are they simply suggestive examples whose applicability is restricted to particular technologies, industries or economies? Both the analytical and policy significance of collaboration depend in large part on its extent, and on the relative importance of different types of collaboration across the system as a whole. How widespread is collaboration in the innovation performance of firms across the economy as a whole, and who are the primary actors in such collaboration? Answering such questions requires a broader approach, and it is precisely the *general* significance of collaboration that is assessed in the survey reported here.

The aim of the project

This study is part of the National Innovation Systems (NIS) project, co-ordinated by the Working Party for Technology and Innovation Policy (TIP) through the Directorate for Science, Technology and Industry in the OECD. The study examines technological innovation and the extent and patterns of inter-firm collaboration in Australian manufacturing firms, at both the firm and project level, using interview data. Because of the link with the NIS project, however, the focus of this chapter goes beyond Australia and compares Australian results with those found in the other participants in the OECD project. A *direct* comparison of international data is not possible because slightly different methodologies and questionnaires were used. However, a standard empirical framework and core set of research categories was developed and applied by participating countries, so some useful international comparability can be attained.

The core research questions explored in this project encompass:

- The extent to which firms engaged in new product innovation engage in collaboration with external partners.

- Type of collaboration partner.
- Importance of collaboration with the partner.
- Duration and intensity of collaboration.
- Mobility of labour during collaboration.
- The use of external services related to product development (Christensen *et al.*, 1999).

As noted above, this type of study was initiated in Denmark, as part of the Danish DISKO (Danish Innovation System in a Comparative Perspective) project, and was subsequently replicated in more or less modified form in other countries. The Australian study replicates the DISKO approach, in terms of interview design and collection methodology.

The sample

A random sample of 1 003 manufacturing firms with ten or more employees was selected from an Australian business information database in November 1998 (Dunsfile from Dun and Bradstreet). This database contained approximately 22 268 entries under the category of manufacturing. The sample from Dun and Bradstreet was then coded according to Australian and New Zealand Industrial Classification (ANZIC) sub-divisions.

Table 1. **Australian sample distribution**

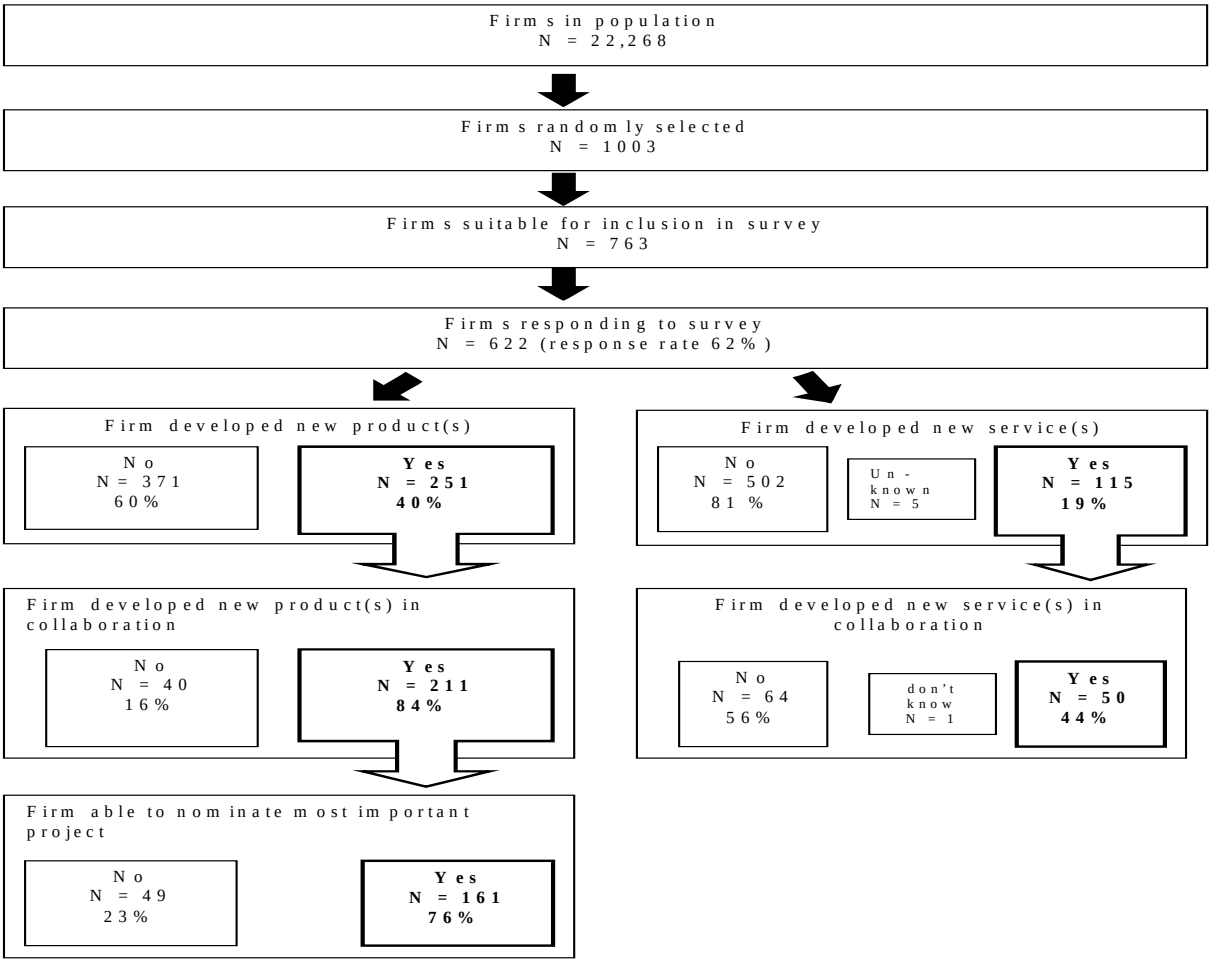
Percentage of total

Manufacturing industry sectors	Australian ABS population	DISKO sample	Successful interviews
Food, beverages and tobacco	11.9	7.9	6.8
Textiles, clothing, footwear and leather	9.5	10.5	8.7
Wood and paper products	7.8	6.9	7.4
Printing, publishing and recorded media	11.3	9.9	9.0
Petroleum, coal, chemical and associated products	8.5	11.6	13.0
Non-metallic mineral products	3.6	3.8	4.5
Metal products	17.1	15.3	16.6
Machinery and equipment	19.7	27.4	28.6
Other manufacturing	10.5	6.6	5.5
Total percentage	100.0	99.9	100.1
Number	14 460	997	622

Note: The DISKO sample comprised 1 003 firms. Six firms drawn in the sample were non-manufacturing and were removed.
Source: Australian DISKO survey (1999) and ABS commissioned data 1999.

The DISKO sample broadly corresponds to the Australian manufacturing population structure, with however a certain over-sampling in petroleum, coal, chemical and associated products, and also in machinery and equipment, and a slight under-sampling in other manufacturing and food, beverages and tobacco. However, both the sample for this project and the successful firm interviews reflect the relevant Australian industrial structure. The following figure illustrates the composition of the sample and the basic structure of the survey (Figure 1).

Figure 1. **Australian sample profile**



The interview method

This study was based on structured telephone interviews – in effect, a questionnaire was administered by telephone, but the interview approach also gave scope for expanded comments.

The Australian study used the Danish DISKO questionnaire, with minor modifications: six questions on prototypes were removed and three new questions on intellectual property (IP) were added. Two additional sampling questions (number of employees and number of subsidiaries) were also included.

The structured telephone survey was conducted by Datacol Research, an Australian social research firm, using computer-aided telephone interviewing (CATI). CATI was an effective method for data collection in this project: it eliminated a separate data entry stage and allowed for the efficient management of a sample that required multiple call-backs to complete the interview. It also had the added feature of automatic programming for call-backs and performed automatic question sequencing.

A pilot study was conducted in January 1999 and no further alterations were made to the questionnaire. The full process of data collection went ahead from February to October 1999. The interviews varied in length from 3 minutes to 75 minutes, with an average length of 14 minutes.

Methodological constraints and considerations

As with many surveys of this type, the sampling process may have some complexities that should be borne in mind. The most important of these are that the sampling list used for this study classified firms according to their *main* line of business, which may have eliminated some firms that manufacture in a small way. In addition, firms with a variety of manufacturing divisions may have been under-represented in the sample because only one legal entity was contacted. Only one person from each manufacturing firm was interviewed so firms with multiple divisions were only contacted once.

Only firms with ten or more employees were targeted in the sample. A routine sampling question was added to the questionnaire to determine accurately the number of employees. Sixty-two firms stated that they had less than ten employees at the time of the interview. These firms have been included in the Australian analysis in parts of this report on the basis that they formed a useful comparison group.

Of the 1 003 firms randomly selected, contact was made with 788 firms and 622 firms were interviewed. Seven categories for exclusion were apparent and these are summarised in Table 2 below. In all, 265 firms in the total sample were unsuitable for inclusion in the survey: some firms were not a manufacturing firm, others were no longer manufacturing or had ceased trading, and many firms could not be contacted.

Table 2. **Australian response rate**

Interview outcome	Number	Percentage
Success	622	62
Refusal	116	12
Unable to contact firm	172	17
Unable to make contact with the relevant person	25	3
Ceased trading	18	2
No longer manufacturing	19	2
Not a manufacturing firm	6	0.6
Unknown	25	3
Total	1 003	100

Source: Australian DISKO survey.

The Danish DISKO questionnaire was translated into English without an independent back translation. Various nuances may have been lost in the process; this is a well-known problem with internationally comparable surveys, and should be borne in mind when interpreting international comparisons. For reasons outlined below, we do not believe that this is, in general, a significant problem in this project. Specific Danish examples were replaced with Australian equivalents, where possible.

Results and discussions

Product innovation

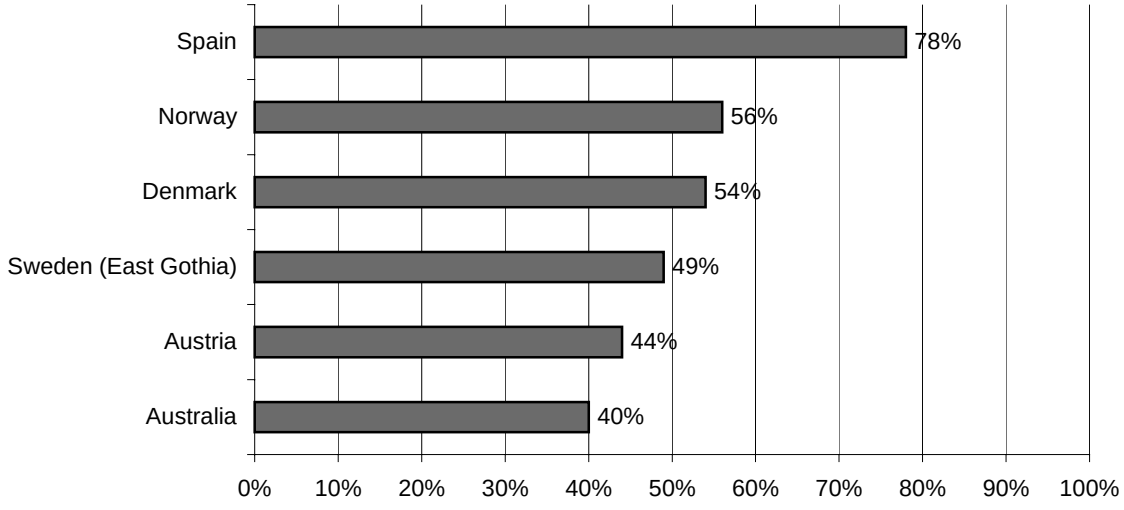
The interviewer began by defining product innovation in order to establish a common understanding of the term with the respondent. Product innovation was defined as:

> "The development of a tangible product which in its design, its construction, its productive capacity or in any other way is new for the firm. We are not thinking of small modifications …. Nor are we thinking about cases where the firm's products are adapted … as a matter of routine. Nor does the survey cover development of new processes in the firm's production, … or a new organisation of the production process." (DISKO questionnaire, 1997)

The DISKO inter-firm collaboration surveys began by asking manufacturing firms if they had developed one or more new products during the past two-three years.[1] Of the 622 Australian firms interviewed, 40% had developed one or more new products during the past two years. As Figure 2 shows, new product development in Australian manufacturing was the lowest among the countries participating in the study,[2] and this may reflect the size of the manufacturing base (14%) and the faster decline of manufacturing as a share of GDP compared to the OECD average. Spain reported that 78% of firms interviewed had developed one or more products. The level of innovation was somewhat lower in the other countries: 53% in Norway (Ørstavik and Nås, 1998), 54% in Denmark (Christensen *et al.*, 1999) 44% in Austria (Schibany, 1998) and 49% in Sweden[3] (Edquist *et al.*, 2000).

Figure 2. **Product innovation in participating countries**

Unweighted



Source: Australian DISKO survey (1999); Christensen *et al.* (1999); Edquist *et al.* (2000); Ørstavik and Nås (1998); Sanz-Menéndez *et al*. (1998); Schibany (1998).

These figures are generally different than those reported in the closely-related Community Innovation Survey (CIS) for 1997: they were higher for Norway (where the CIS figure for innovating firms was 48%), but lower for Denmark (CIS = 69%), Austria (CIS = 67%), Sweden (CIS = 54%). In Australia, the Australian Bureau of Statistics (ABS) reported an innovation rate of 47% in manufacturing (ABS, 1998). These differences seem to reflect slight differences in the questions: the DISKO survey asks for the proportion of firms introducing *new* products, whereas the CIS and ABS survey asks for firms introducing *new* or significantly *changed* products *and processes*, so we would expect higher proportions from the CIS and ABS data, which is indeed what we see. The Norwegian researchers believe that the inverse effect there follows from a slightly broader definition of innovative products.

Product innovation distribution across sectors

How is innovation distributed across sectors? The proportion of innovating firms in Australian industry sectors varied from 53% in machinery and equipment manufacturing to 17% in wood and paper product manufacturing. These results are shown in Table 3 below. A key point here is that in terms of new product innovation, *all* sectors are innovative and there are no marked leaders. It is important to note that high proportions of innovating firms are found in such low-technology, "old-economy" sectors as food and beverages, textiles and clothing, and metal products. Innovation is not confined to the "new economy". Only two sectors (printing and publishing and wood and paper products) have less than 30% of the sampled firms generating innovation: but here it is important to remember that this is a survey of product innovation activity, and these are sectors that innovate primarily via process change, something that is not picked up in this investigation. There is a frequent tendency within both the innovation studies literature, and in innovation policy environments, to focus on only a relatively restricted range of allegedly "technology-intensive" sectors (normally identified with R&D-intensive sectors) as the bearers of innovation activity. These data suggest that such an emphasis is one-sided at best.

Table 3. **Percentage of firms innovating by industry sector in Australia**

Unweighted

	Food, beverages, tobacco	Textiles, clothing, footwear	Wood, paper	Printing, publishing	Petroleum products, coal, chemicals	Non-metallic minerals	Metal products	Machinery and equipment	Other manufacturing
One product developed	10	7	9	11	14	11	9	20	3
Several products developed	33	30	9	9	32	39	23	33	41
No product development	57	63	83	80	54	50	68	47	56
	(n=42)	(n=54)	(n=46)	(n=56)	(n=81)	(n=28)	(n=103)	(n=178)	(n=34)

Source: Australian DISKO survey (1999).

This result appears to confirm one of the main propositions of the "innovation systems" literature, namely that *innovation is a pervasive phenomenon.* It is not something that occurs only in a relatively restricted group of highly innovative firms, but something which is widely dispersed across the firm population as a whole. This suggests important policy implications, one of which would be that innovation cannot be fostered by targeting only a small number of firms, but must be considered in terms of the system as a whole.

Product innovation and firm size

How does innovation relate to firm size? We examined innovation according to the variable of firm size based on the number of employees. We found that larger firms developed more new products than smaller firms and that this pattern was also evident in the other participating countries. The European surveys used three size categories in reporting their results (10-19 employees, 20-99 employees and 100 or more employees). We introduced more categories in order to deepen some of the Australian analysis (under 10, 10-19, 20-49, 50-99, 100-249, 250-499 and 500 or more employees).[4]

What emerges is a generally rising innovation performance with firm size. This result is consistent with results from the two cycles of the CIS and the ABS Innovation in Manufacturing Survey, which generally showed a monotonically increasing share of innovative firms as firm size increased. It is consistent also with other innovation-related indicators, such as R&D data and patent data: large firms are responsible for most of the world's R&D and patents. However, it is important to remember that this may not mean that larger firms are more innovative in some absolute sense: it may mean that they are more often innovative simply because they have a larger array of products. Thus, it is not clear whether this result reflects lower innovative potential in small firms or whether it reflects a wider product mix (and hence more frequent product renewal) in larger firms. Table 4 suggests that the latter is the case since the "several products" category rises sharply in larger firms.

Table 4. **Innovation and firm size in Australia**

Percentages, unweighted

	Under 10 employees	10 to 19 employees	20 to 49 employees	50 to 99 employees	100 to 249 employees	250 to 499 employees	500+ employees
One product developed	19	11	10	17	12	22	0
Several products developed	15	21	34	24	31	41	66
No product development	66	69	57	58	57	37	35
	(n=62)	(n=175)	(n=194)	(n=86)	(n=58)	(n=27)	(n=20)

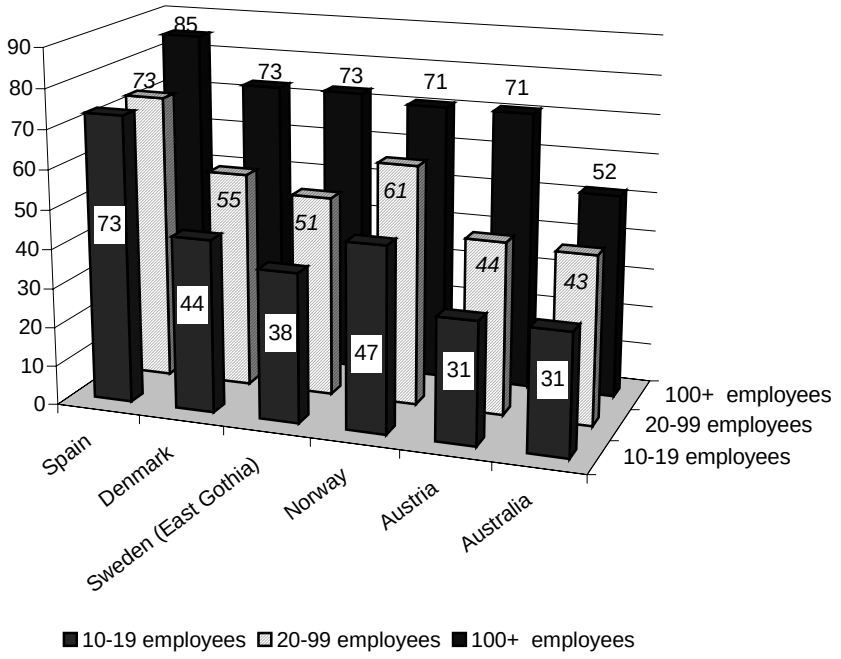
Source: Australian DISKO survey (1999).

This suggests that small firms might be more innovative in terms of new product development per employee, and this indeed appears to be the case. In Australia, product development per employee was 0.9 for firms with less than ten employees, 0.6 for 50-99 employees and 0.02 for firms with 500 or more employees. In Denmark the rate was 0.3 for firms with 10-19 employees and 0.1 for firms with 50 or more employees (Christensen *et al*, 2000, p. 7).

A similar type of size distribution of innovation is found in the other participating countries, and seems to reflect a general characteristic of the size distribution of manufacturing firms, as Figure 3 indicates. It is interesting to note that Australian firms with 100 or more employees are innovating noticeably less than in the other countries. However, this follows from the lower innovation performance of firms in the disaggregated size category 100-249 (see Table 4), which reduces the aggregated rate. These medium-sized firms are likely to be Australian-owned, with fewer resources than larger firms.

Figure 3. **Innovation and firm size in participating countries**

Percentages, unweighted



Source: Australian DISKO survey (1999); Christensen *et al.* (1999); Edquist *et al.* (2000); Ørstavik and Nås (1998); Sanz-Menéndez *et al*. (1998); Schibany (1998).

Collaboration

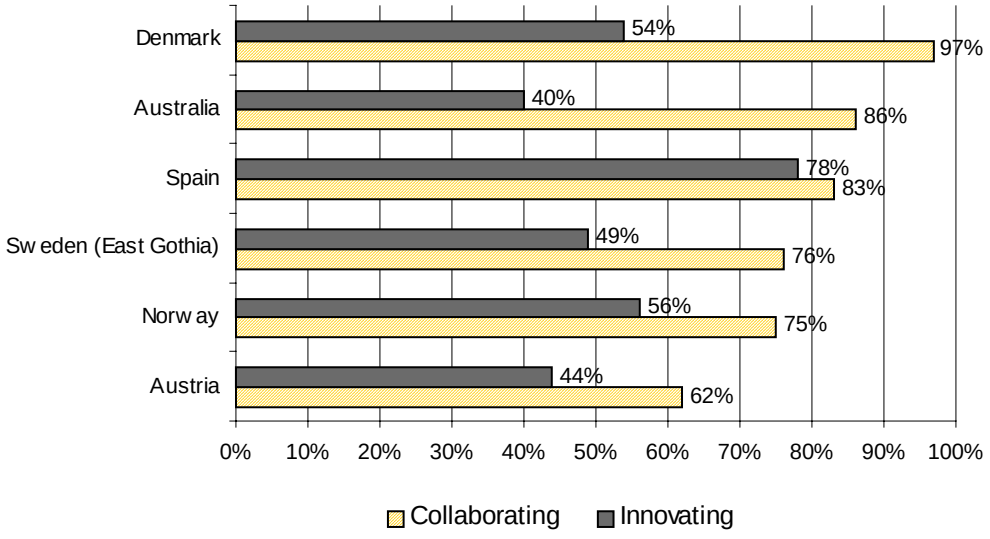
Firms that had innovated were then asked if they had collaborated with any external partners during the development process. Here, the results are striking and appear to be robust across countries. Most innovative firms are also collaborative firms: with the exception of Austria, all of the participating countries report collaboration rates of 75% or above. Australia's rate of collaboration in the development of new products was the second highest among the countries in the study, at 86% (Figure 5). However, it should be noted that a strong majority of firms collaborate even in Austria (62%).

Collaboration and firm size

Once again, a positive relationship between firm size and collaboration was evident in both the Australian and international results, as Figure 6 suggests – large firms collaborated more than small firms in the innovation process. This may reflect the higher rate of new product development in large firms as well as easier access to collaboration partners and more resources. The variation between countries, particularly in the firm size categories 10-19 and 20-99, is worthy of note. A possible explanation may hinge on the different industrial structures of the counties; however, this requires further investigation.

Figure 5. **Percentage of firms innovating and collaborating in participating countries**

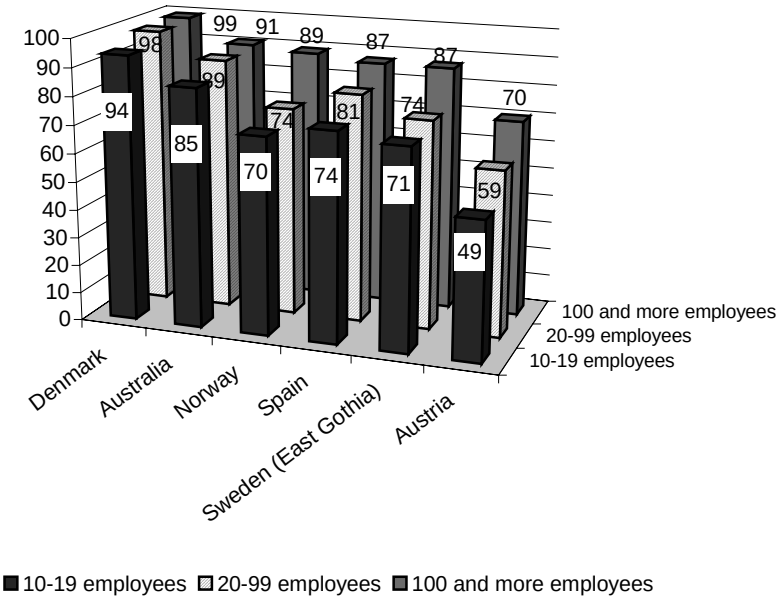
Unweighted



Source: Australian DISKO survey (1999); Christensen *et al.* (1999); Edquist *et al.* (2000); Ørstavik and Nås (1998); Sanz-Menéndez *et al*. (1998); Schibany (1998).

Figure 6. **Percentage of firms collaborating in the development of new products by firm size in participating countries**

Unweighted



Source: Australian DISKO survey (1999); Christensen *et al.* (1999); Edquist *et al.* (2000); Ørstavik and Nås (1998); Sanz-Menéndez *et al*. (1998); Schibany (1998).

In Australia, the relationship between firm size and collaboration appears to be neither strong nor linear at a higher level of disaggregation, since firms with 10-19 employees have the same propensity to collaborate as firms with 100-249 employees (Table 5).

Table 5. **Innovation and collaboration by firm size in Australia**

Percentages, unweighted

Number of employees	% of which innovating	% of which collaborating
Under 10	34	48
10-19	32	84
20-49	43	89
50-99	42	86
100-249	43	84
250-499	63	88
500 +	65	100

Source: Australian DISKO survey (1999).

Collaboration and Australian industry sectors

In Australia, most industry sectors had very high rates of collaboration even in sectors that had relatively low innovation levels. Thus, the extent of collaboration in the economy as a whole is not shaped by industrial structure and appears to be independent of industry type: the (unweighted) average here is 82.4%, the standard deviation is 8.3%, and so the coefficient of variation is very low, at 0.1. The textiles, clothing and footwear sector had the lowest level of collaboration, followed by printing and publishing.

Table 6. **Innovation and collaboration in Australian manufacturing sectors**

Percentages, unweighted

Industry sector	% of which innovating	% of which collaborating
Wood, paper	17	88
Printing, publishing	20	73
Metal products	32	88
Textiles, clothing, footwear	37	65
Food, beverages, tobacco	43	89
Other manufacturing	44	80
Petroleum, coal, chemical	46	89
Non-metallic minerals	50	86
Machinery, equipment	53	85

Source: Australian DISKO survey (1999).

Type of collaboration partner

When firms collaborate, who do they collaborate with? The striking result here is the importance, on the one hand, of customers (both private and government), and, on the other hand, of suppliers of materials and components. Once again, the results seem to be rather robust across countries. These results confirm one of the core hypotheses of the national innovation systems literature; namely, that user-producer interaction is at the core of interactive learning in the innovation process. Neither customers nor input suppliers should be seen as conventional market traders, simply buying a well-

defined product on the basis of price or quality, but rather as technological collaborators, helping to define product characteristics and attributes, and helping thereby to shape new product innovation.

The extent of user-producer interaction, however, should not blind us to other collaboration partners. Two that deserve attention are suppliers of technical services, and universities and research centres.

The former have a rather consistently high share across all countries, and may reflect the increasing importance of services related to monitoring, instrumentation, quality testing, and so on. The latter vary significantly across countries, perhaps reflecting differences in the nature of the institutions and hence the structure of the innovation systems. However ,the Spanish result seems to be a definite outlier.[5] Universities and research centres are, of course, very important from a policy point of view since they are normally a part of the knowledge infrastructure and are more or less strongly publicly funded. A key question from the Australian point of view is whether 17% is a high or low number: does this level of collaboration indicate that universities and research centres are important or relatively unimportant in the kind of innovation discussed here?

Table 7. **Distribution of collaboration partners in participating countries**

Percentages, unweighted

	Australia	Austria	Denmark	Norway	Spain	Sweden (East Gothia)
Private customers	64	56	71	59	53	61
Government customers	15	33	21	20	25	30
Suppliers of materials and components	52	62	74	57	58	83
Suppliers of machinery and production equipment	26	29	44	35	49	55
Suppliers of technical services, testing and control	43	42	43	45	-	42
Marketing/management consultants	28	18	32	18	33	-
Competitors	7	20	13	28	15	35
University and research centres	17	33	17	23	60	36
Parent/subsidiary	30	39	33	-	37	-

Note: Firms can have more than one collaboration partner.
Source: Australian DISKO survey (1999); Christensen *et al.* (1999); Edquist *et al.* (2000); Ørstavik and Nås (1998); Sanz-Menéndez *et al*. (1998); Schibany (1998).

We would argue that these figures for universities and research centres are high, perhaps higher than we might expect, and that they indicate a strong role for such institutions in the innovation process. The reason for this is that, although we are looking at innovation in the sense of new products, much of this change tends to be incremental and small-scale in character (although it is very important in terms of long-run quality improvements). It is often argued that innovation rests on cumulative change that tends to be carried out on the basis of previous experience, and of engineering or design modifications that do not usually require R&D (Kline and Rosenberg, 1986). If this is the case, such innovations would not seem to need university-type inputs, so we might not expect such a widespread degree of collaboration. This might suggest, therefore, a more important role for university and research centre collaboration not only in research-based radical innovations, but also in the "everyday" innovation that, after all, makes up most of the innovation that drives economic change.

It is worth noting that collaboration with universities increases with firm size in all of the countries in the survey. In analysing the Austrian DISKO data, Schibany notes that:

> "The strong relationship between size and co-operation with universities seems to be a sensitive result given that larger enterprises tend to employ highly qualified personnel [and are] more likely to have in-house R&D facilities. Large science-based firms might be well prepared to communicate with universities knowing their codes and their culture, while smaller firms may have greater difficulties in this respect. In addition, small firms often do not have the personnel and the financial resources in order to co-operate with universities." (Schibany, 1998, p. 56)

The Australian data suggest that large firms collaborate more than small firms with a parent or subsidiary. This is not surprising given the ownership structure of these firms. Particularly in the context of R&D, parent firms are usually major locations for R&D, which would suggest that large firms are more reliant on inter-enterprise relationships and less on suppliers for collaboration.

Table 8. **Distribution of collaboration partners in Australia by firm size**

Unweighted

	Under 10 employees	10 to 19 employees	20 to 49 employees	50 to 99 employees	100 to 249 employees	250 to 499 employees	500+ employees
Private customers	30	72	64	65	67	60	62
Government customers	0	15	19	26	5	0	15
Suppliers of materials and components	40	52	49	58	71	47	39
Suppliers of machinery and equipment	20	26	25	32	38	13	15
Suppliers of technical services, testing and control	50	48	45	39	48	40	15
Competitors	50	9	32	29	29	40	23
Marketing/management/legal consultants	0	7	11	3	0	0	23
University and research centres	0	17	13	16	19	27	31
Parent/subsidiary	30	13	32	32	29	60	46

Note: Firms can have more than one collaboration partner.
Source: Australian DISKO survey (1999).

In Australia, however, we should note that university collaboration is asymmetrically distributed across industries: it is zero in four industries, and relatively high in petroleum, coal and chemicals, in metal products, and in machinery and equipment (Table 9). Table 9 also highlights the different types of collaboration partners across industry sectors. The point to note here is that there are rather large differences in these patterns; this is an area where sectoral case studies would be required to clarify both the patterns and the relative significance of different types of partners. This would seem to be an area where policy makers need to be aware of sectoral diversity in the design of policy instruments.

Table 9. **Distribution of collaboration partner by industry sector Australia**

Percentages, unweighted

	Food, beverages, tobacco	Textiles, clothing, footwear	Wood, paper	Printing, publishing	Petroleum, coal, chemicals	Non-metallic minerals	Metal products	Machinery, equipment	Other manu-facturing
Private customers	75	54	71	50	67	50	69	64	58
Government customers	13	15	14	38	6	0	17	20	8
Suppliers of materials and components	56	54	43	50	64	25	45	53	58
Suppliers of machinery and equipment	38	15	14	38	27	25	31	25	17
Suppliers of technical services, testing and control	50	54	29	25	49	50	45	43	17
Competitors	0	8	0	0	9	17	0	11	0
Marketing/management/ legal consultants	38	8	0	13	30	25	38	26	33
University and research centres	0	0	14	0	33	8	21	19	0
Parent/subsidiary	31	15	14	50	42	25	24	32	17

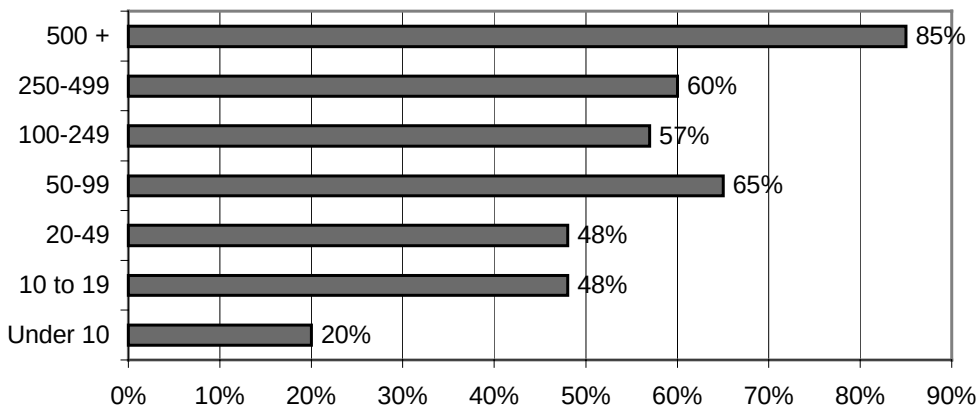
Note: Firms can have more than one collaboration partner.
Source: Australian DISKO survey (1999).

Foreign collaboration

Fifty-three per cent of Australian firms that undertook product innovation had a foreign collaboration partner. This may reflect the high level of foreign ownership in Australian manufacturing. The propensity to collaborate with a foreign partner tended to increase with firm size and this is displayed in Figure 7 below. The key point here is that Australia has historically had very high levels of inward foreign direct investment; thus, large firms in Australia are more likely to have a foreign parent and this may have influenced this result. At the same time, however, large firms have more resources, a wider set of contacts, and so on, so it may be easier to develop foreign relationships.

Figure 7. **Percentage of Australian firms with foreign collaborator, by size of firm**

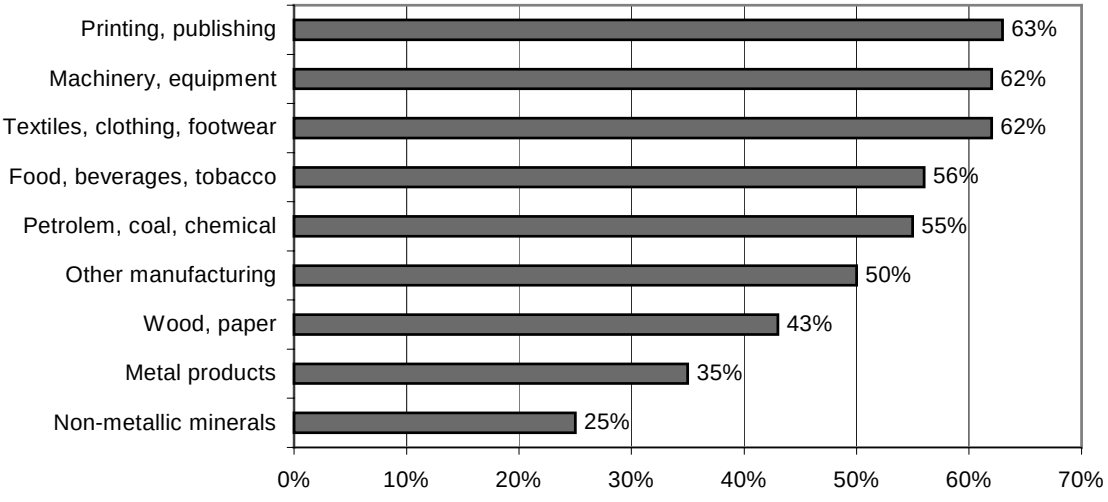
Unweighted



Source: Australian DISKO survey (1999).

The level of foreign collaboration between the industry sectors was roughly similar with the exception of non-metallic minerals and metal production. Given Australia's geographical distance from trading partners, it is interesting to note that foreign collaboration was quite widespread, and one suggestion might be that globalisation is a more significant phenomenon in terms of cross-border collaboration than might have been recognised.

Figure 10. **Percentage of Australian firms with foreign collaborator, by Australian industry sector**
Unweighted



Source: Australian DISKO survey (1999).

Many Australian firms were unwilling to supply the contact details of their partner. Therefore, unfortunately, we are unable to determine the exact location of these foreign collaborators. However, we can say something about the types of partners involved in foreign collaboration, and compare it with those of other countries. Table 10 suggests a broad correspondence between the importance of different types of partners, although with a smaller proportion of foreign universities/research institutes for Australia than for other countries (presumably reflecting access problems related to physical distance).

It is interesting to note the degree of foreign collaboration in all of the participating countries. A shared culture is often considered to be an important mechanism for building trust, usually seen as an essential element in a collaborative relationship. For example, Freeman suggests that:

> "Personal relationships of trust and confidence (and sometimes of fear and obligation) are important both at the formal and informal level … For this reason, cultural factors such as language, educational background, regional loyalties, shared ideologies and experiences and even common leisure interests, continue to play an important role in networking." (Freeman, 1991, p. 503).

Table 10. **Distribution of domestic and foreign collaboration partners in participating countries**

Percentages, unweighted

	Australia domestic	Australia foreign	Austria domestic	Austria foreign	Denmark domestic	Denmark foreign	Norway domestic	Norway foreign	Spain domestic	Spain foreign
Private customers	58	28	56	37	62	41	57	28	45	21
Government customers	15	2	33	14	20	9	21	3	67	6
Suppliers of materials and components	43	28	62	42	64	41	51	38	38	17
Suppliers of equipment	20	12	29	22	37	20	26	24	43	18
Suppliers of technical services, test and control	38	10	42	18	39	14	44	13	-	-
Marketing, management consultants	27	3	18	7	30	8	19	4	79	12
Competitors	6	2	20	11	9	5	23	12	57	34
University and research centres	16	1	33	11	15	6	25	4	77	5
Parent company or subsidiary	20	11	39	24	21	16	-	-	39	47

Note: Firms can have more than one collaboration partner.
Source: Australian DISKO survey (1999); Christensen *et al.* (1999); Ørstavik and Nås (1998); Sanz-Menéndez *et al*. (1998); Schibany (1998).

This data does not support Freeman's claim; on the contrary this level of foreign collaboration suggests that firms are keen to develop international links in a climate of changing market conditions and globalisation. This does not, of course, mean that foreign collaboration is equally attractive across all types of partners and all types of activities. Christensen *et al.* highlight that foreign collaboration partners in some areas are not as attractive:

> "Suppliers of technological services rank low as foreign collaboration partners ... technological services (suppliers of technological services, other private technical consultancies and marketing and management) largely seem to be appropriated in a national setting. A possible explanation could be that at the core of the "products" of knowledge-intensive services lies expert knowledge, problem-solving know-how, etc. An inherent problem in "buying" information is the fact that the value of the information is unknown before the actual purchase. Accordingly, the choice of supplier is crucial to what you get. In a business which is rather opaque, firms might prefer to adhere to national collaboration partners, where additional problems like language barriers, differences in culture, etc., are reduced." (Christensen *et al.*, 2000, p. 11)

Duration, intensity and effect of collaborative relationship

Is collaboration opportunistic, reflecting *ad hoc* needs, or does it persist over time? The DISKO surveys indicate that technological collaboration involves sustained interactions over long periods of time. The majority of firms in Spain, Denmark, Norway and Australia had collaborated with their partner before. The Australian data reveal that collaboration is both ongoing and widespread: 66% of firms had collaborated with their partner before and, on average, collaborative relationships had begun ten years before. In Spain, less than 30% of firms were first-time collaborators (Sanz-Menéndez *et al*., 1998, p. 12). In Norway, too, collaboration was long-term, and it has been argued that:

> "The growing complexity of the knowledge base and the more rapid rate of change seems to make it attractive for most of the product-innovating firms to establish selective relationships which are medium- to long-term. For instance, preliminary results of the Danish data reveal that of the firms having collaborated with one or several partners over the last two years, only a minority were collaborating with these partners for the very first time. A similar conclusion seems to hold for the Norwegian case too." (Ørstavik and Nås, 1998, pp. 14-15).

These collaborations were generally regarded by firms as being important in carrying through innovation projects. Nearly 60% of responding firms in Australia regarded the collaboration partner as crucial to the success of the project. Collaboration is thus neither transient nor peripheral to project success, and the picture is one of sustained knowledge interactions over time among these firms.

Services related to product development

It has now become commonplace to note that as industrial economies have changed, they have moved from a focus on manufacturing towards even greater participation in the production of services. Services are now a major component of economic activity in Australia. In OECD economies, service activities now make up around 70% of output and about 60% of employment (OECD, 1999). This standard characterisation of services, however, may be highly misleading. Often, statistical categories refer to services in isolation from other activities.

However, examining services requires care, because services usually do not develop in isolation in the economy but are closely linked to other areas, notably manufacturing and resources. Karaomerlioglu and Carlsson (1999) demonstrate that around half the economy of developed countries is formed by the linked manufacturing-services area. Recent work in Australia by Pappas and Sheehan (1998) shows the existence of an integrated manufacturing-services sector. The input-output data they present indicate that Australia's manufacturing sector draws heavily on purchases from service firms, particularly from services such as transportation, communication services, finance, insurance, property services, building services and others. Moreover, this consumption of service inputs has increased rapidly since the late 1970s. As these writers indicate, there is a new blurring between manufacturing and services.

The significance of these trends lies not so much in the growth of services *per se*, but in the interaction and interdependence between the services and manufacturing sectors. Lester argues:

> "The traditional boundary between manufacturing and services is fast becoming obsolete. Manufacturing has traditionally meant the production of tangible goods, but for today's customers it is the bundling together of the tangible object with an array of intangible services that makes for the most desirable, 'service-enhanced product'." (Lester, 1998, p. 15)

The Australian DISKO data indicate that manufacturing firms are engaged in the provision of services. Nineteen per cent of firms in our sample developed new services which were supplied in conjunction with their products and, of these, 44% had collaborated with an external partner in doing so. These results are similar to those reported in Austria and Denmark. In Austria, 25% of firms had developed services and of these 41% had collaborated. The rate in Denmark was 22% and 47% respectively (Schibany, 1998, p. 77).

Table 11. **Percentage of firms innovating, developing services and collaborating by firm size in Australia**

Unweighted

Number of employees	% innovating	% of which collaborating	% developing services	% of which collaborating
Under 10	34	48	10	33
10-19	32	84	13	48
20-49	43	89	17	47
50-99	42	86	26	32
100-249	43	84	33	47
250-499	63	88	23	17
500 +	65	100	35	71

Source: Australian DISKO study (1999).

Table 12. **Innovation, provision of services and collaboration in Australia, by industry sector**

Percentages, unweighted

Industry sector	% innovating	% of which collaborating	% developing services	% of which collaborating
Wood, paper	17	88	13	33
Printing, publishing	20	73	25	64
Metal products	32	88	15	67
Textiles, clothing, footwear	37	65	19	30
Food, beverages, tobacco	43	89	24	20
Other manufacturing	44	80	18	17
Petroleum, coal, chemical	46	89	17	50
Non-metallic minerals	50	86	14	75
Machinery, equipment	53	85	21	36

Source: Australian DISKO study (1999).

As indicated in Tables 11 and 12, the propensity to develop services in Australia, and the propensity to do so in collaboration with others, increased with firm size. There were no significant differences across industry sectors. This supports the findings of other recent research on service provision in the Australian economy which found that non-service sectors were developing a wide range of services to complement their products (AEGIS, 2001).

Australia-specific results

In what follows, we turn to specifically Australian results where the data are currently unavailable for other countries or not strictly comparable with that of the other countries participating in the project. Some of the following discussion is based on results concerning the project level, rather than the firm level. Firms that had innovated and collaborated were asked to nominate their "most important project" involving an external collaboration partner, and then answer a series of questions relating to their "most important product" (MIP). Of the 211 firms that had developed a new product and collaborated, 76% were able to name a single MIP (N = 161).

Reputation and trust

What is the basis for collaboration? Firms that were able to nominate a MIP and had engaged in their *first* collaborative arrangement with a nominated partner, were asked a series of questions about the way the relationship was structured. Only 54% of these firms formalised the collaboration. The data therefore indicate that collaboration does not necessarily rest on purely contractual relationships. Mutual trust has been argued to be a central feature in interactive learning, and in user-producer interactions more generally (Lundvall, 1988). The effective management of collaboration requires trust and co-operative relationships between firms, and Dodgson suggests two reasons why this is so important:

> "The first relates to the sort of knowledge being transferred. It may be tacit, uncodified, firm-specific, and commercially sensitive. It is, therefore, not readily transferable … Furthermore, it is often proprietorial. What is being exchanged is the kind of knowledge and competence that is not easily replicated or purchased by competitors and thus can provide important elements of a firm's defining competencies and competitiveness." (Dodgson, 2000, pp. 178-179)

Many firms did not have a formal contract before starting the project and this suggests that the level of trust *before* they started the collaboration was high. Reputation seems to be more important: 81% of Australian firms involved in a MIP entered the collaboration on the basis of the good reputation of the partner.[6] It seems clear from the data that trust is a key component of collaboration, strongly present in the firms studied here.

Intellectual property

Thirty-one per cent of firms involved in a MIP *did not* have a formal agreement about the division of intellectual property (IP) rights, and this again suggests a degree of mutual trust among firms. Firms were also asked how they protected their IP rights during the MIP collaboration: 39% had their own patent, and only 4% had a joint patent. Twenty per cent of firms reported "other" IP protection and 37% stated that it was not relevant. Of the 109 firms with a formal agreement on IP rights, 89% made the agreement at the start of the project. Only 6% of firms had a dispute about IP rights which could not be solved in house.

These results seem to indicate that the management of innovation requires the formation of trust and co-operative relationships between firms, and that this is a key element in knowledge management at the firm level.

Market introduction of product

The majority of new products developed through the collaborative process were successfully introduced in the market (Table 13). This suggests that the collaborative relationship was in some degree successful in overcoming technological or market uncertainty. It is difficult to assess these figures, since we know little in general about the degrees of success in introduction of new products, although the accepted wisdom is that risks are high and success rates low. If this is indeed the case, then collaboration appears to make a difference to innovative success.

Table 13. **Market introduction of product, level of success, Australia**

Percentages, unweighted

Above expectations	31
As expected	51
Less than expected	8
Much less than expected	2
Withdrawn	1
Never released	8
	(n=161)

Source: Australian DISKO study (1999).

Labour exchange during collaboration

Knowledge transfer is widely recognised as important for innovation, and in recent years employee exchange has been increasingly seen as one of the most important mechanisms for this. It facilitates the transfer of knowledge and enhances the firm's learning capacity. Employees hold tacit knowledge (know-how); exchanging personnel gives firms access to new skills and sources of information. Such mobility appears to be a central component of the collaboration processes studied here.

Thirty-eight per cent of firms exchanged employees during the MIP collaboration process. The exchange of employees, and the length of exchange from the innovating firm to the collaboration partner and from the collaboration partner to the subject firm was roughly the same: 20 and 15 days, respectively. The exchange of employees tended to increase with firm size. This may be because larger firms are in a better position to "spare" employees, but it might also simply reflect a greater prevalence of co-operation among such firms.

Conclusions and policy implications

From a policy perspective, there are two broad issues concerning innovation collaboration (Howells, 2000, p. 11). The first concerns the *extent* and *persistence* of collaboration in innovation processes – whether or not it is widespread, growing and, in general, a significant component of innovation. The second concerns the factors that shape the effectiveness and performance of collaborative relationships and networks. The first of the issues determines whether collaborative behaviour deserves attention from policy makers – after all, if it is insignificant in extent or impact or duration, then it is certainly peripheral to policy concerns. If collaboration is important, however, then the next question is how policy can affect it. To what extent can legal and regulatory frameworks, general policy incentives, or specific instruments, foster collaboration and increase its effectiveness?

The results from both the Australian and the international surveys seem to answer the first of these questions. The key result from the DISKO surveys is that the emphasis that has been placed on inter-firm collaboration by researchers working in a case-study context is not misplaced: it is generalisable across the economy as a whole. On the basis of comparable survey methodologies and similar data sets, the survey data indicate that:

- Innovation activity is widely distributed across economic sectors and industries.

- Technological collaboration with other firms and with a range of research and technology organisations is pervasive among innovating firms.

- Collaborative relationships are not transient but persist over long periods of time.

- Foreign collaboration is a significant part of collaboration efforts.

- Science and technology infrastructural institutions – such as universities and research institutes – play a significant part in the collaborative process.

- The structures of these collaborative relationships are somewhat similar across countries, suggesting some commonalities among national innovation systems.

Many forms of policy incentive for innovation assume that the primary problem in innovation is to strengthen the knowledge-creating capabilities of individual firms. The data presented above cast doubt over such approaches. If collaboration is extensive and of long duration, there are serious questions to be raised about policy approaches that are based on an underlying assumption that firms are separable, independent, well-defined organisations whose working relations with other firms are mainly in terms of market transactions.

This suggests that collaboration is a central feature of innovation and, therefore, that policies to promote innovation must relate to such phenomena as collaboration, networking, knowledge exchange, and so on. What does this imply in terms of policy action? Here, we briefly discuss the implications for four areas of policy action – R&D incentives, infrastructure policies, the design of industry support programmes, and international links.

First, a common form of innovation incentive is the R&D tax credit. The basic concept behind this in most countries is that individual firms are the relevant knowledge-creating units. The pervasiveness of collaboration, however, suggests that credits which both encourage collaboration and networking, and allow effective cost-sharing and sharing of tax benefits, might be an appropriate direction for policy analysis.

Second, there is the issue of the knowledge infrastructure and social capital. Case-study research on networking has strongly suggested that good social capital improves network performance (Howells, 2000, p. 19). The data presented here suggest that collaboration is in large part tied up with relations between firms and infrastructural institutions such as universities, research institutes, and this too may require greater policy attention. At the present time, we probably do not know enough about how the routine support of infrastructural institutions affects their collaborative capabilities, and how this in turn impacts on performance of the business sector. The data suggest that there are important sectoral differences in the roles of infrastructural institutions, which means that policy makers need to be sensitive to industrial structural issues in thinking about infrastructural policies.

Third, we have seen that both innovation and collaboration are present across many sectors and industries. However, the patterns of collaboration – in terms of types of partners, IP rights issues, roles of universities, and so on, differ across industries. This has implications both for the rationale for and the design of industry support programmes, particularly where underlying knowledge bases are changing – appropriate policy measures cannot, in this context, be derived from general principles, but should be designed with specific industrial and knowledge structures in mind.

Finally, we have seen that international collaboration plays an important part in the collaborative behaviour of Australian firms, as it does in other countries. In an era of globalisation, this is of clear

importance, and the policy issue seems to be not so much to promote this as to make sure that specific instruments (such as accounting regulations or tax polices) do not inhibit its further development.

NOTES

1. The timeframe was two years in Australia, Austria, Denmark and Sweden, and three years in Norway and Spain. In Norway, three years was chosen because it is consistent with the Community Innovation Survey (Personal communication, STEP, June 2000).

2. The cross-country comparisons are based on raw data, and are unweighted. This means they should be treated with some caution, since they involve different samples, cut-off points, and so on. They can certainly be treated as indicative, but strong conclusions should not be drawn concerning the significance of inter-country differences.

3. Sweden's study was slightly different from the others. It had a regional rather than national sample (East-Gothia), and the sample was drawn from *establishments* with one employee and above. The size category 1-9 has been excluded from the results presented in the following figures and tables for comparability. In the Swedish study, establishment means "a single place of work, which may be part of a larger multi-establishment firm" (Edquist *et al.*, 2000, p. 55).

4. As mentioned earlier, the Australian sample targeted firms with more than ten employees. At the time of the interview, however, some firms had less than ten employees. These firms have been included in some of the analysis for comparative purposes.

5. Sanz-Menéndez *et al*. note that the Spanish sample was drawn from a database owned by the Spanish Ministry of Industry responsible for "promoting technological development in firms"(1998, p. 27), and this may have affected this result.

6. N = 129, excludes competitors and parent/subsidiary.

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Chapter 8

DIFFERENCES IN THE PROPENSITY TO INNOVATE BETWEEN LESS AND MORE DEVELOPED REGIONS: HOW A SYSTEM OF INNOVATION APPROACH CAN EXPLAIN THEM

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Introduction

This chapter uses a system of innovation approach to analyse geographical differences affecting firms' innovation activities. There are many reasons for carrying out this type of analysis. First, innovation and technological change are central to economic growth in developed countries and go a long way to explaining convergence and divergence processes among regions. Second, innovation is largely a territorial phenomenon; that is, the innovation process is partly based on resources that are location-specific, *i.e.* resources that are tied to particular places and cannot be copied or reproduced elsewhere. Third, innovation occurs differently in different regions, depending on firm and industry structure, as well as on social and cultural conditions.

This chapter investigates the role of local externalities, firm networking and public policy variables in explaining regional differences in firms' propensity to innovate, *i.e.* the propensity to introduce product innovations. The empirical application concerns regional differences in innovation activities of firms in Italy, where there are major differences in the propensity of firms from the North and South of the country to carry out innovative projects. To enable regional innovation policy to be tailored to varying local conditions, it is essential to understand how the innovation process takes place, *i.e.* to pinpoint the factors that explain the innovation behaviour of firms in particular regions.

The basic model used to explain firm's innovation performance is the "classical" Schumpeterian equation, to which we add other variables representing inter-firm organisation, local spillovers and policy. The dependent variable is the propensity to introduce product innovations.

Using firm-level data collected by the Mediocredito Centrale, we investigated the role of these variables in the innovation behaviour of firms located in three different geographical areas: the North-West, the North-East-Centre (the so-called Third Italy) and the South (the *Mezzogiorno*).

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* This chapter is a revised version of a previous piece of work by Potì, B. and R. Basile (2001), *Convergence Project*, December.

Since the focus of the study is on regional development and growth, this chapter begins with a brief review of issues related to the role of innovation and technological change in economic growth. This is followed by an analysis of microeconomic issues related to innovation processes, which highlights the role of organisational strategies in shaping the creation of new knowledge by firms. In the third section, data and methodological issues are presented; the fourth section deals with the main findings of the empirical analysis; and the final section concludes.

Catching up and national/local systems of innovation

Catching-up theories introduce a specific conceptualisation of technological change to explain disparities in economic growth across countries. The basic assumption is that "the growth rate of productivity for a country over a period of time is negatively proportional to the level of productivity at the beginning of the period" (Gregersen and Johnson, 1997). International movements of capital and transfer of technologies from high- to low-productivity countries are at the root of this phenomenon.

The process of catching up is not automatic and depends on the ability of countries to overcome technological gaps. Abramowitz (1994) introduces the concept of "social capabilities", which comprise a country's organisational and institutional factors. This concept relates to the ability of a country: to imitate products realised abroad, to adapt imported technologies to the national context and to import suitable organisational and institutional models from abroad. Moreover, catching-up economies may show rapid economic growth and structural change (if they are able to build up absorptive/imitative capacity) over a short period of time, but sooner or later they are confronted with the need to build up their indigenous science and technology bases.

Recent developments in growth theory have stressed that economic growth is the endogenous outcome of an economic system, and not the result of outside forces. It is driven by the accumulation of knowledge by forward-looking enterprises. Investment in technological activities create opportunities for new investments and growth. Growth is explained by the fact that R&D processes involve dynamic increasing returns arising from the special properties of the output – knowledge, with its natural externalities. Each firm learns, both from its own investments and from the investments of other firms, through externalities and spillovers (Romer, 1986, 1990). Other empirical studies have shown that knowledge spillovers and externalities are often spatially localised (Jaffe *et al.*, 1993).

New approaches which enable a better understanding of the differing levels achieved by catching-up economies in terms of growth and specific patterns of development are now receiving growing attention. Among these, the national system of innovation approach has strong appeal. While adopting the idea that externalities and spillovers positively affect firm/industry productivity, the system of innovation approach underlines the relevance of firms' interactions (networks and formal agreements) and of the institutional context supporting the creation of externalities. Technology transfer is the core activity in an innovation system. Some technologies may be transferred unintentionally or accidentally (through spillovers), other transfers are deliberate and occur via market or non-market links. In all cases, the transfer of knowledge requires considerable investment in internal R&D and in external knowledge acquisition through networking.

Firm behaviour is strongly influenced by the local "organised market structure", which includes the user-producer relationship (Lundvall, 1988), industrial clusters (Jacobson and Carlsson, 1996), socially based rules and routines (Dosi, 1988). The firm's propensity and capacity to innovate depend on the system of linkages in which it is embedded, the institutions regulating distribution of and access to knowledge, and the organisation and combination of different competencies and technologies. Linkages and interactions increase the social value of knowledge and market opportunities.

The interactions between different actors shape national technological trajectories. These interactions can be described at three levels: firms' investment in (co-operative) networking; local clusters of economic agents at intermediary level; the linkages between knowledge infrastructures and firms. The capacity to exploit technological opportunities lies in these interactive patterns of knowledge production:

- *Localised and firm-specific knowledge: i.e.* technical, but also organisational knowledge. At this level, it is important to understand if and how firms integrate and co-ordinate a heterogeneous range of activities, both internally and externally.

- *Industrial generic knowledge*: a set of knowledge and practices which are, in principle, available to all firms in an industry. These externalities are non-market-mediated interdependencies that are sometimes sector-specific (sector-specific labour skills), and sometimes cut across sectors (technology spillovers). The dissemination of this knowledge is aided by various institutions and organisations (technical infrastructure) and requires firms' internal resources in order to be absorbed. At this level, it is important that the analysis covers intermediary structures (smaller than a national economy, but larger than individual firms), such as clusters and networks, that can be geographically concentrated (Krugman, 1991).

- Another source of knowledge for firms originates from the *general science base*: there are good reasons to believe that spillovers from university to firms take place, especially since academic researchers have little incentive to keep their results secret.

All these aspects (firms' integration of external knowledge, innovative clusters and spillovers from public sector knowledge institutions) form highly specific national or regional contexts for innovation.

Determinants of endogenous innovation: firm investments in R&D and networking and geographically mediated spillovers

Growth is sustained by technological progress; this requires deliberate investments of resources by profit-seeking firms – innovation is the engine of growth.

The literature on regional systems of innovation has emphasised the role of the local environment in shaping firms' innovative activities, through the supply of different inputs for innovation. The spatial context influences the rate and direction of the firm's research activities that lead to innovation. Studies have pointed to significant regional differences in research and technical activity and in technical specialisation within a national territory.

Some authors have found that innovation is geographically localised in areas where there is a concentration of knowledge spillovers from specialised resources Audretsch and Feldman, 1996). The proximity of a variety of knowledge inputs offers a greater likelihood of information transfer and sharing, and leads to a positive and self-reinforcing process of innovation. An actively innovative region will develop a set of specialised resources that will give it a comparative advantage for the next round of innovation. The externalities achieved are of two types: *i)* the R&D carried out by firm *i* benefits firm *j* at time *t*; and *ii)* the experience of the past is relevant for the future. Proximity to sources of knowledge that allow close collaboration between users and suppliers is most important when a product is in the early stages of its life cycle (Carlsson and Jacobbson, 1991). In addition, firms tend to co-operate when they have to cope with complex and rapid technological developments (Lundvall, 1988).

The capability of a firm to use spillovers from other firms' R&D activities depends on its investment in internal R&D, *i.e.* on its absorptive capacity. This effect partially offsets firms' disincentives to perform R&D activities, the benefits of which could spill over to competitors, and has a positive effect on firms' decisions to participate in co-operative research.

Cohen and Levinthal (1989), modelling the generation of a firm's technological knowledge, make it a function of: the firm's own R&D; the fraction of knowledge generated by other firms that spills over (into the public domain); and the character of the knowledge to be absorbed (*i.e.* more or less tailored to the core activities of the firm). The quantity of knowledge to be assimilated, and the ease of learning, both influence the firm's R&D spending: even if a firm is located near a source of knowledge, the cost of learning can be significant.

There is a link between local spillovers and firm networking/clustering: when knowledge spillovers are high, there are greater incentives for firms to invest in network and collaboration activities and mutually benefit from the sharing of information. Some studies suggest that firms in clusters/networks are more likely to introduce innovations than firms that are isolated. Feedback (interactions) dynamises systems; the greater the interaction among the components of a system, the more dynamic it is.

Opportunities for networking and co-operation arise from both unintended spillovers and deliberate agreements. Changes in firms' attributes can also contribute to network growth: a network often has its origins in an agreement to share information and capabilities. Some studies find a link between networks and inter-firm co-operation; the fact that firms are embedded in dense networks makes inter-firm co-operation more effective. However, this also depends on the characteristics of the network: behaviour is easier to predict in a fully connected (*i.e.* not open) system, thus facilitating the setting of norms for co-operation.

The market is not always the best channel for acquiring new capabilities: some assets are not easily and rapidly tradeable. Formal agreements remain the most reliable indicators of resource sharing among firms and of the connectivity of a system.

Finally, networking and co-operation are not always conducive to better innovative performance in a system. Even when they enable an increase in the level of R&D expenditure, and even when spillovers are high and opportunities low, the contribution of the network to the creation of collective value depends on the inter-firm organisational capacity to produce mutual advantages and promote trust and reciprocity (Chesnais, 1996; Hamel *et al.*, 1989). Public policy aimed at fostering networks can help to obtain better collective results.

The role of public policy

The system of innovation approach enables non-economic factors to be included in the determinants of innovation; these can be institutional, organisational, social and political factors. There is a growing literature on public policy and innovation systems, and studies on technological catching-up patterns recognise that government intervention is a key element in the national propensity of innovation. Government policies promoting industrialisation (granting of credits and protection of domestic markets) have served to sustain the large, vertically integrated firm model in Korea, while the Chinese Taipei model, based on linkages between small and medium-sized firms and large public research institutes, has been strengthened by government policies fostering technology diffusion, promotion of product consortia, standardisation and procurement (Wong, 1999).

It is now widely recognised that the effectiveness of public policies targeting innovation depends on the capacity of policy makers to understand innovation as a system. The traditional linear approach was mainly based on the funding of scientific research; this is still vital, but other instruments are necessary too. Programmes aimed at redesigning organisations and institutions, and the relationships between them, can be more effective than subsidies and other financial incentives.

Some authors have shown that when R&D becomes a critical issue in a newly industrialised country (once the benefits to be derived from reliance on imported technology have been exhausted), the state has an important role to play. The successful penetration of R&D throughout the economy requires an extensive learning process (collective, multidisciplinary and cumulative). In a first phase, governments need to provide wide-ranging, search-oriented support to promote the endogenisation of R&D in the economy. This can be done through the sponsorship of promising R&D projects, but also through network-based regional development strategies, in order to enhance the creation of social capital and increase the innovative capacity of less-developed regions. This learning approach of policy implies the creation of conditions conducive to the sharing of experiences and non-proprietary information among participants. In a more mature phase, the role of policy is to stimulate firms to undertake riskier and more complex projects.

Policy intervention in Europe, in general, and in Italy, in particular, has traditionally been based on the provision of financial incentives to industry. One way of studying its impact is to look at the differential effects which have occurred in more or less extreme situations: small and medium-sized firms, the South of Italy.

Failures are generally of two kinds: limited interactions and low learning capacity; and absence or weakness of key elements (brokerage functions; suppliers; research institutes). Policies designed to improve linkages (among complementary activities; among university and industry), build competence and enhance public procurement are important determinants of firms' propensity to innovate and are often more effective than financial and market incentives in promoting innovation (Malerba, 1996).

The model: hypotheses and variables

The conceptual model is based on the incorporation within a common theoretical framework (factors relevant to firm innovation behaviour) of different, complementary strands of the literature.

An extended version of the Schumpeterian equation on the determinants of firm innovation is applied to a database of Italian firms, allowing us to test the hypothesis that firm networks and local spillovers are relevant to firm innovation decisions, by controlling to see if this extended version performs better than the simple model.

Some innovation-inducing inputs at firm level, such as internal R&D activity and workforce skills, and some components of the new models based on the local system of innovation literature, *i.e.* firm's networking and local concentration of innovative activities and scientific research activities, were sequentially added to a Schumpeterian equation, with its focus on firm size and market structure. Finally, the effect of public support to innovative activities as a determinant of the probability to innovate, was introduced. Sectoral and regional fixed effects were also controlled for.

The dependent variable is the propensity of firm *i* located in region *j* to bring new products to the market. In synthesis, the model of innovation is specified as follows:

$$\text{INNOVATION}^*_{ij} = \text{SIZE}_{ij} + \text{MARKET INCENTIVES}_{ij} + \text{TECHNOLOGICAL REGIME}_{ij} + \text{REGION}_i + \text{ORGANISATION}_{ij} + \text{SPILLOVERS}_j + \text{PUBLIC R\&D}_j + \text{PUBLIC SUPPORT}_{ij}$$

where the subscript *i* indicates the firm and *j* indicates the province.

As a first step, the regression was estimated for the country as a whole, in order to investigate whether sector and region have a significant impact on the dependent variable. This result was taken as the benchmark for the regional comparisons.

By estimating separate regressions within regions [*e.g.* one regression for North-Western firms, one for firms from the Third Italy (North-East-Centre), and one for Southern firms], region-specific effects are automatically estimated.

The role of the factors of the so-called Schumpeterian hypothesis, firm size and market structure, was investigated, controlling for sector-specific effects, as suggested by the "technological regime" hypothesis, and general regional effects.

Schumpeter conjectured that product market structure, coupled with firm size, should increase firms' propensity to innovate by facilitating the retention of rents. Empirical tests on this hypothesis have given controversial results. The so-called Schumpeterian hypothesis suggests that a monopolistic structure favours innovation since in such markets firms accumulate the financial resources required for innovation. However, Arrow (1962) reports an opposite result: firms operating in a perfectly competitive market have stronger incentives to introduce innovations in order to attain a monopolistic position. The ambiguity of these findings is caused by the unequal distribution of incentives and of capacity to innovate among firms and industries (Coombs, 1988).

Scherer (1967) suggested that the most important determinants of innovation were scientific and technological opportunities, which vary widely among industries. Several studies have confirmed this finding (Kamien and Schwarz, 1982). In more recent studies, market structure variables are used to analyse the determinants of firms' propensity to innovate as a complement to other variables, such as firm organisation (Veugelers and Cassiman, 1998).

Basically, firms' innovative behaviour and market structure have a two-way relationship which is influenced by a multiple set of contingencies. In particular, firm-level variables, such as a firm's investment in co-operative agreements, can facilitate innovation, even when the product market structure could theoretically reduce the incentives to innovate. This is because co-operative mechanisms can free firms' decisions to undertake innovative activity from the constraints of the market.

The role of organisational strategies (networking) is examined with reference to inter-firm formal agreements. Various strategies of external growth (or integration in external networks) that are potentially conducive to innovative activities were considered: acquisitions and group membership (ownership strategies), on the one hand, and co-operation (co-ordination strategies), on the other, as well as different combinations of the two (see Annex).

Other firm-specific factors are those which capture the specific competencies of firms: internal R&D activity and the educational level of the workforce.

Furthermore, the role of factors specific to the firm's location is explored: these include the existence of localised technological spillovers from public research, and agglomeration of innovative firms at sub-regional level (*i.e.* in the province in which the firm is located).

Finally, the effect of public support to innovative activities was analysed. This factor might capture both the ability of the firm to take advantage of policy incentives (from this perspective, it should be interpreted as a firm-specific variable) and the efficiency of local institutions in the

promotion of the these incentives (from this perspective, it should be interpreted as a region-specific variable).

Table 1. **The variables**

	Description
Size, competitive environment region and technological opportunities	
LnEMP	Log (employees)
LnEMP2	Quadratic term of LnEMP
SKILL	Number of employees with a degree to total employment ratio
R&DEMP	Number of employees in R&D department to total employment ratio
SAMEPRO	Competitors localised in the same province
EUROPE	Competitors localised in European Union countries
NORTHWEST	1 if the firm is localised in the North West (0 otherwise)
SOUTH	1 if the firm is localised in the South (0 otherwise)
TRADITIONAL	1 if the firm operates in a traditional sector (0 otherwise)
SCALE-INTENSIVE	1 if the firm operates in a scale-intensive sector (0 otherwise)
SPECIALISED-SUPPLIER	1 if the firm operates in a specialised-supplier sector (0 otherwise)
Organisational variables	
ONLY_COORDINATION	1 if the firm undertook a co-ordination integration strategy (0 otherwise) (see Annex)
ONLY_OWNERSHIP	1 if the firm undertook a ownership integration strategy (0 otherwise) (see Annex)
COORD.&OWNERSHIP	1 if the firm undertook a ownership integration strategy (0 otherwise) (see Annex)
Spillovers	
SPILLOVERS	Number of innovative firms to total number of firms within the province ratio
PUBLIC R&D	Number of university departments plus the number of CNR institutes
Public support	
LAW “SABATINI”	1 if the firm took advantage of Law “Sabatini” (0 otherwise) (see Annex)
LAW 317	1 if the firm took advantage of Law 317 (0 otherwise) (see Annex)
LAW 4682A	1 if the firm took advantage of Law 4682A (0 otherwise) (see Annex)
LAW 4682B	1 if the firm took advantage of Law 4682B (0 otherwise) (see Annex)

The sample

The work draws on a rich data set of firm-level observations collected by Mediocredito Centrale (1995) for 1992-94. This survey covered a sample of some 4 400 manufacturing firms operating in Italy with more than ten employees, and all firms with more than 500 employees. The sample is random and stratified according to the size of the firm, in terms of number of employees, and the sector. Furthermore, the sample is representative at a regional level.

The distribution of the sample by region, sector and size class confirms the well-known characteristics of the structure of industry in Italy (Sapelli, 1992). The North-West region is characterised by the presence of a small core of oligopolistic firms operating in heavy industries and scale production, which, through their demand for capital equipment, sustain the development of capital goods producers. In the recent past, this kind of industrial development was driven by two main factors:

- A process of corporate diversification in large firms.
- The development of mechanical competencies specifically biased towards capital equipment production, with a learning-by-interacting trajectory guided by user-supplier relationships.

This virtuous circle of growth fostered the birth of a new wave of firms in traditional sectors (textiles, wood products, leather and shoes).

In the Third Italy (North-East-Centre regions), specialisation in traditional sectors and in small size classes has followed a specific path, known as the flexible specialisation model. This type of industrial development is characterised by autonomous entrepreneurial development and by the presence of systematic factors, fostering the opportunities available to firms to create and maintain small-scale productions (Barca and Magnani, 1989). Small firms are organised in local systems, different from the Marshallian industrial districts since they share a common culture and create collective institutions which allow co-ordination of activities and the open up the possibility to exploit scale economies through collaboration. The limit of this model is in its strong inertia: it tends to reproduce itself along the same paths. Some scholars maintain that this model of development, which continues to offer a competitive advantage at international level, is now reaching its limits (Varaldo *et al.*, 1998). It would appear that there is a need for organisational innovation in order to move away from small, family-managed firms to the creation of large industrial groups headed by a leader enterprise.

The South (the *Mezzogiorno*) has experimented with dual industrial development: on the one hand, heavy, large-scale industries supported by the state; on the other, small firms specialised in traditional sectors. The two main limits of this pattern of industrial development are: the quasi-existence of specialised suppliers; and the isolation and small numbers of small firms. Some scholars have built a sort of demographic picture of industrial districts in Italy (Brusco and Paba, 1997). According to these studies, systems of small firms, which were recorded in the 1951 Census in the South, had disappeared by the time of the following one, probably as consequence of competition by firms from the North and Third Italy on the local markets. However, new systems of small firms were registered in the 1991 Census; these are concentrated in two Southern regions, Puglia and Molise. Moreover, a process of learning by interacting seems to be operating in the South through the diffusion of subcontracting agreements (Mazzola and Bruni, 2000). These subcontracting agreements are quite different from those which are used in the North of Italy since they do not imply externalisation of research, design and engineering, but are instead characterised by low levels of autonomy. However, subcontracting by large firms remains an important channel of knowledge transfer even in the South.

The propensity of firms to introduce product innovations was used as a proxy for innovation activity. The Mediocredito survey asked firms whether they had introduced: *a)* a product innovation; *b)* a process innovation; *c)* both; or *d)* no innovations whatsoever, during 1992-94. It is a well-known fact that changes in product and processes imply different risks and uncertainties for the firm: process innovations concern changes in production techniques, and the uncertainty is related to the engineering dimension; product innovations, on the other hand, concern new or improved products that face uncertainties related to market acceptance and require a more complex innovation strategy (Archibugi *et al.*, 1994), which includes the building up of new capabilities. Product and process innovations are, nevertheless, often closely intertwined and difficult to separate. In particular, product innovations are rarely introduced without an accompanying process innovation. The results of Mediocredito survey confirm this empirical fact. Thus, firms who replied positively to items *a), b)* and *c)* were classified as "innovative".

In terms of the distribution of innovative firms in each region, a higher presence of innovators was found in the North-East-Centre region (Third Italy) than in the other areas. A notable exception concerns the medium size class (251-500 employees) in the South, where the share of innovating firms higher was found to be higher than the national average.

Econometric results

The goal of the estimation is to assess regional differences in firms' innovation activity. Nevertheless, it is interesting to introduce the results of the hypothesis testing for the country as a whole (Table 2), as the benchmark for the regional comparison.

Using a "from specific to general" strategy, four different nested models are presented. The baseline case (column 1) introduces only "size, competitive environment", as well as regional and technological dummy control variables (the regional reference category is NEC, when firm *i* is localised in the North-East-Centre region). The model (in column 1) resembles the specification generally used in the so-called Schumpeterian literature. The advantage of beginning with a specification that is similar to others employed in the literature is that it allows us to check that there are no peculiarities in our sample of Italian manufacturing data, resulting in estimated effects for regressors different from those previously found. Moreover, by starting with a common framework, it is possible to determine the contribution that other variables make to the estimates.

The following three columns list the coefficients when firm organisational variables (column 2), local spillovers (column 3) and public policy variables (column 4) are added sequentially. It should be noted that the inclusion of these different groups of variables improves the fit of the model: McKelvey and Zavoina's (1975) pseudo-R2 starts at 0.430 in the baseline case and improves in each successive column (especially in the third one), ultimately reaching 0.451.

Turning to the coefficient estimates, in the baseline model (column 1) both SIZE and SIZE2 are significant and have opposite signs. These results confirm the presence of a non linear (U-shaped) relationship between the likelihood to innovate and firm size. The hypothesis that firms competing in oligopolistic markets are more likely to innovate (the second Schumpeterian hypothesis) is also confirmed (EUROP is positive and highly significant, while SAMEPRO is not significant). In addition, a higher presence of skilled workers and workers carrying out R&D activity within the firm strongly affects the probability of introducing new products.

The region dummy variable (being located in the South) has a negative sign, suggesting that there is a general locational influence on the propensity to innovate. The region dummy variable becomes insignificant when local spillovers are explicitly introduced into the equation (column 3).

The three sector dummy variables (TRADITIONAL, SCALE-INTENSIVE, and SPECIALISED-SUPPLIER), that approximate different technological regimes, are all significative and negative (the reference category is SCIENCE-BASED). It should be emphasised that, in contrast to the results obtained by Malerba and Orsenigo (1997) and others, the two Schumpeterian hypotheses are confirmed even when technological regime is controlled for.

Table 2. **Italy: determinants of the probability to innovate**

Marginal effects and t values in parenthesis

Variable	(1)	(2)	(3)	(4)
Size, competitive environment, region and sector				
LnEMP	+0.280*** (6.65)	+0.280*** (6.63)	+0.270*** (6.44)	+0.260*** (6.07)
LnEMP2	-0.025*** (-5.35)	-0.025*** (5.40)	-0.024*** (-5.27)	-0.024*** (-5.05)
SKILL	+0.005*** (3.17)	+0.004*** (2.78)	+0.004*** (2.64)	+0.004*** (2.67)
R&DEMP	+0.002*** (4.20)	+0.002*** (4.00)	+0.002*** (4.13)	+0.002*** (3.01)
SAMEPRO	0.003 (0.42)	0.001 (0.10)	-0.001 (-0.06)	
EUROPE	+0.053*** (6.44)	+0.049*** (5.93)	+0.048*** (5.68)	+0.046*** (5.52)
SOUTH	-0.069*** (-2.48)	-0.060*** (-2.15)	+0.001 (0.77)	+0.035 (1.15)
TRADITIONAL	-0.180*** (-4.12)	-0.169*** (-3.81)	-0.164*** (-3.55)	-0.162*** (-3.50)
SCALE-INTENSIVE	-0.162*** (-3.69)	-0.151*** (-3.42)	-0.150 (-3.26)	-0.153*** (-3.32)
SPECIALISED-SUPPLIER	-0.078* (-1.72)	-0.078* (-1.70)	-0.08* (-1.68)	-0.089* (-1.85)
Organisational variables				
ONLY_CO-ORDINATION		+0.092*** (4.62)	+0.094*** (4.65)	+0.09*** (4.50)
ONLY_OWNERSHIP		-0.022 (-0.86)	-0.023 (-0.88)	-0.021 (-0.85)
COORD.&OWNERSHIP		+0.100*** (3.85)	+0.095*** (3.63)	+0.086*** (3.25)
Spillovers				
SPILLOVERS FROM FIRMS			+0.008*** (7.90)	+0.009*** (7.82)
PUBLIC R&D			-0.007 (-1.58)	-0.007 (-1.59)
Public support				
LAW “SABATINI”				+0.039* (1.86)
LAW 317				+0.035 (1.16)
LAW 4682A				+0.181*** (2.96)
LAW 4682B				+0.109*** (2.65)
% of correct predictions	0.64	0.65	0.65	0.65
Log likelihood	-2 582	-2 562	-2 500	-2 486
McKelvey and Zavoina’s R2	0.430	0.435	0.445	0.451

The core of the model concerns the importance of firm networking and local spillovers for firm innovation. As far as organisational strategies (column 2) are concerned, the results suggest that co-ordination strategies and combinations of ownership and co-ordination strategies are both conducive to innovation, while ownership strategies alone have no impact on the probability to introduce new products. The robustness of this result is confirmed by the fact that general region and sector effects have been controlled.

A simple analysis of the Mediocredito data suggests that product innovation is predominantly a collective process. In all geographical areas, isolated firms innovate less than firms with external growth opportunities. Co-ordination integration strategies, both alone and in combination with ownership strategies, seem to be the dominant organisational patterns among innovative firms, although some regional differences can be observed. Ownership integration strategies by themselves do not show a strong relation with innovation behaviour. Moreover, ownership strategies are more common among non-innovating firms. This may indicate that ownership strategies by themselves are mainly implemented for reasons other than innovation, such as export opportunities, access to sources of finance, access to public support programmes (Barbetta *et al.*, 1996).

Spillovers from other innovating firms localised in the same province are a very important source of knowledge, while being located near a university department or a CNR institute is not relevant for the innovation performance of the firm (column 3). This last result does not mean, however, that public research is not important for the innovative success of private manufacturing firms. Indeed, it is reasonable to think that public research output is highly codified and thus easily transferred far from its source. In other words, spillovers from public research are not localised and geographical proximity is not relevant.

Finally, public support is a key factor for product innovation in Italian firms. Particularly important is Law 46, aimed at financing applied research (Law 46a) or technological innovation (Law 46b).

The estimation results for each region (Tables 2, 3 and 4) demonstrate which factors make the difference between more and less successful regional systems. The best way to discuss them is to compare the coefficient estimates for each group of variables. It should be noted that size and market structure variables act at the regional level as they do in the country as a whole. Thus, a U-shaped relationship between size and product innovation is confirmed for each geographical area; and the coefficient of EUROP is always positive. There is a slight difference in the level of significance of this variable for the South, probably because Southern firms are less internationalised and thus less exposed than Northern ones to international competition.

Skilled and R&D workers play a vital role in firms' innovation behaviour at the regional level. However, only for the North-Western firms were we able to disentangle the effect of each variable. In the case of the Third Italy and the South, however, there is strong correlation between the two variables, thus only the R&D effect has been introduced.

Interestingly, the coefficient of specialised supplier is not significantly different from zero for the North West and the Third Italy, while it is negative for the South, confirming the lack of machine-tool producers in this area.

As far as organisational variables are concerned, some important results can be observed. In synthesis:

- The South is characterised by a higher number of isolated firms. This is consistent with the economic development of the South: autonomous firms are rarely organised in systems or districts.

- In line with national average results, in all three geographical areas, ownership strategies (alone) do not seem to play a significant role in innovation success.

The relevance of firms' networking strategies is different in the three regional areas: positive and highly significant in the North-West, it has a less strong significant effect on the firm propensity to innovate in the Third Italy. Here, the effect of local spillovers – Marshallian economies induced by a concentration of innovating firms – is stronger than in the North-West area. Moreover, in the Third Italy, networking is a relevant factor when it incorporates a mixed strategy of ownership and co-ordination.

In the South, networking strategy (mainly co-ordination) has a positive impact on firms' innovating activities, although the effect is less strong than in the North-West area,. Moreover, when the local spillover effect is introduced, firms' networking strategies become less relevant. It would be expected that the probability of becoming an innovating firm in the South is lower in the case of networking (including technical, commercial and subcontracting agreements) than in the case of firms located in one of the provinces characterised by a high concentration of innovating firms. This is probably due to the prevalence of subcontracting agreements in the South and to the not-always innovative contents of these relations.

Another important regional difference concerns the role of different public support systems in innovation. While in the North West, Law 46/82, which supports R&D activities, seems to be more important, in the Third Italy, the Law "Sabatini", which targets the modernisation of capital investment, *i.e.* the innovation process, plays a more relevant role for innovation performance. However, the most important result concerns the South: public support has no significant effect on the success of firms operating in Southern regions. This evidence may be interpreted in two ways: either Southern firms are not able to exploit public incentives for innovation; or local institutions do not efficiently promote the use of the innovation incentive system.

If the performance of the extended model (including networking, spillovers and policy) is compared with that of the more simple Schumpeterian one (column 1) for each region, the three added groups of variables are likely to be important complementary factors, thus allowing a more in-depth explanation of firms' participation in product innovation. In all three geographical areas, the value of the McKelvey and Zavoina R2 test increases from column 1 to column 4, showing a better fit of the model. The major increase of the test concerns the North West region which boasts a higher concentration of knowledge-intensive industries.

Discussion and conclusions

The aim of the study was to test the possibility of explaining divergences in economic growth among countries/regions using a system of innovation approach. An extended "Schumpeterian" model was used to relate firms' internal and external sources of knowledge to innovation performance.

A probit model was adopted, with the key variables being chosen from the most important studies on innovation determinants, matching different approaches in an addititive way. Results of recent studies which suggest that many factors play a relevant role for innovative success were taken into consideration. These include latent sector-specific technological opportunity; local components of

technological opportunity dependent on the effects of spillovers and externalities; firm knowledge absorption capacity and networking strategies (Cohen, 1995).

It was hypothesised that the regional environment of the firm was likely to influence the firm's propensity to innovate, both directly through spillovers (concentration of industrial innovative activities and scientific knowledge sources) and indirectly through its effect on the firm's investments in networking.

A complementary relation between a firm's internal R&D and external knowledge acquired through formal links and unintended local spillovers was hypothesised in the model, following Cohen and Levinthal (1989).

By adding networking and spillovers to a "Schumpeterian" basic model, the value of internal R&D (measured by the number of the firm's employees working on research activities) remained positive and highly significant. Other studies have more tested the relationship between internal R&D and firm networking in a more direct way, leading to different results: found a complementary relationship, Love and Roper (1999; 2001) found that for all firms external and internal sources of knowledge are substitutes, while Audrestch and Feldman (1996) found that external and internal R&D are substitutes in low-technology industries and complements in high-technology industries. In all events, all the studies emphasised the necessity of including external sources of knowledge among the factors explaining firms' innovation performance. The model presented in this chapter points to an additional positive effect: the extended model better explains the capacity of firms to introduce new products on the market.

The model allows the effects of firms' participation in innovative projects to be captured, although the level of commercial exploitation of the new products is not explored. Other studies have shown that R&D and networking strategies related to the acquisition of new knowledge are not able to explain the commercial success of the innovation. However, the variables included in the model do seem to represent some basic conditions for entering the innovation process.

Both firms which have strategies of co-operation and those which use mixed strategies of co-operation and integration have a major probability of innovating. The same holds true for firms which are embedded in a local environment characterised by a high concentration of innovating firms. The importance of spillovers and other external sources of knowledge for innovation output has been investigated in many recent studies (for example, Jaffe *et al.*, 1993). Firms located in strong clusters tend to grow faster and attract new entrants. Innovative activity and output are closely associated with firm entry and productivity growth. Moreover, given the cumulative nature of knowledge, firms located in strong innovation areas are more likely to benefit from this self-reinforcing process.

The model presented in this chapter does not "directly" explore the relevance of the geographical environment on firms' networking activities, although the relationship turned out to be positive in an additive way in the case of the more developed regions. When the model is applied to the Southern region, networking strategies become insignificant, while local innovative intensity remains positive and significant. Other studies have shown the existence of a link between regional factors and co-operative agreements, and specifically identify a positive relation between high local spillovers and co-operative agreements. The relevance of a general regional and sectoral effect was visible, but the model does not allow insights to be gained into the "relative" importance of regional and sectoral factors.

An interesting result of the model is that it is useful to explain the innovation performance of developed regions, such as the Northern West in Italy, and, as a consequence, to identify the factors which are lacking in the lagging areas. Another complementary result is that linkages and networking

are not always positive or are not sufficient to explain good performance: the propensity to innovate depends on the local availability of knowledge resources, on the characteristics of organisational agreements, and on the policies devoted to supporting the process of collective knowledge creation.

The relationship between innovation and firm organisation (*i.e.* firm strategies of external growth) differ among regions. In the North West, external integration through co-operation (or co-ordination) strategies is the organisational form most conductive to innovation success; in the Third Italy and the South, combined strategies, *i.e.* strategies incorporating both co-operation and ownership integration, are the most relevant to innovation performance.

Organisational forms have been regrouped into groups, following the taxonomy suggested by Langlois and Robertson (1995). The various types of "external growth" strategies were then compared with the isolated firm solution. Nevertheless, it was not possible to explain why different organisational types are more relevant to innovative propensity in different environments, since this would require a breakdown of innovation into more and less radical types and a finer description of the environment.

As far as "local" externalities are concerned, these were represented by "spillovers". Spillovers require a strong assumption of easy imitation and accessibility, motivation and capability to utilise information. A better variable would be "local clusters" which can both influence and reinforce the propensity of firms to co-operate by creating mutual expectations and furnishing a stock of knowledge for the participating firms. A fine-grained taxonomy of clusters would allow a better description of the firms' local environment and a more effective application of the system of innovation approach, by providing more qualitative connections among the variables.

Finally, a useful factor in discriminating among regions was public support to innovation. Indeed, it was observed that innovative firms operating in the North West and the North-East-Centre regions use different public support instruments. Moreover, over the study period, public support to innovation did not play a significant role in the determination of firms' propensity to innovate in the Southern regions.

Annex

"Schumpeterian" hypothesis

In our model, the natural logarithm of total number of employees (lnEMP) is used to measure firm size. Its quadratic term (lnEMP2) is also included in order to test the presence for non-linearity in the relationship between innovation and size.

Generally, a concentration index (*e.g.* the Herfindhal index) is used to proxy market structure. This is an industry-level variable. We claim that there is strong heterogeneity within each industry in terms of the type of competition. Thus, we use the respondents' perception of the intensity of competition within the industry, *i.e.* the localisation of competitors (same province: SAMEPRO; European Union countries: EUROP), as a proxy for the competitive environment. These are categorical variables defined on an ordinal scale (from zero to four). Our hypothesis is that international competitiveness (and, in particular, competitiveness within Europe) is based on research and innovation rather than on price. Hence, it would be expected that competitive pressure from foreign firms is more likely to have a positive effect on innovation than is local competition by domestic firms.

Technological regimes

In our model, we refer to sectors as determinants of the propensity of firms to innovate mainly in the sense of strong/weak opportunities, taking into account the sectoral main sources of knowledge, as indicated in Pavitt's (1984) taxonomy. In our opinion, this meaning of opportunity is not absolute, since it changes in different geographical contexts in relation to different strategies of competence development by the actors involved (public research institutes, user demand, supplier competencies) and to the character of their interrelations.

Firm creative/absorptive capacity and quality of internal skills

The firm's propensity to innovate is strongly related to its investment in R&D. After capital investment, R&D expenditures represent the most relevant investment in innovation (ISRDS, 1997). Internal R&D is an internal source of knowledge, but is also fundamental for identifying, selecting, adopting and transforming external sources of knowledge. In other words, there is a complementary relationship between internal and external sources of knowledge (Cohen and Levinthal, 1989; Veugelers and Cassiman, 1998).

We consider institutionalised R&D activities (number of employees devoted to research, RDEMP) and skilled or highly educated (SKILL) human resources to be indicators of the firm's general capacity to innovate.

Organisational strategies

The firm may pursue different organisational strategies in order to innovate. These correspond to different external sources of knowledge and to different external growth strategies: *i)* acquisition of other firms; *ii)* membership of a group; *iii)* licensing; *iv)* technological and commercial collaborations; and *v)* subcontracting alliances.

The Mediocredito survey allows all these strategies to be analysed, using different dummy variables:

- *Acquisition:* 1 if the firm purchased another firm.
- *Group:* 1 if the firm is a member of a business group.
- *Licensing:* 1 if the firm acquired technology through licensing.
- *Technological collaboration:* 1 if the firm acquired technology through technological alliances with other firms either within the country and/or abroad.
- *Commercial collaboration:* 1 if the firm established a commercial collaboration with other firms either within the country and/or abroad.
- *Subcontracting alliances:* 1 if the firm established subcontracting alliances.

Following Langlois and Robertson (1995), acquisition and group membership were considered to be ownership integration strategies, while licensing, technological, commercial, and subcontracting alliances were classified as co-ordination integration strategies. Firms were thus broken down into four groups:

- ONLY-COORDINATION = Co-ordination integrated firms.
- ONLY OWNERSHIP = Ownership integrated firms.
- COORD&OWNERSHIP = Both co-ordination and ownership integrated firms.
- "Isolated firms" (the reference category).

"New growth theory" hypotheses: spillovers from public research and from the agglomeration of innovative firms

Competitiveness has a systemic dimension; it depends not only on the firm's own capacity and strategies but also on the interaction between firms and the capabilities available in the external environment. These can be observed either in terms of firms' relations with the principal education/research institutions and with other firms or, as we have done here, in terms of spillovers arising from agglomeration of innovative firms and research institutions. This type of externality helps to accelerate the processes of learning and technological diffusion.

Our measure of technological spillovers is given by the number of innovative firms in the total number of firms (SPILLOVERS) and by the number of public research institutions (university departments and public research institutes) situated in the province in which the firm operates (PUBLIC R&D).

Public support

As discussed above, public financial support may have a strong impact on the probability to introduce an innovation. In Italy, the main financial instruments by which the State supports innovative activities of firms are, first, the Law "Sabatini" 1329/65, which is one of the most important public aids to investment in industrial machinery for small and medium-sized firms. A second key public support is Law 317/91, which includes a set of instruments aimed at promoting development, competitiveness and innovation among small and medium-sized firms. A third public instrument is Law 46/82, aimed at financing applied research or technological innovations. Mediocredito has collected information on the use of these instruments: dummy variables indicate whether firms took advantage of Law "Sabatini" (LAW SABATINI), Law 317/91 (LAW317), or Law 46/82, either for applied research (LAWL4682A) or for technological innovations (LAW4682B).

Table 2. **North West: determinants of the probability to innovate**

Marginal effects and t values in parentheses

Variable	(1)	(2)	(3)	(4)
Size, competitive environment and technological trajectories				
LnEMP	+0.20*** (3.35)	+0.20*** (3.28)	+0.189*** (3.05)	+0.177*** (2.80)
LnEMP2	-0.016*** (-2.41)	-0.016*** (-2.38)	-0.014*** (-2.18)	-0.014*** (-2.08)
SKILL	+0.004* (1.62)	+0.004* (1.43)	+0.004* (1.51)	+0.004* (1.56)
R&DEMP	+0.001** (2.18)	+0.001** (2.06)	+0.001** (2.06)	+0.001 (1.32)
SAMEPRO	0.018 (1.56)	0.018 (1.51)	0.017 (1.50)	0.017 (1.45)
EUROPE	+0.051*** (4.17)	+0.046*** (3.69)	+0.045*** (3.59)	+0.045*** (3.48)
TRADITIONAL	-0.20*** (-2.95)	-0.19*** (-2.80)	-0.19*** (-2.76)	-0.184*** (-2.64)
SCALE INTENSIVE	-0.17** (-2.48)	-0.17** (-2.42)	-0.16** (-2.31)	-0.16** (-2.28)
SPECIALISE SUPPLIER	-0.097 (-1.38)	-0.100 (-1.42)	-0.100 (-1.34)	-0.102 (-1.42)
Organisational variables				
ONLY_COORDINATION		+0.136*** (4.39)	+0.143*** (4.57)	+0.135*** (4.28)
ONLY_OWNERSHIP		+0.024 (0.61)	+0.032 (0.79)	+0.038 (0.95)
COORD.&OWNERSHIP		+0.095** (2.39)	+0.103*** (2.56)	+0.090*** (2.23)
Spillovers and public R&D				
SPILLOVERS			+0.10** (2.70)	+0.010** (2.91)
PUBLIC R&D			-0.001* (-1.89)	-0.001* (-1.95)
Public support				
LAW “SABATINI”				+0.028 (0.89)
LAW 317				+0.070 (1.45)
LAW 4682A				+0.158* (1.71)
LAW 4682B				+0.156*** (2.79)
% of correct predictions	0.63	0.64	0.64	0.65
Log likelihood	-1 074	-1 063	-1 059	-1 050
McKelvey and Zavoina’s R2	0.423	0.429	0.672	0.69

Table 3. **Third Italy: determinants of the probability to innovate**

Marginal effects and t values in parentheses

Variable	(1)	(2)	(3)	(4)
Size, competitive environment and technological trajectories				
LnEMP	+0.375*** (5.76)	+0.379*** (5.80)	+0.383*** (5.80)	+0.364*** (5.44)
LnEMP2	-0.037*** (-4.99)	-0.037*** (-5.07)	-0.038*** (-5.14)	-0.037*** (-4.86)
R&DEMP	+0.005*** (3.98)	+0.005*** (3.96)	+0.005*** (4.13)	+0.004*** (3.39)
SAMEPRO	-0.013 (-1.23)	-0.015 (-1.38)	-0.019* (-1.70)	-0.021* (-1.89)
EUROPE	+0.057*** (4.81)	+0.056*** (4.67)	+0.051*** (4.28)	+0.051*** (4.21)
TRADITIONAL	-0.156** (-2.23)	-0.146** (-2.07)	-0.140** (-1.95)	-0.140** (-1.95)
SCALE-INTENSIVE	-0.147** (-2.09)	-0.137** (-1.92)	-0.143** (-1.98)	-0.149** (-2.07)
SPECIALISED-SUPPLIER	-0.021 (-0.28)	-0.022 (-0.31)	-0.038 (-0.51)	-0.048 (-0.64)
Organisational variables				
ONLY_COORDINATION		+0.050* (1.75)	+0.051* (1.77)	+0.051* (1.74)
ONLY_OWNERSHIP		-0.053 (-1.39)	-0.062 (-1.59)	-0.061 (-1.56)
COORD.&OWNERSHIP		+0.084** (2.21)	+0.084** (2.17)	+0.077** (2.00)
Spillovers and public R&D				
SPILLOVERS			+0.008*** (6.06)	+0.008*** (5.95)
PUBLIC R&D			+0.000 (0.05)	+0.000 (0.01)
Public support				
LAW “SABATINI”				+0.057** (1.92)
LAW 317				+0.009 (0.22)
LAW 4682A				+0.163* (1.85)
LAW 4682B				+0.049 (0.75)
% of correct predictions	0.64¨	0.64	0.64	0.64
Log likelihood	-1,237	-1,230	-1,211	-1,206
McKelvey and Zavoina’s R2	0.444	0.448	0.466	0.469

Table 4. **South: determinants of the probability to innovate**

Marginal effects and t values in parentheses

Variable	(1)	(2)	(3)	(4)
Size, competitive environment and technological trajectories				
LnEMP	+0.309** (2.30)	+0.323** (2.34)	+0.339*** (2.46)	+0.340*** (2.45)
LnEMP2	-0.026* (-1.72)	-0.028* (-1.89)	-0.031** (-2.05)	-0.031** (-2.02)
R&DEMP	+0.006** (2.04)	+0.005* (1.74)	+0.007** (2.19)	+0.006** (1.98)
SAMEPRO	+0.016 (0.58)	+0.000 (0.02)	+0.004 (0.13)	+0.007 (0.25)
EUROPE	+0.063** (1.97)	+0.061* (1.89)	+0.067** (2.11)	+0.062** (1.93)
TRADITIONAL	0.212* -(1.90)	-0.193* (-1.70)	-0.194* (-1.71)	-0.181 (-1.56)
SCALE-INTENSIVE	-0.188* (-1.67)	-0.167 (-1.46)	-0.175 (-1.53)	-0.159 (-1.36)
SPECIALISED-SUPPLIER	-0.345*** (-2.60)	-0.342*** (-2.55)	-0.355*** (-2.63)	-0.338*** (-2.46)
Organisational variables				
ONLY_COORDINATION		+0.150** (2.28)	+0.120* (1.80)	+0.116* (1.74)
ONLY_OWNERSHIP		-0.044 (-0.60)	-0.028 (-0.39)	-0.035 (-0.47)
COORD.&OWNERSHIP		+0.159* (1.88)	+0.133 (1.57)	+0.132 (1.55)
Spillovers and public R&D				
SPILLOVERS			+0.011*** (3.94)	+0.011*** (3.93)
PUBLIC R&D			-0.000 (-0.28)	-0.000 (-0.37)
Public support				
LAW “SABATINI”				-0.084 (-0.67)
LAW 317				0.029 (0.17)
LAW 4682B				0.110 (0.53)
% of correct predictions	0.70	0.72	0.74	0.74
Log likelihood	-232	-1 230	-217	-216
McKelvey and Zavoina’s R2	0.434	0.446	0.482	0.483

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Chapter 9

NETWORKING IMPACTS OF THE EU FRAMEWORK PROGRAMME

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Introduction

The EU Framework Programme is a networking programme *par excellence*. It is based on a model of collaborative R&D among European firms and among firms and public sector research institutes. Collaborative R&D is a means, not an end; its goal is to raise the technological level of European industries, thus enhancing their competitiveness. The Framework Programme is a networking programme in another sense, too, since one of its basic rules is that there is a requirement for collaboration among organisations in at least two EU Member States (or a Member State and an associate state). It is thus a programme aimed at promoting cross-country collaboration. It is the only major cross-country programme in Europe that finances joint research, and not just meetings.

The impacts of the Framework Programme have been studied in many EU Member States (Georghiou *et al.*, 1993; Larédo, 1995; Reger and Kuhlmann, 1995; Ohler *et al.*, 1997). These studies have paid attention, among other things, to the fact that the programme has promoted knowledge creation and networking. The types of network and the extent of cross-sector networking have not, however, been properly examined. The following analysis of different networking effects will draw on the survey findings of a recent Finnish impact study of the Fourth Framework Programme (Luukkonen and Hälikkä, 2000).[1]

The model for research consortia in the Framework Programmes, first introduced in ESPRIT, was based on collaboration between firms, research centres and universities and, in the beginning, the participating firms were major competitors (see, for example, Peterson, 1991). The research to be undertaken was pre-competitive, generic research that had applications across many economic sectors (Peterson and Sharp, 1998, p. 6). The model was originally taken from Japan. Over time, there have been changes in emphasis and actual programme practice. This chapter attempts to gauge the extent of different networking types, though it cannot measure potential change over time.

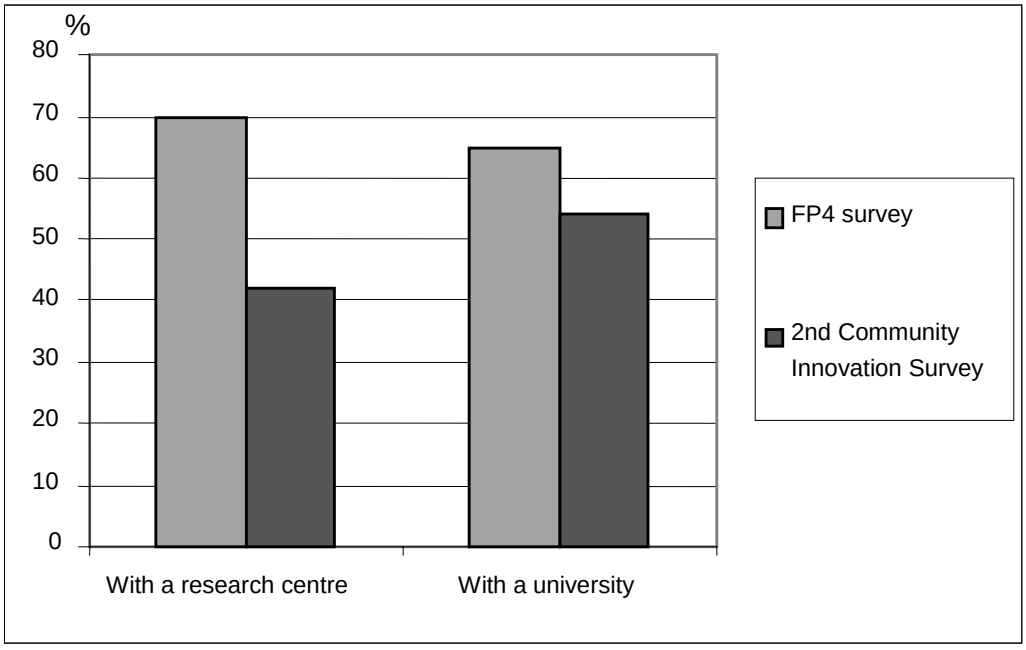
* The author is grateful to Sasu Hälikkä and Tanja Tanayama for their help in handling the empirical material, and to Jesper L. Christensen and Phoebe A. Isard for their useful comments on this chapter.

Cross-sector collaboration patterns

University-company or public sector research institute-company relationships are important because they offer an important avenue for interaction among knowledge-exploiting (companies) and knowledge-producing (universities and research centres) organisations around research agendas of common interest. It is not simply a question of diffusing research findings to practice or of a linear process of information relay, but rather one of reframing or redefining research agendas.

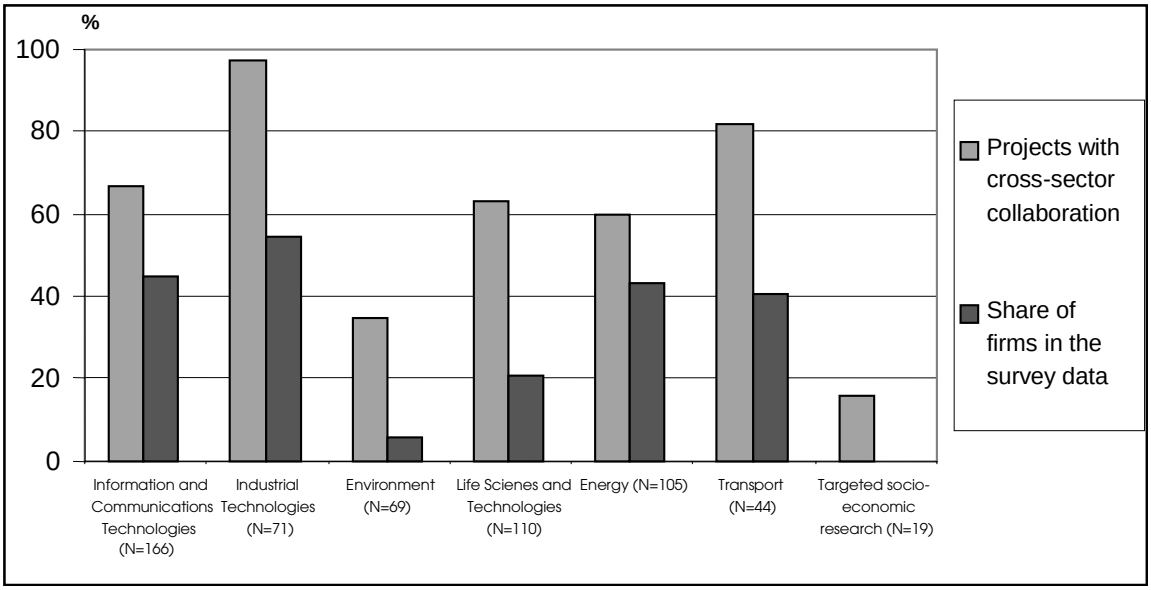
Peterson and Sharp (1998) claim that the Framework Programme has fostered few university-company or public sector research institute-company relationships. They base their claim of few cross-sector links on indirect and insufficient evidence, although it is fair to say that this matter has not really been examined (European Commission, 1997). Our recent Finnish findings, however, show that in the Fourth Framework Programme, 64% of the projects with Finnish participants involved company-university, or company-research centre, collaboration. When viewed from the perspective of companies, over 80 of this sector's participations in projects entailed partners from either a university or a research centre: 70% of the companies participating in an EU project collaborated with a university and 75% with a research centre. These figures are much higher than those obtained in the Second Community Innovation Survey for Finland (Figure 1) (see Eurostat, for example, through the New Cronos database). There is reason to believe that in their answers to the Community Innovation Survey, Finnish firms defined innovations as synonymous with R&D; therefore these figures can be regarded as comparable.[2] If this assumption holds true, we could conclude that EU framework projects effectively promote cross-sector collaboration.

Figure 1. **The extent to which companies collaborated with a research centre or a university in the Fourth Framework Programme and according to the Second Community Innovation Survey**



Cross-sector collaboration varied by programme line (Figure 2). In industrial technologies, nearly 100% of the projects had cross-sector collaboration, while in environment programmes, the proportion was only 35%. The prevalence of cross-sector collaboration was, however, to some extent, a function of the participation of companies in each programme line, if the share of firms in the survey data is taken as a rough indicator of firm participation in each programme line (Figure 2).

Figure 2. **Collaboration between companies and research centres or universities by programme line**



The Framework Programmes have particularly attracted university or research centre participants who had previous experience of collaborating with other firms and who were more prone to do so in this context. Most of the research centres, universities and non-profit organisations had collaborated with firms prior to the EU project, with research centres having the largest share of past collaboration agreements (Table 1). There were several reasons why such organisations sought collaboration with firms in EU projects. For universities, the most often cited reason for collaboration was that the companies came with the project (which shows that there was no particular motivation within the universities to collaborate with firms). All three groups of respondents wanted to learn from companies about progress in the field and to participate in the commercialisation of products – although in most cases the respondent non-firm organisation did not, in fact, benefit from the commercialisation of the results.

Table 1. **Collaboration with companies before the EU project**

Percentages

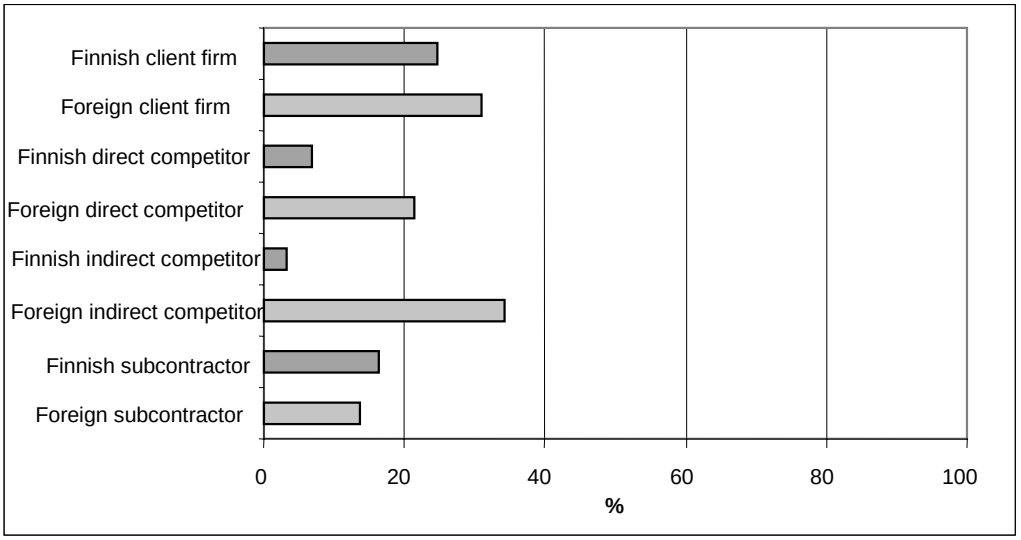
	Research institutes	Universities	Non-profit organisations
In Finland	81	71	65
In other European countries	50	39	27
Outside Europe	18	22	10
	N=223	N=200	N=77

Inter-firm collaboration

Frequency of consortia types by size of firm and industry

A general pattern of inter-firm collaboration was that companies very rarely collaborated with their direct or indirect domestic competitors (Figure 3) although most companies engaged in inter-company collaboration (83%) in the EU project. They did, however, collaborate with their foreign competitors to some extent. Overall, Finnish companies collaborated with foreign firms more than with domestic firms (64% *vs.* 40%).[3]

Figure 3. **Collaboration between companies**



It is likely that even in the case of foreign competitors, the companies had different market segments or catered to different market niches. The virtual absence of collaboration with domestic competitors highlights the fact that in truly competitive situations, even pre-competitive collaborative R&D projects are difficult to manage for reasons of confidentiality. By contrast, R&D collaboration with clients, whether Finnish or foreign, was more frequent. Among subcontractors, Finnish partners were more common than foreign partners.

The presence or absence of competitors was decisive for the breakdown of company collaboration relationships by vertical *vs.* horizontal dimensions used in this chapter. Horizontal collaboration was defined as agreements with direct or indirect competitors but with neither clients nor subcontractors; vertical collaboration were defined as agreements involving clients and/or subcontractors but not competitors. These are the traditional inter-firm networks described in te research literature (Arnold *et al.*, 1992; Dodgson, 1994). The Finnish study also defined mixed collaboration as agreements involving at least one competitor and a subcontractor or a client. The last category, “other”, comprises collaboration with non-company participants (or, if other company participants are involved, they are not in any of the above relationships with the respondent firm). Research centres or universities participated alike in the different types of company consortia.[4]

Figure 4. **Vertical *vs.* horizontal collaboration relationships**

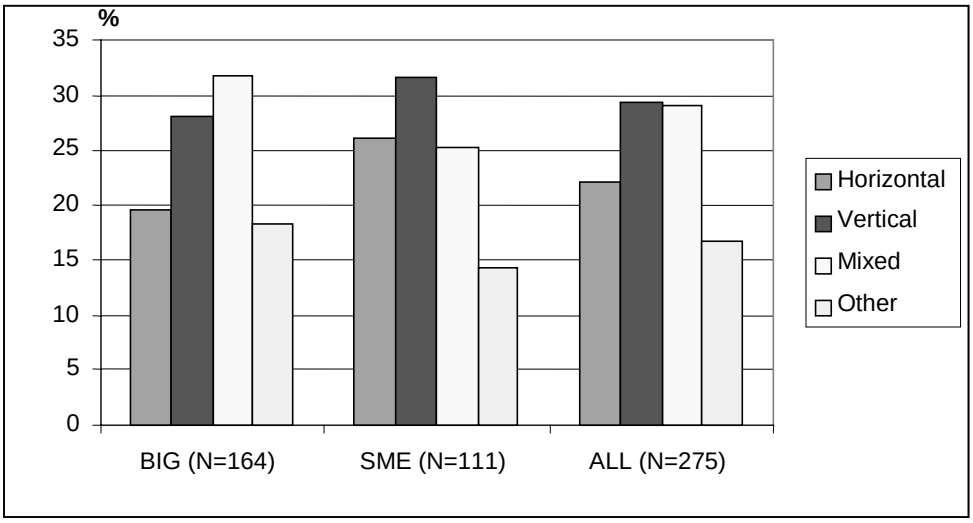
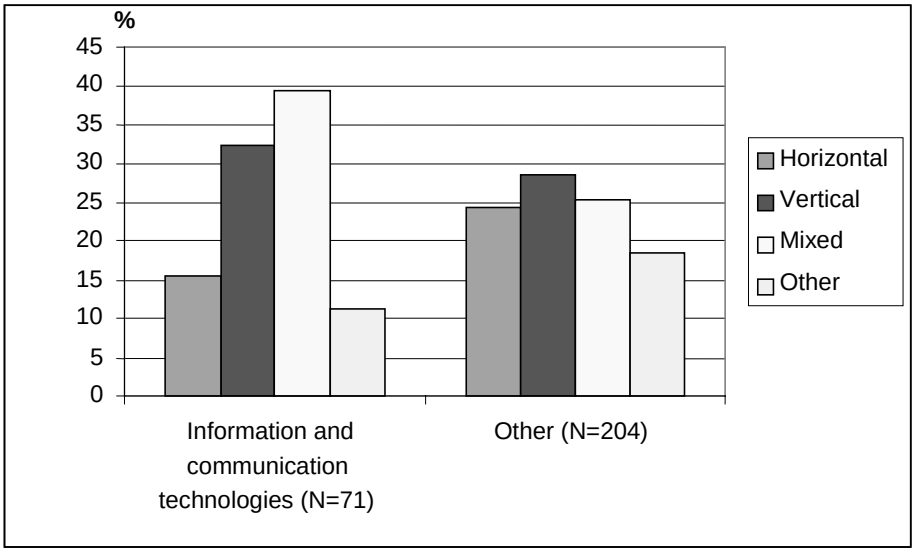


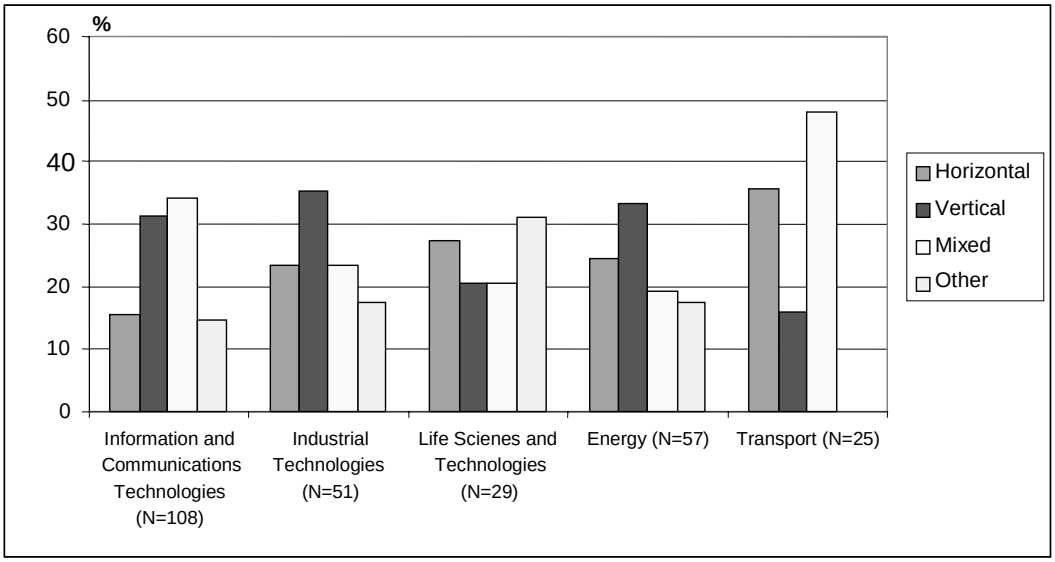
Figure 4 illustrates the frequency of the different types of company network, calculated on the basis of participations. Overall, vertical or mixed networks were more frequent than horizontal ones. There were some differences between SMEs and large companies, although the differences were not statistically significant.[5] SMEs had a somewhat larger proportion of both purely vertical and horizontal networks than did large companies, while the latter had more networks of the mixed kind. Mixed networks were most complex in their participant structure; it is interesting to note that for large companies, mixed networks represented the most common consortia type in the Fourth Framework Programme. However, the differences were not large.

Figure 5. **Company network types, by industry**



Some differences became apparent in the frequencies of network types by industry when the information and communications-related industries, on the one hand, and the rest of the industries, on the other, are grouped together (Figure 5).[6] In the most high-technology industry group, information and communications technologies (ICT), mixed networks were the most common network type. For ICT firms, vertical networks were also quite common, while the other network types were little used. Overall, vertical networks were most frequent for the remaining industries, although the frequencies of different network types were fairly evenly distributed. The remaining industries are grouped together in Figure 5 as when they were considered separately, they did not show clear patterns of collaboration.

Figure 6. **Company network types, by programme line**



Contrary to expectations, horizontal networks were not related to standardisation projects. A minority of industrial partners wishing to promote standardisation at the European level collaborated in horizontal networks while nearly half (43%) participated in mixed networks. Mixed and vertical networking was the dominant pattern, particularly in the ICT programmes (Figure 6).[7] In other programme lines, the proportion of each network type differed. When only telecommunication-related participations were considered, mixed and vertical networks dominated (Tables 2 and 3). These results indicate that, in an area of rapid technological change, for example telecommunications, collaboration in mixed or vertical networks was especially pertinent.

Table 2. **Telecommunication-related participations, by type of network**

Percentages

	Telecommunication-related participations
Horizontal	17
Vertical	31
Mixed	36
Other	13
Missing	3
	100
	N=121

Note: Significant at the 10% level of significance (p=0.07).

Table 3. **Company participations, by project focus**

Percentages

	Telecommunication-related participations	Other participations		
Horizontal	34	66	100	N=61
Vertical	46	54	100	N=81
Mixed	54	46	100	N=80
Other	35	65	100	N=46
Missing	57	43	100	N=268

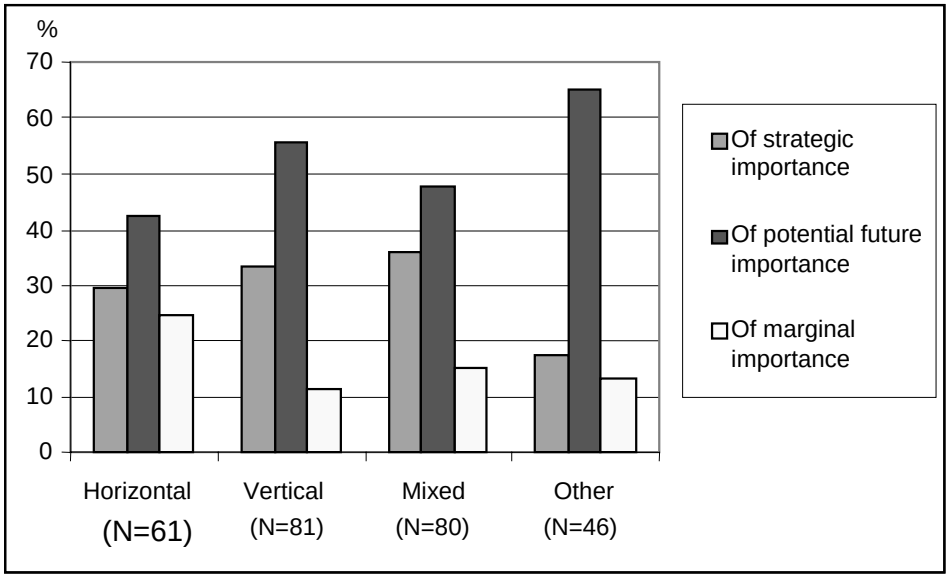
Note: Significant at the 10% level of significance (p=0.07).

It appears that the horizontal model is only rarely the most relevant model of collaboration for industry in the EU projects. Potential problems related to working with competitors, such as fear of knowledge leakages and the division of intellectual property rights, are important, particularly in EU projects. In such projects, the model rules require that the consortium participants share the findings. However, these are not the only reasons for the lower frequency of horizontal consortia. Interviews with a sample of firms indicated that it is possible to collaborate with competitors in projects that are far removed from the market phase. The low frequency of the horizontal networks highlights the fact that an increasing share of RTD activities is becoming more complex and requires knowledge and skills obtainable only in collaboration with partners that are in different positions in the value chain and the RTD process. This applies especially to rapidly developing fields, such as the R&D-intensive field of telecommunications. The above results also highlight the fact that the traditional network types, horizontal and vertical, are no longer sufficient to describe collaboration patterns among companies: the relationships have become more complex.

Strategic importance of project and inter-firm collaboration

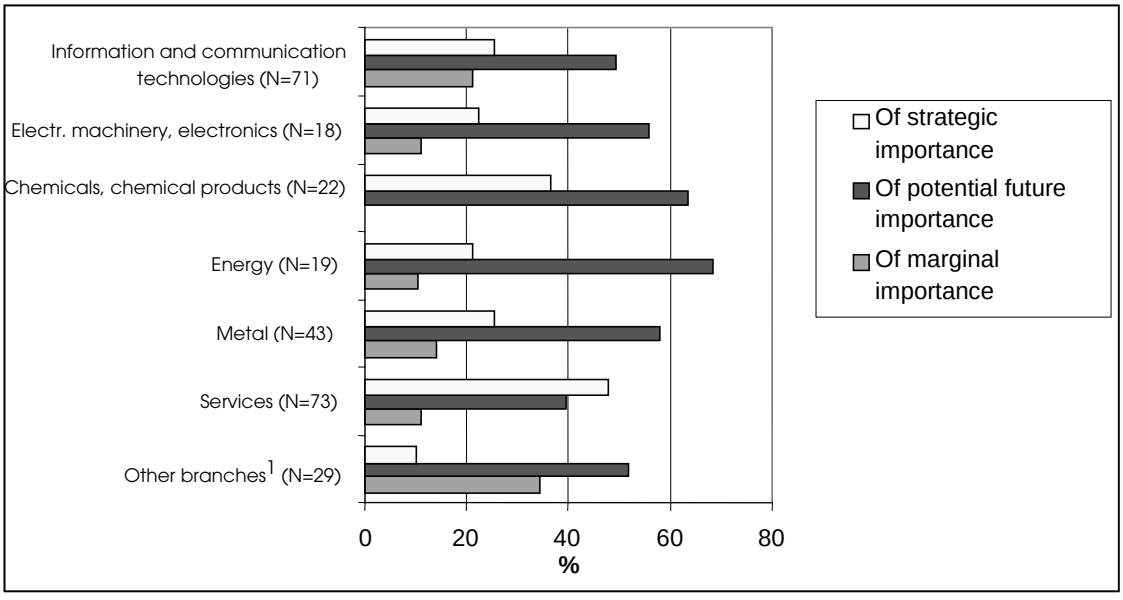
Mixed and vertical consortia had the largest percentages of projects of strategic importance (Figure 7).[8] The way in which strategic importance was defined was not explained, thus all respondents gave it their own meaning. Previous studies have, however, highlighted that strategic importance is related to the perspectives of the present-day understanding of the preferences of a company and does not entail new and potential future directions that a company might take (Luukkonen, 1999). Thus it is not surprising that consortia entitled “other” were least often of strategic importance. Projects with such a consortium structure were presumably longer-term projects with less immediate commercial value and, consequently, had the largest percentage of projects of potential future importance. Horizontal consortia, which had direct or indirect competitors as partners, had the largest number of projects of marginal importance and the smallest number of cases of potential future importance. This may be an indication that collaboration with competitors took place in less strategic projects and entailed alliances formed for shorter-term goals.

Figure 7. **Strategic importance of project, by type of company network**



When the strategic value was examined by industry (Figure 8),[9] strategically important projects were the largest category only in the service sector. SMEs represent a large proportion (71%) of the firms in this sector, and Framework Programme projects were more often of strategic importance for the SMEs than for larger companies. This is understandable when one considers that SMEs have fewer resources for R&D in general; the R&D that they do carry out tends to be more directly related to their short-term commercial and strategic interests.

Figure 8. **Strategic value by industry**



1. Forest and food industries, construction, textiles, clothing and footwear.

In the case of industries outside the service sector, possible future importance was by far the largest category in all sectors. In contrast to additionality, there was no clear pattern in the relationship between R&D intensity and the strategic value of EU projects. Overall, the fact that EU projects were of potential future importance indicated that, in many cases, the research funded was still somewhat removed from the market phase and that the commercial value of the projects was in future applications rather than in immediate economic gain.

Additionality

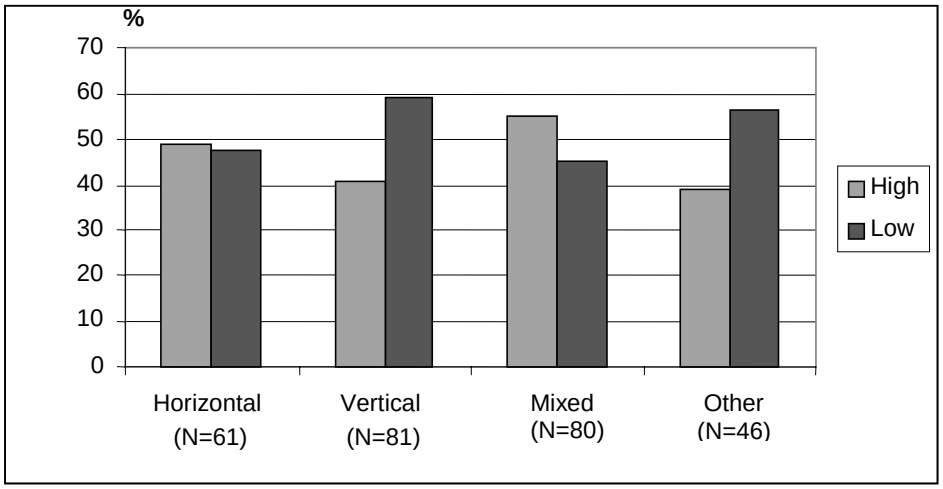
Additionality is an important issue in public support of R&D activities in companies. Additionality aims to capture the incentive effect of public support. It is used in the evaluation of Framework Programme support, although it is not formally used as a criterion in the granting of funds. An important underlying issue is the fear that public support would substitute for indigenous R&D investments made by companies themselves, which would, therefore, make the support superfluous.

The concern with additionality is based on a neo-classical economic view of market failure and the presumption that, if left alone, companies will under-invest in R&D because its results cannot be sufficiently appropriated by the company (Nelson, 1959; Arrow, 1962; Dasgupta and David, 1994). Additionality is expected to gauge the difference between the presumed under-investment by firms and the actual joint investment by firms and public agencies in RTD prompted by public programmes.

In the Finnish study, additionality was measured in the way it is conventionally measured in these impact studies; that is, by asking participants to assess the degree to which they would have realised the project in the absence of EU funding. High additionality means that the project would not have been carried out without EU funding, while low additionality in most cases included answers saying that the project would have been realised in a different form, either on a smaller scale, with a longer time schedule or with different objectives. Very few respondents said that it would have been realised in the same way or on the same scale.

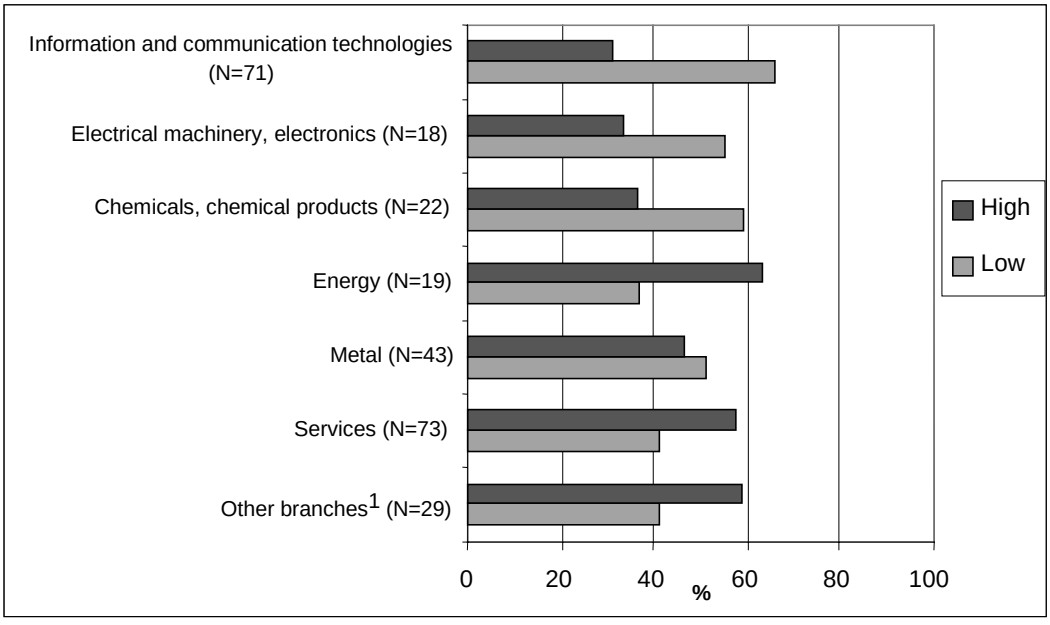
Figure 9 shows that, using the above mentioned method, additionality was highest in mixed networks and lowest in vertical consortia and networks that either had no other firms or only firms that were neither competitors nor in any specific relation to each other, although overall, the differences were not statistically significant ($p=0.22$). These firms would, in a majority of the cases, have carried out the research in some form, irrespective of EU funding. By contrast, projects that demanded complex network structures, *i.e.* mixed consortia, were probably too complicated to organise without the EU collaboration framework and funding. It should be noted that, in the case of EU framework programmes it is not only – or often not so much – a question of funding as such, but of a ready-made legal collaboration frame, the existence of which facilitates the creation of cross-country and cross-institutional projects (Luukkonen and Niskanen, 1998). The benefit of a legal collaboration framework may be the greater, the more complicated the network structure.

Figure 9. **Additionality, by company network type**



In terms of additionality by industry, by and large, the lower the R&D intensity of the industry, the higher the additionality (Figure 10).[10] For ICTs, the majority of projects had low additionality, while for industries with lower R&D intensities, the majority of projects had high additionality. This finding shows that the incentive effect of EU Framework Programmes was highest with companies that did not conduct a great deal of R&D by themselves. In high-technology industries, the majority of the projects would have been carried out somehow – although differently – in the absence of EU support, either on a smaller scale, with slower time schedules or with lower budgets. Very few projects were rated as having no additionality at all; therefore, we should be cautious not to read too much into the above findings.

Figure 10. **Additionality, by industry**



1. Forest and food industries, construction, textiles, clothing and footwear.

As noted above, this interpretation of additionality is based on a neo-classical economic view of market failure, focusing on the influence of public funding as a catalyst of new R&D investment. Georghiou (1994) calls this "input additionality". He draws attention to behavioural additionality, which is based on evolutionary perspectives of technological change. The evolutionary perspective highlights the importance of knowledge flows and interactions within the innovation system (see, for example, Metcalfe, 1995). Collaboration among different types of organisation is important because it expands the knowledge frontiers of current technological know-how and enhances the knowledge base of the companies involved in collaboration. Changes in the ways in which companies carry out R&D, for example, their collaborative behaviour, are important for furthering technological progress.

Additionality vs. strategic value

Additionality was juxtaposed with the strategic value of the project, and interpreted within a general framework of evolutionary perspectives on technological change. As mentioned above, the dimension of low additionality could be interpreted to represent behavioural additionality, a term coined by Georghiou (1994). This class is based on survey questions which enquired about alternatives of doing the research project faster, on larger scale or with different objectives; in sum, differently. Doing research differently is closely related to doing research in a collaborative consortium, which offers new opportunities for knowledge flows and expertise. If we interpret "low additionality" as "behavioural additionality", we come up with the following (Table 5).

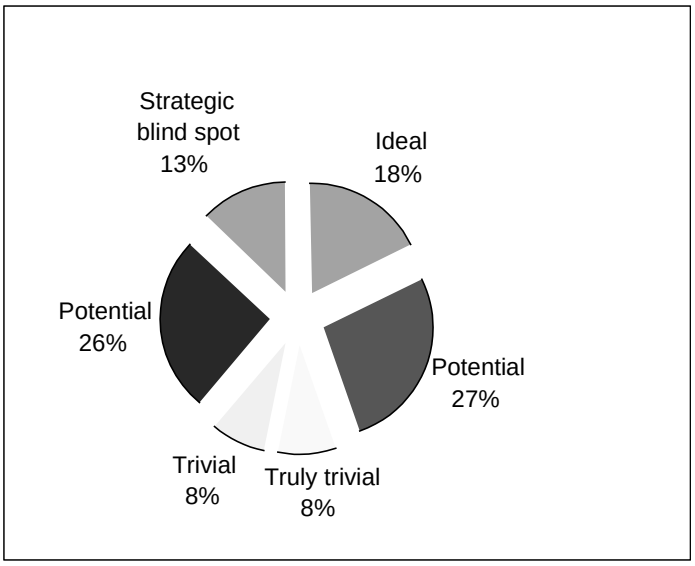
Table 5. **Additionality reinterpreted**

Strategic value	Additionality		
	Input	Behavioural	No additionality
Great	Strategic blind spot	Ideal	Substitution
Potential	Potential	Potential	Marginal
Marginal	Trivial	Truly trivial	Truly marginal

Input additionality in Table 5 refers to Georghiou's classification of additionality (1994) and means the extent to which a subsidy is reflected in increased R&D expenditure by a firm. This concept draws on the-market failure approach, and Table 4 is in fact based on a mixture of the above-mentioned neo-classical and evolutionary approaches. Low additionality in Table 5 is divided into two classes, behavioural additionality (doing the research differently) and no additionality. These two classes have, however, been merged together in Figure 11, since "no additionality" was cited in only 3% of cases.

The rationale for the terms coined to described the categories is the following. Where companies do not finance projects of great strategic importance and need public funding to do so, such project represent "strategic blind spots" for the company. By contrast, promoting research of great strategic importance which involves collaboration can be considered as an "ideal case", since the evolutionary perspectives have highlighted the importance of collaboration among different types of organisation. There are two "potential" cases. However, the one which has behavioural additionality would be more valuable since it involves doing the project differently and benefiting from collaboration with the partners. Funding research of marginal interest to the company, by contrast, represents a trivial and less successful case (from the funder's perspective).

Figure 11. **Additionality reinterpreted**



When the frequencies of the different categories have been calculated (Figure 11), we can conclude that the "potential" cases represented by far the largest groups, as was shown in the previous section. The two are equally large when compared with each other. The Framework Programme particularly promotes longer-term research, the value of which is not yet known. The ideal cases are a much smaller group, but larger than those of strategic blind spot.

When this scheme was applied to large companies and SMEs, the latter had larger classes of "strategic blind spots" (19% for SMEs *vs.* 9% for large companies). This highlights the fact that, compared with large companies, SMEs have fewer resources of their own to carry out strategically important research, and public support can play a greater role in this respect (Luukkonen, 2001).

With regard to different network types, the above analysis revealed a few differences (Luukkonen, 2001). For example, horizontal networks had more "trivial" and "truly trivial" projects than other types. This probably reflected difficulties in collaborating with competitors and the fact that companies could only choose less important topics for collaboration with their competitors. The "other" network type had more "potential" cases in the behavioural sense, suggesting that the projects were probably longer-term and more knowledge-oriented than the projects of other networks types. The "other" class comprised projects in which a company either only had research organisations as partners or, if it had other companies, these had no special relationship with the responding company. Vertical and mixed networks were fairly similar to each other except for the fact that vertical networks had many more cases of "potential" projects in the behavioural sense.

The different network types had slightly different profiles of additionality. This probably reflects their different nature in terms of orientation, types of project, and problems with intellectual property rights. However, the differences were not large, indicating that the Framework Programme mainly promotes fairly long-term, knowledge-promoting networking. The proportions of "trivial" and "truly trivial" projects (Figure 11) were small, and we can, therefore, regard this collaborative programme as being relatively successful in promoting research consortia of significance, albeit in the long-term and, at the time of assessment, with a degree of uncertainty as to the outcomes.

Conclusions

The EU Framework Programme has been reasonably successful in promoting different types of networking among European companies and research organisations. This chapter has drawn attention to cross-sectoral and inter-firm collaboration. With regard to inter-firm collaboration, the Framework Programme has promoted particularly complex networking structures, called mixed networks in this study. It is clear that the primary form of collaboration – cross-border collaboration – is growing. Bibliometric data from Finland indicates a strong increase in Finnish scientists collaborating with colleagues from other EU countries (Persson *et al.*, 2000).

Any attempt to assess the outcomes and benefits of collaborative research programmes needs to consider the substantive results of collaborative consortia, and not simply look at types of networking. Another study of the Framework Programme by the author (Luukkonen, 2002) showed that, in addition to promotion of learning and knowledge, this type of collaboration can also promote commercial utilisation; in one-third of the projects of the companies surveyed, commercial utilisation took place during the project or soon after the project ended. Surprisingly, the majority of the projects were so-called pre-competitive; that is, research which is a few years removed from the market phase. It was found that there was no contradiction in a project being pre-competitive while advancing commercial objectives and helping to create commercial outcomes. Companies often carry out parallel commercial projects and these can draw on the pre-competitive EU project. EU collaboration is, in fact, more effective in its outcomes if the company has other, parallel, projects going on in house. These findings highlight the fact that the Framework Programme has many uses and enables the pursuit of a number of knowledge-related and commercial objectives.

NOTES

1. The number of respondents in the survey totalled 664 (response rate 70%). Of these, 244 were firms: 146 large and 98 SMEs with response rates of 72% and 68%, respectively (Luukkonen and Hälikkä, 2000). The original population covered all Finnish firms that participated in the so-called shared-cost projects of the Fourth Framework Programme.

2. For instance, in Finland, the proportion of innovative firms was found to be much smaller than in other EU countries; suggesting that Finnish firms have overlapping definitions for innovations and R&D activities. According to Eurostat (the New Cronos database), among Finnish companies with over 20 employees, 36% of manufacturing firms reported having made innovations, while the corresponding figure for the EU, on average, was 53%; in services, the figures were 24% and 42%, respectively.

3. Foreign partners were more usual in practically all partner categories for respondents from all organisation types since, overall, the consortia had more foreign than Finnish participants.

4. The following analysis into horizontal *vs.* vertical and other networking types will use the classification of participations defined by the Finnish participating companies. It should be noted, however, that if sufficient information was available, projects might be classified as belonging to different network types. We attempted such a classification of projects using the information obtained from the Finnish participating companies. There were several projects in which the participating companies had classified the project differently clearly because of their different points of view. Projects that were classified, for example, as mixed by one company and as vertical by another were subsequently classified as mixed. The end result was that there was a larger percentage of mixed consortia than when the classification was based on participations alone. A “true” classification of the consortia would have required information from the foreign participating companies. This we did not have. The trial classification based on information from the Finnish companies was, nevertheless, indicative of the fact that the proportion of mixed consortia is probably larger than indicated by our analysis. In particular, mixed consortia were the most frequent network type in ICT programme projects, thus strengthening our argument that this is the dominant collaboration pattern in the most rapidly developing fields.

5. According to the chi-square test, the p-value was 0.05362. Although not specifically mentioned, the chi-square test was also used later in the analysis.

6. In the tables showing data by industry, service firms doing business in ICT areas have been merged together with this sector, making this industry close to a cluster classification. The reason for this was that these firms had more in common with ICT firms than with other service firms in terms of their consortia types. Firms with multiple product areas were merged within the sector to which the division in question was related. The result of a chi-square test was 0.061, a 10% level of significance.

7. The patterns of collaboration by programme line were different at the 10% level of significance (p=0.095).

8. Significant at the 10% level (p=0.0813).

9. Significant at the 1% level (p=0.0025).

10. Significant at the 5% level (p=0.02).

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Chapter 10

KNOWLEDGE SPILLOVERS THROUGH R&D NETWORKING

by

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Introduction

In spite of the abundant research on the relationship between spillovers and the optimal outcome of co-operation in R&D *vs.* non-co-operative set-ups, and the increasing occurrence of co-operative agreements, the fact that firms are able to manage and increase spillovers through R&D co-operation has yet to be fully addressed using an empirical approach. In this chapter, the authors will show that the policy rationale for promoting R&D co-operation is dependent on the theoretical perspective adopted and on the magnitude and nature of spillovers – an issue that remains open to empirical scrutiny.

Public policies based on an analysis of existing national value-added linkages may be more inward- and backward-looking than those which take into consideration the (inter)national collaborative patterns that will partly shape the future economic and technological space.

Previous attempts to provide proxy measurements for spillovers have tended to focus on supplier-buyer linkages or on patent data. For our study, we computed knowledge spillovers using linkages between European firms established through "pre-competitive" collaborative R&D. The European Framework Programmes (FWPs) are without doubt the most basic and popular mechanism through which publicly funded collaborative research has been performed in Europe over the last two decades.

We found that the pattern of intra- and intersectoral spillovers is country specific (although more so for user sectors than for supplier sectors), and cannot simply be inserted into the value-added chain. The degree of intrasectoral spillovers is relatively high and, surprisingly, significantly higher in large countries than in smaller countries. This result calls for a more thorough examination as it could indicate collusive behaviour. However, given the "pre-competitive" nature of the FWP projects and the theoretical advantages to be gained from co-operation at the R&D stage, it should not automatically be assumed that this finding points to collusion, although there are some indications that the FWPs may have reinforced the oligopolistic tendency of the European IT market.

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We argue that the mapping of R&D collaboration allows knowledge spillovers to be measured in a fairly straightforward way that can complement or qualify some of the conclusions resulting from other methodologies.

How embodied are knowledge spillovers?

Technological or R&D spillovers are most often strictly defined as externalities (Grossman and Helpman, 1992) although more recent definitions also comprise the *voluntary* exchange of useful knowledge (Steurs, 1994; Llerena and Matt, 1999; Rycroft and Kash, 1999; and De Bondt, 1999).

In his review of research on R&D spillovers, Griliches (1992) concludes that, despite a considerable number of methodology and data constraints, such studies generally seem to confirm the presence and relative magnitude of R&D spillovers. Griliches makes a distinction between "embodied" and "disembodied" R&D spillovers.

Embodied spillovers

Spillovers are qualified as embodied when they relate to the purchase of equipment, goods and services. Embodied spillovers can also be defined as rent spillovers to the extent that improvements – resulting from one firm's efforts – in products sold to other firms are not fully absorbed by a concurrent price increase. Embodied spillovers are generally measured through input-output tables, supplemented by survey data or data on R&D expenditures, or by flows of international trade (Terleckyj, 1974; Coe and Helpman, 1995; OECD, 1999a).

Although the importance of supplier-buyer linkages for innovation is well established (Debresson *et al.*, 1997 ; Christensen *et al.*, 1999; OECD, 1999b), innovative networks are usually too complex to be reduced to value-added chains.

Since, as pointed out by DeBresson (1999), innovative networks often straddle nations and encompass foreign partners, the use of R&D collaboration data can broaden the framework of inter-firm networking by focusing on both national and international linkages, while I/O analysis is mainly confined to national or regional networking. DeBresson and Hu (1999) find that I/O-based methods are in general not very reliable for small, open economies and are limited to mapping innovative activities within the "old economic space".[1]

Public policy which is based on such national/regional analysis would tend to be more inward- and backward-looking than policy that takes into consideration the direction in which the international technological space is likely to evolve. An I/O-based policy may also run the risk of promoting inefficient and/or collusive lock-in situations. We argue that an I/O-based approach is perhaps appropriate to analyse incremental changes, which are certainly very important but will probably take place anyway, with or without government support.[2] However, breakthrough innovations resulting from new combinations of complementary technological knowledge are unlikely to be fully explained by existing value-added links.

The high degree of uncertainty relating to fundamental innovations and their significant welfare-increasing consequences appear – to a far greater extent than is the case for incremental innovations – to call for specific policy measures and support. Analysing (pre-competitive) R&D networking can be instrumental in this policy-making process and in assessing the impact of policies targeting network promotion.

Disembodied spillovers

Disembodied spillovers are described by Griliches (1992, p. S36) as " [...] ideas borrowed by research teams of industry i from the research results of industry j". It is not clear that this kind of borrowing is particularly related to input purchase flows; in Griliches' view, disembodied spillovers are more significant than embodied spillovers.

According to Griliches, the main difficulty in computing knowledge spillovers is obtaining an accurate definition of the technological proximity or closeness of firms, as an inverse relationship between spillovers and technological distance may be expected.

Scherer (1982) constructed a matrix of technology flows by linking data from a 1974 business survey on R&D expenditures to patent data while Jaffe (1986, 1989) proposes a method which characterises a firm's technological position based on patent data, thus allowing "technologically close" firms to be identified. In Jaffe's view, the magnitude of spillovers is a function of the technological distance between firms. Using the distribution of firms' patents over patent classes and defining the spillover pool as the weighted sum of all other firms' R&D, with the weights proportional to the technological proximity, he finds evidence of a positive effect of technologically close firms' R&D on the productivity of own R&D.

Verspagen (1997) points to the importance of intersectoral spillovers and argues that the magnitude of spillovers between firms is not necessarily related to their "technological similarity". In our view, technological proximity is a better proxy for the absorptive capacity of firms than for spillovers between firms, especially if there are substantial "voluntary" spillovers.

Katsoulacos and Ulph (1998) propose a model in which complementarity of knowledge is an important parameter in information sharing. If the research discoveries of partners are perfect complements, as is usually assumed, progress will be optimal. If partners' discoveries are perfect substitutes, there is total overlap and no useful information can be shared.

Rycroft and Kash (1999) argue that networks are highly effective mechanisms for incorporating tacit (*i.e.* non-codified) knowledge. Co-operation therefore seems to be a somewhat neglected channel for knowledge spillovers. This can probably be explained to a large extent by the fact that most scholars define spillovers as externalities and therefore do not consider "voluntary" spillovers.

We are well aware that innovative networks entail far more than R&D networking, since the former also relate to the commercial exploitation of the results of R&D activities, and innovation does not always imply R&D activities. Rycroft and Kash (1999) rightly warn against the danger of a policy overemphasis on R&D.

Throughout this chapter, the terms "co-operation" and "networking" are used interchangeably. It is clear that firms that have no other co-operative agreement besides their involvement in a single FWP project can questionably be regarded as network agents. Our focus here will be on those firms and sectors that actively and frequently co-operate and are assumed do so on the basis of a strategic appreciation of their partners' contribution to a relatively clearly defined collaboration.

Rationale for a public policy for promoting R&D co-operation

Llerena and Matt (1999) show that the rationale for a policy aimed at promoting inter-firm co-operation in R&D depends on the theoretical perspective adopted by policy makers. If a market or transaction cost stance is adopted, co-operation is often regarded as an (unstable) exception to competition.

The FWPs were set up as block exemptions – dictated by the specific nature of pre-competitive R&D – to the strict EU rules on competition. However, the European Commission also promotes the follow-up of participation in its FWP by near-market collaboration in EUREKA projects,[3] and thereby somewhat bends its own competition rules.

In the United States in the early 1980s, policies to promote R&D co-operation consisted, in addition to changes to intellectual property right rules, in a relaxation of antitrust regulation. Concerns about loss of international competitiveness *vis-à-vis* Japan prompted US policy makers to judge research partnerships no longer merely on their static collusive effects but also on their dynamic benefits (Hagedoorn *et al.*, 2000, pp. 580-581).

From a more evolutionary perspective, inter-firm agreements act as a powerful co-ordination mechanism for creating and diffusing knowledge throughout a vast, complex and rapidly evolving technological space. While, traditionally, public policy is concerned with correcting for market failures, the evolutionary perspective calls on policy makers to take into consideration evolutionary failures related to learning processes, lock-in and negative externalities (Llerena and Matt, 1999, pp. 188-194).

The extensive game-theory research that followed from d'Aspremont and Jacquemin (1988) highlighted the fact that co-operation at the R&D stage and competition at the subsequent production stage lead to a social welfare optimum. Given the nature of R&D activities (non-excludability, uncertainty and inappropriability), market resource allocation will not be socially optimal. Policy can resolve this market failure by promoting co-operation, subsidies and intellectual property rights. These findings were seen to support the EU FWPs and national policies aimed at promoting R&D collaboration. However, the theoretical support for such policies is not quite so straightforward.

Amir (2000) compares the models that followed the d'Aspremont-Jacquemin (AJ) publication to the Kamien-Muller-Zang (KMZ) model (Kamien *et al.*, 1992). Amir argues that the AJ models are in conflict with the stylised fact that industry R&D levels are decreasing in the spillover rate. The KMZ models confirm this stylised fact, leading Amir to conclude that the AJ model is not fully valid, especially for large spillovers, *i.e.* precisely those situations that justify policy support in the AJ model.

The strategic investment literature views R&D competition as more effective than collaboration where spillovers are small; where spillovers are large, the private and social welfare optima coincide and public subsidies will not elicit many additional R&D activities. In such a case, publicly subsidised R&D collaboration programmes are only appropriate if spillovers are asymmetric (*i.e.* if there is sufficient diversity between firms in terms of research capabilities).

If a distinction is made between "voluntary" and "involuntary" spillovers, the welfare results – and hence the policy conclusions – are less clear-cut (Llerena and Matt, 1999, pp. 182-186).

Cassiman and Veugelers (1998) point out that the fact that firms can manage spillovers within and through R&D co-operation, has yet to be fully addressed in an empirical way.

Cohen and Levinthal (1989), Nelson (1992) and Teece (1992) have argued that – contrary to the notion of knowledge as a public good – tacit knowledge does not spill over in an effortless way. However, co-operation may increase knowledge flows between partners and can allow partners to internalise spillovers. In most theoretical models, spillovers are exogenous to the decision as to whether or not to co-operate. Cassiman and Veugelers (1998) review some models that recognise that partners may voluntarily increase spillovers among themselves.

The model proposed by Katsoulacos and Ulph (1998), in which spillovers are endogenised, predicts that firms from different sectors will fully share information even if no co-operative agreement is concluded. Following Katsoulacos' (1993) finding that most R&D co-operation in the FWPs took place between firms in different sectors, they conclude that EU subsidies aimed at encouraging the sharing of information probably had low additionality. Contrary to Katsoulacos (1993), the spillovers that we computed show a high degree of intrasectoral co-operation.

Pérez-Castrillo and Sandonís (1996) show that EU cost subsidies may be counterproductive to knowledge sharing and argue that patent subsidies could be more effective. This is an extremely forceful argument since, combined with the point raised by Katsoulacos and Ulph (1998), it suggests that current EU RTD policy supports projects that would occur anyway and discourages projects that might induce significant disclosure of knowledge. In other words, the policy rationale is justified, but the policy focus and instrument are wrong.

Irrespective of the theoretical perspective endorsed, the magnitude and specificities of spillovers are crucial for the rationale of public policy aimed at promoting R&D collaboration, and this issue calls for further empirical study.

EU policy aimed at promoting R&D co-operation

The successive EU Framework Programmes covering "shared-cost" types of collaborative research have played a significant role in the development of European scientific and technological co-operation. EU involvement in R&D co-operation can be traced back to the Treaty of Rome – which established the European Atomic Energy Community – and the multi-annual research programmes carried out through the Joint Research Centre (JRC) or through funding to organisations in EU Member States (Caloghirou and Vonortas, 2000).

At the beginning of the 1980s, concerns were raised that European firms were falling behind their American and Japanese counterparts in terms of innovation and world market shares, especially in IT. Therefore, in 1984, the Community launched a first Programme (ESPRIT 1), aimed at strengthening the scientific and technological basis of the European IT industry. ESPRIT 1 served as the model for a more general "umbrella-type" programme, the First Framework Programme. The Framework covered various Programmes in many technological areas, aimed at promoting co-operative research and technological development (RTD). The objective was to link up the diverse and complementary technical capabilities of companies, universities and research laboratories in European countries in pursuit of common technological goals (European Commission, 1997; Peterson and Sharp, 1998; Mollina, 1996). The main RTD policy instrument of the Framework Programmes has been "shared-cost" contract research projects (the Commission provides 50% of the total costs of joint research for companies, and up to 100% of marginal and additional costs for universities and research institutes). Four Framework Programmes have now been completed (1984-87, 1984-91, 1990-94 and 1994-98), and the Fifth is currently running (1998-2002).

The basic rationale for co-operative R&D lies in issues related to competitiveness and market failure. However, political and economic changes have transformed the European scene: a number of countries have joined the EU – and others are likely to become members in the near future – and new countries have emerged. Although the basic policy rationales have not altered, they have merged with the cohesion and employment rationales for providing support to collaborative R&D. It has been argued that "there may be a trade-off between competitiveness and cohesion which may decrease the effectiveness of the Framework Programmes for RTD" (Caloghirou *et al.*, 2000).

The results of the FWPs have been mixed. On the one hand, the Programmes have yet to have any substantial impact on European competitiveness and trade performance, although this can be partially explained by the fact that collaborative research has been undertaken under the "pre-competitive" label. Too often, successful projects have not produced marketable results, either because "they have been isolated from market and social considerations despite their technical excellence, or because the means by which they were to be exploited were not specified or even thought about at the earliest stages of work" (PREST, 2000).[4] On the other hand, the FWPs have been instrumental in keeping Europe in the technological race.

However, the most important effect of the FWPs is that they have gradually become the driving force behind the formation of dynamic networks which go beyond formal collaboration since they bring together researchers from the best laboratories in European firms and give private firms the opportunity to benefit from a larger pool of resources than is available in a single nation. They have unquestionably fostered the emergence of closer linkages and the creation of a critical mass through networking. In addition, they provide stable financial support, reduce unnecessary competition among researchers and between researchers and industry, and provide access to complementary skills, means and tools (Vavakova, 1995; Lucchini, 1998). EU policy aimed at promoting networking has materialised solely through the funding of these research consortia. The success of this policy instrument (at least at that level) has prompted the EU to adopt additional measures in this direction: the establishment of multiple transnational networks for technology transfer and dissemination (CEC, 1994) has recently become a key policy tool. Moreover, EU funding of R&D collaboration among organisations throughout Europe remains the major policy instrument for the promotion of networking, with positive effects notably for SMEs (Caloghirou and Vonortas, 2000).

Data

The Laboratory of Industrial and Energy Economics (LIEE) at the National Technical University of Athens (NTUA) has developed an extensive new databank (STEP TO RJVs),[5] which builds upon a number of databases comprising detailed information on collaborative R&D in Europe. The present chapter draws upon the EU-RJV database, especially for information on European cross-national R&D collaboration established through the FWPs.[6] Two basic criteria were used to develop the database for this project. First, we selected those Programmes with a focus on industrial research and excluded those that simply provide support, disseminate information, etc., or represent other EU actions. The database includes 64 Programmes from the five FWPs, including large programmes such as ESPRIT, BRITE/EURAM, RACE, etc., but also some of the smaller programmes through which R&D co-operation is performed.[7] Second, we selected only R&D consortia that included at least one participant firm,[8] thus excluding, for example, co-operation between universities.

Implementing the above criteria resulted in a set of 9 335 research consortia, over a period of 16 years (September 1983 to December 1998). Some 20 499 organisations from 52 countries participated in 64 476 collaborative research projects. However, the real value-added of this database is the integration of this information with financial data on the participating firms. Drawing on

AMADEUS,[9] nearly 40% of the firms participating in the consortia were identified. Data on 2 722 European firms were retrieved, including sectoral information (primary activity in NACE 1 and CSO classification) for use in our analysis.

Estimating knowledge spillovers through R&D co-operation

The basic hypothesis used to compute intra- and intersectoral knowledge flows is that the number of co-operative links between firms serves as a proxy for the underlying knowledge flows. This hypothesis supports the view that "learning by networking" entails more than simply sharing information (*i.e.* codified knowledge). If such was the only concern then, from an efficiency perspective, the firm's position in a network is more important than the multiplicity of its contacts.

Hagedoorn and Duysters (2000) forcefully argue that, from a learning perspective, multiple contacts in inter-firm networks are more effective than the pursuit of non-redundant contacts, as dictated by the rules on maximising efficiency. From an efficient networking strategy point of view, firms would favour bridge ties (non-redundant links, overarching structural holes, to central network agents) to multiple, and possibly redundant, linkages. However, Hagedoorn and Duysters find evidence to show that, in a dynamic environment (in this case, the international computer industry), the absolute number of network links is more relevant than network status (Hagedoorn and Duysters, 2000, p. 23).

We constructed an asymmetric matrix. The asymmetry results from the hypothesis that in R&D projects there are greater knowledge flows from the partners to the prime contractor than in the other direction, while knowledge flows between "normal" partners are assumed to be balanced. The results of a survey on the impact of the Fourth FWP in Finland show that project co-ordinators were more likely than other participants to assess a project as "successful" (Luukkonen and Hälikkä, 2000, p. 52). Co-ordinators have a central position in the project which, amplified by greater research capacities, probably allows them to gather and absorb more knowledge from the other participants than the other way round. Moreover, the prime contractor is likely to have more contacts with its partners than the partners among themselves, and hence, to benefit from greater learning opportunities.

A final assumption concerns the issue of "intimacy". Compared to larger and more interspersed consortia, knowledge can be more easily exchanged in smaller consortia. We therefore assumed knowledge flows to be inversely related to the total number of participants in each project or agreement. The spillover measures computed are summarised in Box 1.

To limit the analysis to the most significant sectors, we computed a matrix for the 25 most active sectors in terms of participation. This results in matrices with 625 cell values. From these matrices, we computed another set of matrices in which we weighted the spillover values. First, following Cohen and Levinthal (1989), we considered that own-R&D activities enable firms to absorb R&D that spills over. We therefore constructed national sectoral R&D stocks[10] from the OECD ANBERD database and used the average over the period 1985-95 as a measure of the absorptive capacity of a given sector.

We then used national sectoral R&D stocks to construct international sectoral R&D pools. The bilateral measures of revealed comparative preference (RCP), defined in Dumont and Meeusen (2000) and used in OECD (1999b), were used as weights for constructing this international R&D pool The RCP gives an indication of the relative preference of organisations in one country to co-operate with partners from a given country. Thus, similar to Katsoulacos and Ulph (1998, p. 339), our spillovers are the product of a measure for the absorptive capacity with a measure of knowledge sharing.

Box 1. **Mathematical definition of spillovers**

Spillover from sector J (all countries) to sector I in country C:

$$\mathbf{SP_{cij} = \Sigma_n \Sigma_k \Sigma_{l \neq k} (D_{pc})/NP_n \; [(P_{nk} \in C \text{ AND } P_{nk} \in I \text{ AND } P_{nl} \in J) \rightarrow 1;0]}$$

C: country I, J: sector

n: project number

k,l = 1... NP_n

NP_n: Number of particpants in project n

D_{pc} = 2 if P_{nk} is prime contractor and 1 if not

$P_{nk:}$ k-th participant in project n

Spillover weighted by domestic sector I's R&D stock and all countries sector J's R&D stock:

$$\mathbf{SPRD_{cij} = SP_{cij} * (RD_{ci} * \Sigma_m (RCP_{cm} * RD_{mj}))}$$

RD_{ci}: R&D stock of sector i in country c

m = 1 … number of countries

RCP_{cm}: Revealed Comparative Preference (country c-country m)

On the basis of the matrices with weighted spillovers, we derived clusters using cut-off criteria similar to those used by Hauknes (1999) to derive I/O-based clusters for Norway. A first cut-off (link strength) restricts the linkages on the basis of the share of the spillover from a sector to a given sector in the total spillover accruing to that sector. The second cut-off (significant sectors) restricts the linkages on the basis of the share of the spillover from a sector to a given sector in the total spillover accruing to all sectors (Hauknes, 1999, pp. 63-64). The resulting clusters are shown in Figure 1.

Three degrees of linkages are obtained. The strongest linkages represent spillovers that are higher than 30% of the total spillover flowing to the given (encircled in Figure 1) sector and higher than 2% of the total spillover for the given country. These are depicted by thick arrows. The weaker linkages represent, respectively, fractions of 20%-1% (normal arrow) and 10%-0.5% (dashed line).

The technological domains (especially ICT) promoted by the EC through its FWPs obviously influence the pattern of intra- and intersectoral co-operation. The mapping of more near-market collaboration (*e.g.* EUREKA) or of private alliances could preclude this bias.[11]

However, the policy bias should not be overstated since the EC targets broad technological areas and is not concerned with specific sectoral patterns. Moreover, it is precisely the network pattern that follows from the EU policy that we wish to map.

Figure 1. **FWP clusters on the basis of weighted spillovers**

NACE two-digit classification

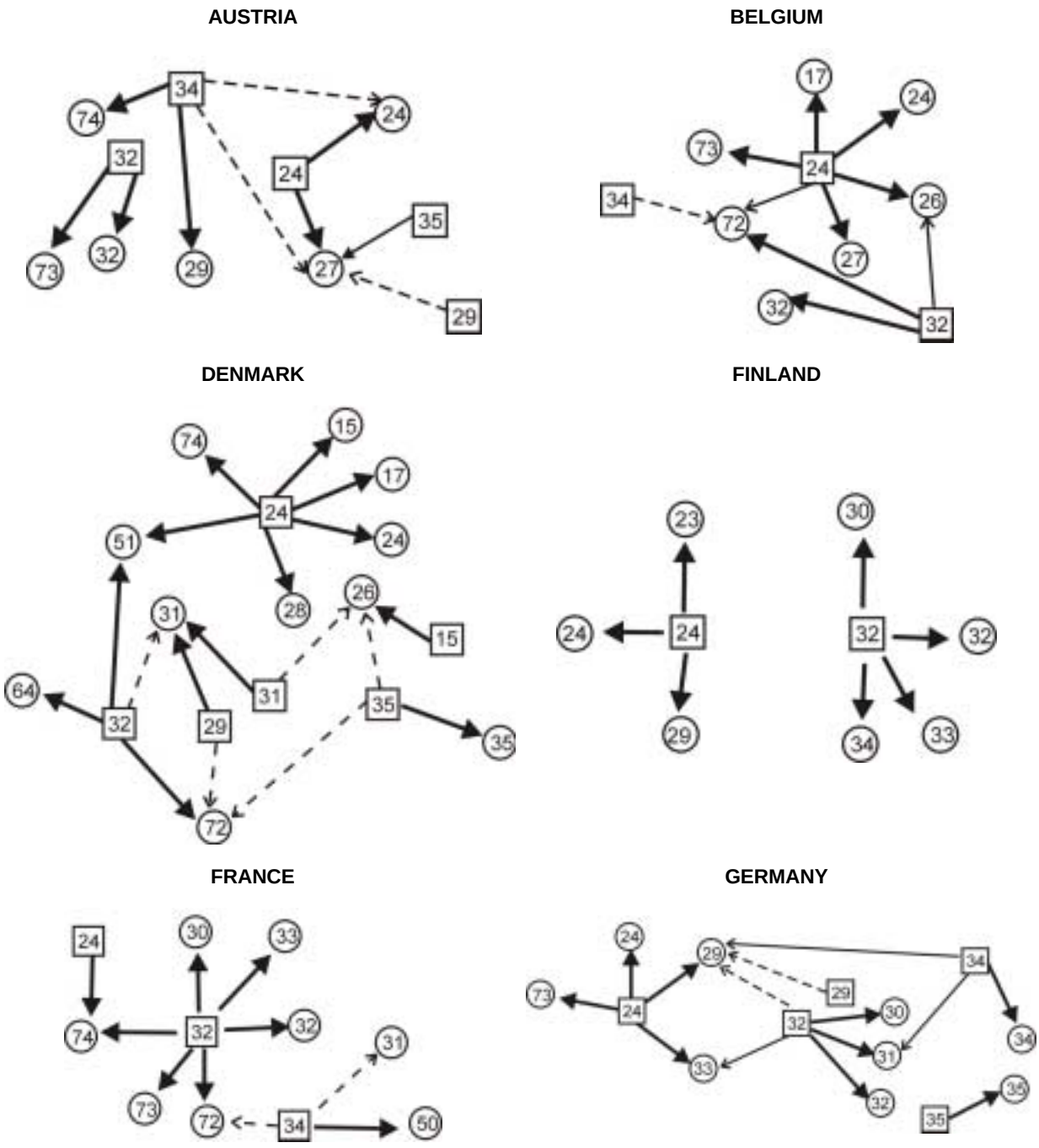
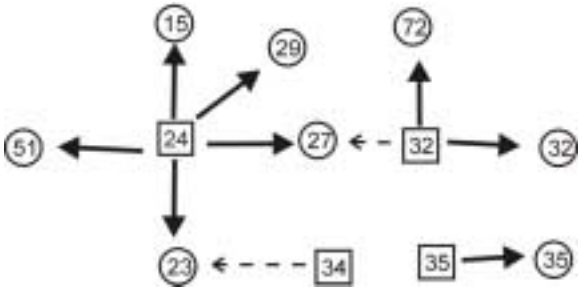
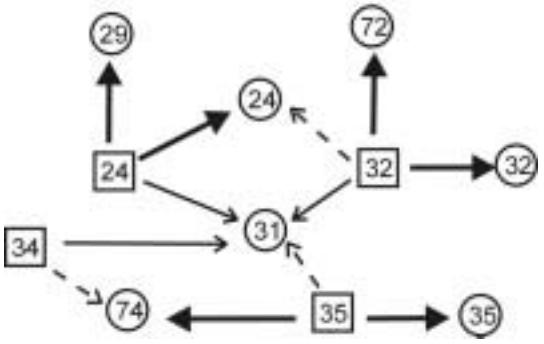


Figure 1. **FWP clusters on the basis of weighted spillovers** *(cont'd.)*
NACE two-digit classification

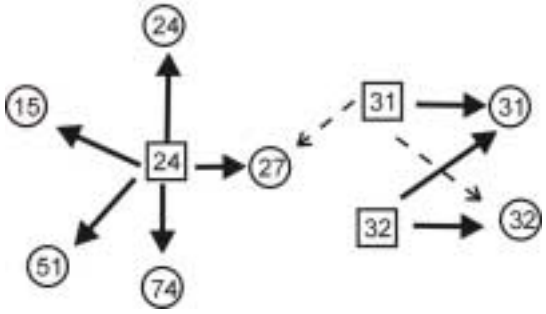
GREECE



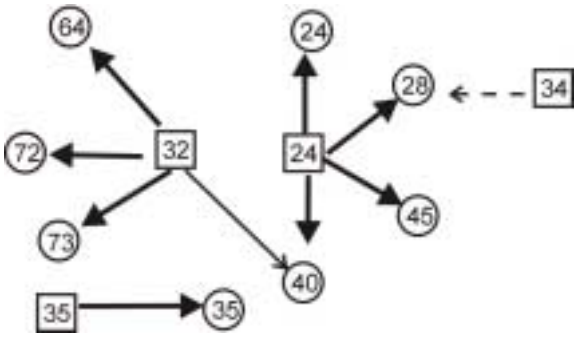
ITALY



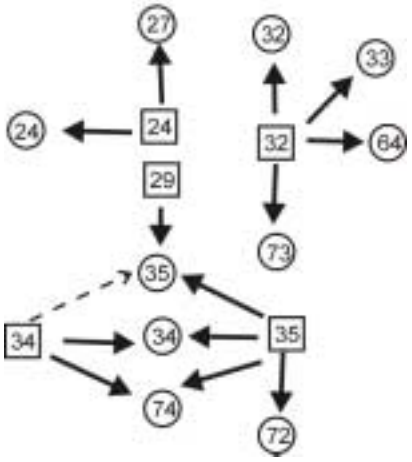
NETHERLANDS



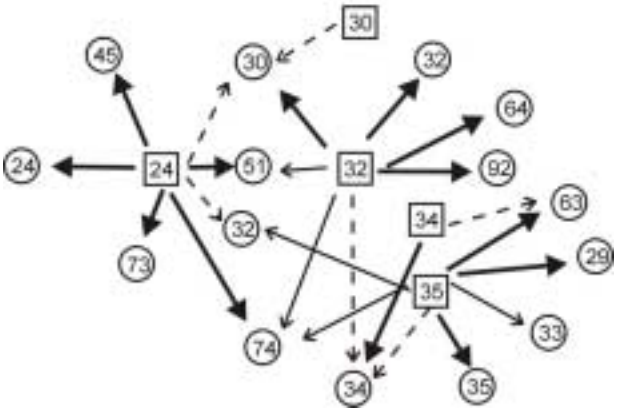
SPAIN



SWEDEN



UNITED KINGDOM



Key:

Supplier sector (all countries)

User sector (country)

SP_{ij} >= 30 % of SP_i AND SP_{ij} >= 0.02* $\Sigma_j SP_j$

SP_{ij} >= 20 % of SP_i AND SP_{ij} >= 0.01*$\Sigma_j SP_j$

SP_{ij} >= 10 % of SP_i AND SP_{ij} >= 0.005*$\Sigma_j SP_j$

Multiplying two R&D stocks may lead to an overestimation of knowledge spillovers to R&D-intensive sectors and an underestimation of spillovers to low-technology industries. It might be useful to find a way to normalise the R&D stocks. R&D-intensive sectors that are active in key EC technological areas are present in all clusters [*i.e. chemicals* (NACE 24) and *electronic equipment and components* (NACE 32)]. From this perspective, the clusters are not very revealing.

Even at the two-digit level, it can be seen that the clusters show some connection to I/O linkages although they cannot simply be reduced to an I/O pattern. There are important differences between countries as to the sectors that benefit from such knowledge spillovers. Figure 1 shows that the clusters are more country-specific with regard to user sectors than with regard to supplier industries. Moreover, some low-technology industries such as *food and beverages* (NACE 15), *textiles* (NACE 17) and *iron, steel and non-ferrous metals* (NACE 27) appear in a number of clusters.

Both the weighted and unweighted spillover measures clearly show that co-operation within the same sector is important in the FWPs, although the two-digit level is too aggregated to allow one to conclude that there is a high degree of co-operation between direct competitors. To obtain a more disaggregated analysis, we computed matrices at the three-digit level. Unfortunately, as no information on the sector of primary activity is available at the NACE three-digit level, we had to use the CSO three-digit level.

We computed matrices of the 40 most active supplier sectors (aggregate of all countries) and the 40 most active user sectors (in a given country), resulting in 1 600 values. From these matrices, we derived three-digit clusters based on similar but less strict clustering criteria[12] than those used for the two-digit matrices. As no data on R&D stocks is available at the CSO three-digit level, the clusters are derived from unweighted spillover matrices; they are shown in Figure 2.

Figure 2 clearly shows the high degree of intrasectoral co-operation within the FWPs. Since the FWPs are targeted at "pre-competitive" collaboration, this finding should not necessarily point to collusive behaviour. Collaboration between competitors at the R&D stage can, at least theoretically, result in a welfare optimum provided that it is followed by competition at the production stage; it could also lead to beneficial standards setting (see, for the latter, Rycroft and Kash, 1999, p. 4). However, policy makers should be attentive to the potential danger of subsidising (non-additional) R&D activities that could result in collusive, lock-in situations. Hagedoorn and Schakenraad (1991) claim that the FWPs may have reinforced the shift towards a more oligopolistic IT market in Europe. A better understanding of this issue could be gained through an analysis of the private networking and market behaviour which precedes (and follows) FWP collaboration (Dumont and Meeusen, 1999, 2000).

The high degree of intrasectoral spillovers is in conflict with Katsoulacos' (1993) finding that the major proportion of FWP co-operation took place between firms of different sectors. It is noteworthy that the degree of intrasectoral spillovers is significantly higher in larger countries than in small ones.[13] This can be seen from Figure 2. Large countries like the United Kingdom, Italy and France, have clusters that to a large extent consist of intrasectoral linkages, while clusters in countries like Austria, Denmark and Finland are far more diversified.

Figure 2. **FWP clusters on the basis of unweighted spillovers**

CSO three-digit classification

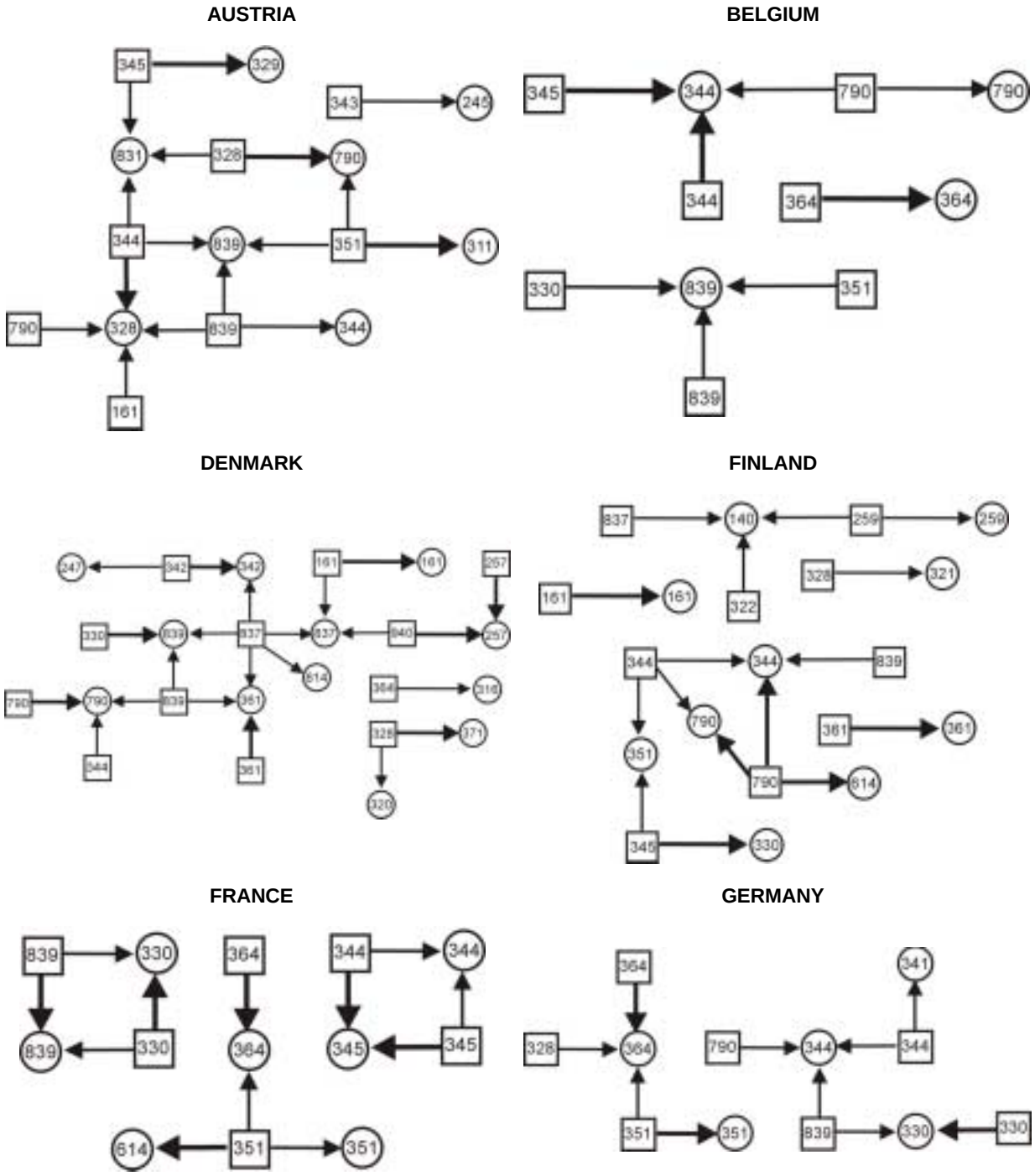
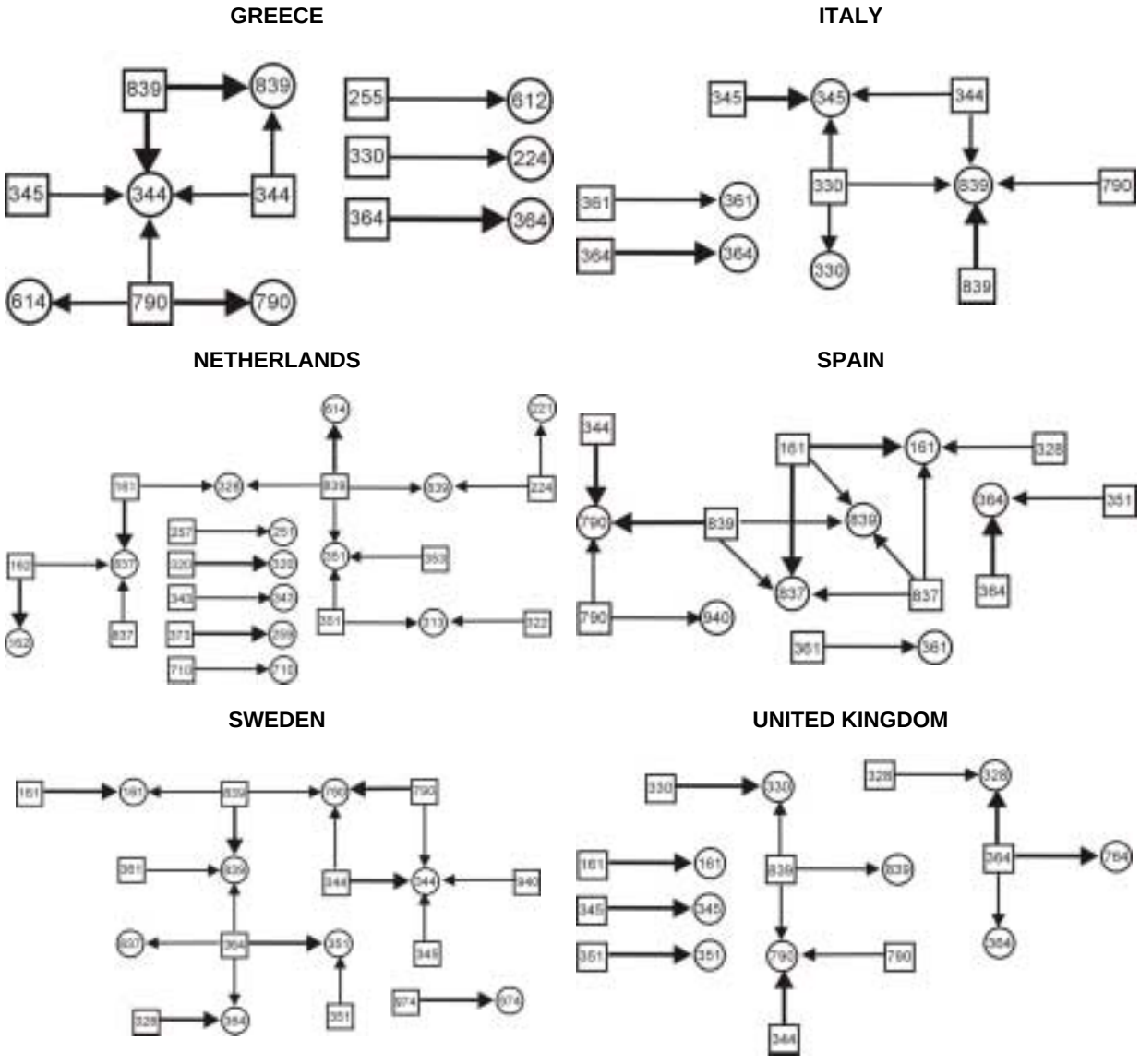


Figure 2. **FWP clusters on the basis of unweighted spillovers** *(cont'd.)*

CSO three-digit classification



This finding could be explained by beneficial standards setting and "pre-competitive" co-operation among MNEs from large countries. However, keeping in mind the model elaborated by Pérez-Castrillo and Sandonís (1996), it could also indicate that competitors self-righteously solve the moral hazard of knowledge sharing through collusive behaviour, and gratefully accept the financial support provided by the FWPs.

Conclusions

In this chapter, available data on subsidised R&D collaboration was used to compute knowledge spillovers between firms. The underlying motive is two-fold: from a methodological perspective, we

argue that data on R&D collaboration may provide a better proxy of knowledge spillovers than methods based on input-output tables since the latter focus on embodied or rent spillovers; from a policy perspective, we indicate that the rationale for public policy oriented towards promoting inter-firm collaboration, irrespective of the theoretical perspective endorsed, depends on the magnitude and specificities of spillovers, and that this issue requires further empirical analysis.

The EU Framework Programmes (FWPs) essentially aimed to enable EU firms to catch up with their counterparts in the United States and Japan. The FWPs provided financial support for transnational collaboration among firms, higher education institutes (HEI) and research institutes (REC) in what were labelled "pre-competitive" R&D projects for which exemptions were issued to the strict EU competition rules.

Official EU data on the FWPs, complemented by firm-level data, were used to compute inter-firm knowledge spillovers, under the assumption that the number of co-operative inter-firm links is a proxy for the underlying knowledge flows.

We hereby endorse a learning perspective which, by focusing on "learning by networking", assumes that multiple, and possibly redundant co-operative links, can be more effective than a strict efficiency perspective.

We constructed matrices for the 25 most co-operating sectors (NACE two-digit). We also constructed matrices of weighted spillovers, in which we considered the absorptive capacity and the spillover pool to be function of sectoral R&D stocks. Using the matrices with weighted spillovers, we derived clusters of those sectors with the highest spillover linkages. Despite the rather strict cluster criteria, low-technology sectors such as *food and beverages; textiles;* and *iron, steel and non-ferrous metals* were present in a number of country clusters. This could be taken to indicate that low-technology firms use the FWPs to find partners that can compensate for their lack of own R&D facilities.

Intrasectoral spillovers are found to be important. This conclusion holds when we look at the three-digit level (CSO activity code) for which unweighted spillovers were computed. Although, given the "pre-competitive" nature of the FWPs and the theoretical benefits of co-operation at the R&D stage, this finding should not necessarily be taken as a warning sign of collusive behaviour, policy makers ought nevertheless to be careful to promote and subsidise only those R&D activities with little additionality and/or potential for creating collusive lock-in situations. This point is even more important as there are indications that, at least in the European IT market, the FWPs may have served to reinforce a trend of gradual concentration.

In our view, the FWPs should be embedded in a more general policy framework that deals, from a dynamic perspective, with all aspects of co-operation *and* competition and that acknowledges the importance of spillovers as a criterion in decisions on whether or not to grant subsidies. Jaffe (1996) argues that policy support should favour projects with the highest spillover gap (which does not necessarily imply the highest spillovers). Although the FWPs promote networking, until now the focus has been more on the R&D aspects of the projects and less on input and behavioural additionality – although the latter is crucial from a "learning by networking" perspective since it entails networking that would probably not have occurred in the absence of support. In his assessment of the Advanced Technology Program (ATP) – the US counterpart of the EU FWPs – Jaffe gives the following advice which is equally applicable to the FWPs:

> "Finally, to the extent that the policy justification for the ATP lies in creating spillovers, then any attempt to evaluate the ATP's success must try to measure those spillovers. Hence

> a better understanding of the process will foster the development of data collection and research efforts that are appropriate to quantification of the spillovers generated by the ATP investments". (Jaffe, 1996, p. 4)

The finding that the degree of intrasectoral spillovers is significantly higher in large countries than in smaller countries is noteworthy and calls for further research. If the matrices and clusters show some connection with I/O tables, it is also clear that the FWP linkages cannot simply be inserted into the value-added chain.

We believe that the method proposed here can be used to complement other procedures for measuring spillovers and that this would be useful both for the empirical issue of measuring or estimating spillovers and for the policy issue of the rationale for promoting co-operation (which to a great extent depends on the magnitude and nature of spillovers).

Further research could be oriented towards another initiative to promote collaboration in R&D: the EUREKA programme provides a useful counterbalance for examining the question as to whether incorporating more near-market projects affects the extent, magnitude and sectoral pattern of knowledge spillovers, compared to the "pre-competitive" EU FWPs. In addition, analysing non-subsidised forms of collaboration (*i.e.* private alliances or strategic technological partnerships) could provide interesting insights into knowledge sharing among partners in the absence of public intervention. The coincidence and chronological follow-up of linkages in the different types of co-operation (pre-competitive/near-market/market alliances) could also be helpful in allowing the outcomes of network promoting policies to be monitored, particularly with regard to potential collusive behaviour.

Since the FWPs also promote collaboration between firms and universities/research institutes, science-industry spillovers could be analysed in a similar way as inter-firm spillovers. The statistical significance of the spillovers should also be tested econometrically.

NOTES

1. In most input-output tables, data on imported goods are not broken down by sector of origin.

2. Luukkonen (2001) found that for Finnish FWP participants, vertical consortia had the lowest additionality.

3. EUREKA is an intergovernmental initiative which was proposed by the French Government in 1985 as an alternative to the American Star Wars programme. EUREKA aims at fostering co-operation between firms. It is not an EU mechanism, although as a member the EU finances some large EUREKA projects mainly in the field of ICT, such as Jessi (microelectronics) and HDTV (high-definition television).

4. That is why in the Fifth Framework Programme, one of the innovations is the recognition of the need for economic and social acceptance of the technologies and other results produced through funded research.

5. The database was constructed in the context of an EU-funded TSER project entitled "Science and Technology Policies Towards Research Joint Ventures" (Record Control Number 39084).

6. The primary source of information was CORDIS.

7. A complete list of the Programmes included in the database is shown in the Appendix 1.

8. In cases where it was impossible (due to the poor quality of information) to identify an organisation as a firm, we preferred to exclude it from the database.

9. A commercial database that contains longitudinal financial information for approximately 200 000 European firms.

10. R&D stocks were computed in line with the formula given in Coe and Helpman (1995).

11. Data on EUREKA collaboration are also available from the EU-RJV database and could be used in future research. Some data sources on private R&D alliances are also available (*e.g.* Merit-Cati).

12. 20% of sectoral spillover and 1.5% of total spillover for the strongest links (thick arrows); 10% of sectoral spillover and 1.0% of total spillover for the weaker links (normal arrows).

13. The correlation between country size and the degree of intrasectoral spillovers is 0.63, which is significant at the 5% level.

Appendix 1

PROGRAMMES INCLUDED IN THE RJV DATABASE

Programme acronym	FWP	Number of projects	Budget (ECU millions)	Average funding per project	Criteria
ACTS	4th FWP	154	671	4.36	152
AERO 0C	2nd FWP	28	35	1.25	28
AERO 1C	3rd FWP	34	53	1.56	29
AGRIRES 3C	1st FWP	113	50	0.44	1
AIM 1	2nd FWP	43	20	0.47	36
AIM 2	3rd FWP	44	97	2.20	35
AIR	3rd FWP	436	377	0.86	184
BAP	1st FWP	366	75	0.20	69
BCR 4	2nd FWP	265	59.2	0.22	160
BIOMED 1	3rd FWP	274	151	0.55	3
BIOMED 2	4th FWP	674	374	0.55	146
BIOTECH 1	3rd FWP	156	186	1.19	33
BIOTECH 2	4th FWP	492	595.5	1.21	274
BRIDGE	2nd FWP	97	100	1.03	49
BRITE	1st FWP	219	185	0.84	206
BRITE/EURAM 1	2nd FWP	378	499.5	1.32	303
BRITE/EURAM 2	3rd FWP	472	770	1.63	388
BRITE/EURAM 3	4th FWP	2 058	1 833	0.89	1 453
CAMAR	2nd FWP	80	55	0.69	21
CLIMAT 3C	1st FWP	108	17	0.16	0
CRAFT	3rd FWP	539	57	0.11	216
DECOM 2C	1st FWP	74	12.1	0.16	6
DECOM 3C	2nd FWP	73	31.5	0.43	31
DRIVE 1	2nd FWP	69	60	0.87	67
DRIVE 2	3rd FWP	66	124.4	1.88	59
ECLAIR	2nd FWP	42	80	1.90	41
ENNONUC 3C	1st FWP	789	175	0.22	136
ENS	3rd FWP	14	41.3	2.95	13
ENV 1C	3rd FWP	560	319	0.57	125
ENV 2C	4th FWP	715	914	1.28	222
EPOCH	2nd FWP	34	40	1.18	10
ESPRIT 1	1st FWP	241	750	3.11	234
ESPRIT 2	2nd FWP	435	1 600	3.68	380
ESPRIT 3	3rd FWP	605	1532	2.53	483
ESPRIT 4	4th FWP	1 599	2 084	1.30	834
EURAM	1st FWP	87	30	0.34	62
EURET	2nd FWP	9	25	2.78	9
FAIR	4th FWP	632	739.5	1.17	240
FAR	2nd FWP	127	30	0.24	16
FLAIR	2nd FWP	34	25	0.74	17
FOREST	2nd FWP	38	12	0.32	14
HYMGEN C	2nd FWP	29	15	0.52	4

Programme acronym	FWP	Number of projects	Budget (ECU millions)	Average funding per project	Criteria
JOULE 1	2nd FWP	267	122	0.46	143
JOULE 2	3rd FWP	401	217	0.54	286
LIBRARIES	3rd FWP	51	22.5	0.44	35
LRE	3rd FWP	25	22.5	0.90	18
MAST 1	2nd FWP	48	50	1.04	48
MAST 2	3rd FWP	93	118	1.27	34
MAST 3	4th FWP	157	243	1.55	85
MAT	3rd FWP	178	67	0.38	57
MATREC C	2nd FWP	71	45	0.63	67
MHR 4C	2nd FWP	211	65	0.31	0
NNE-JOULE C	4th FWP	577			475
ORA	3rd FWP	19	14	0.74	16
RACE 1	2nd FWP	94	550	5.85	83
RACE 2	3rd FWP	123	554	4.50	118
RADWASTOM 3C	1st FWP	217	62	0.29	30
RADWASTOM 4C	2nd FWP	121	79.6	0.66	40
RAWMAT 3C	1st FWP	236	70	0.30	84
REWARD	2nd FWP	13	6	0.46	11
SMT	4th FWP	394	307	0.78	242
TELEMAN	2nd FWP	21	19	0.90	20
TELEMATICS 2C	4th FWP	641	913	1.42	431
TRANSPORT	4th FWP	336	263	0.78	223
Totals		17 596	18 709.6		9 335

Source: Adapted from CORDIS, CD-ROM (1999 III).

Appendix 2

NACE (REVISION 1) LIST OF ACTIVITIES: PRIMARY CODE (TWO-DIGIT)

15	Food and beverages
17	Textiles
23	Cokes, refined petroleum products and nuclear fuel
24	Chemicals
26	Non-metallic mineral products
27	Basic metals
28	Fabricated metal products (except machinery and equipment)
29	Machinery and equipment n.e.c.
30	Office machinery and computers
31	Electrical machinery and apparatus n.e.c.
32	Radio, television and communication equipment and apparatus
33	Medical, precision and optical instruments; watches and clocks
34	Motor vehicles and trailers
35	Other transport equipment
40	Electricity, gas, steam and water supply
45	Construction
50	Sale, repair and maintenance of motor vehicles
51	Wholesale trade (except motor vehicles)
60	Land transport
63	Supporting and auxiliary transport activities
64	Post and telecommunications
72	Computer and related activities
73	Research and development
74	Other business activities
92	Recreational, cultural and sporting activities

Appendix 3

CSO LIST OF ACTIVITIES: PRIMARY CODE (THREE-DIGIT)

140	Mineral oil processing
161	Production and distribution of electricity
162	Public Gas supply
221	Iron and Steel industry
224	Non-ferrous metals industry
245	Working of stone and other non-metallic minerals n.e.c.
247	Glass and glassware
251	Basic industrial chemicals
255	Paints, varnishes and printing ink
257	Pharmaceutical products
259	Specialised chemical products
311	Foundries
313	Bolts, nuts, …; springs; non precision chains; metals treatment
316	Hand tools and finished metal goods
320	Mechanical engineering
321	Agricultural machinery and tractors
322	Metal-working machine tools and engineers' tools
328	Other machinery and mechanical equipment
329	Ordnance, small arms and ammunition
330	Manufacture of office machinery and data processing equipment
341	Insulated wires and cables
342	Basic electrical equipment
343	Electrical equipment for industrial use; batteries; accumulators
344	Telecommunication equipment; electrical measuring equipment; electronic components
345	Other electronic equipment
351	Motor vehicles and engines
353	Motor vehicle parts
361	Shipbuilding and repairing
364	Aerospace equipment manufacturing and repairing
371	Measuring, checking and precision instruments
373	Optical precision instruments
612	Wholesale distribution of fuels, ores, metals and industrial materials
614	Wholesale distribution of machinery, industrial equipment and vehicles
710	Railways
764	Supporting services to air transport
790	Postal services and telecommunications
837	Professional and technical services n.e.c.
839	Business services
940	Research and development
974	Radio and television services

Source: Bureau Van Dijk, *Amadeus* (2000).

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PART III

INTERACTIONS BETWEEN KNOWLEDGE INSTITUTIONS AND INDUSTRY

Chapter 11

INTERACTIONS BETWEEN UNIVERSITIES AND ENTERPRISES IN AUSTRIA: AN EMPIRICAL ANALYSIS AT THE MICRO AND SECTOR LEVELS

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Introduction

Scientific research is an important factor in modern industrial development and long-run growth. Universities, and science in general, contribute substantially to the competitiveness of industries in the long run, but they may also be of great importance in the short run. This is why in most economies, national and regional policy has sought to bring the worlds of scientific and commercially oriented research closer together. However, case studies and surveys on university-firm-interactions have tended to be based on detailed analysis of science-industry links in narrowly defined fields of research and technology (so-called "high-tech" industries) (Bania *et al.*, 1992; Rees, 1991; Acs *et al.*, 1994), on the aggregate effect of university research on knowledge production in firms (Jaffe, 1986; Varga, 2000; Anselin *et al.*, 1997), or on certain types of knowledge interactions such as citations of university research in firm patents (Jaffe *et al.*, 1993; Almeida and Kogut, 1995), and co-publication activities (Hicks *et al.*, 1993, 1996).

In the innovation system approach (Lundvall, 1992; Nelson, 1993; Edquist, 1997), knowledge, learning and the resulting capacity to react to changing demand play a crucial and growing role for firms. Useful products and processes result from knowledge inputs from a variety of sources, and meet performance constraints along multiple dimensions. The current focus on knowledge has – combined with the interactive theory of innovation – led to the analysis of specific factors which determine successful innovations or which influence the absorption of knowledge created outside the firm. In this context, universities, as producers of new knowledge, may play a crucial role. According to the share of R&D by sector of performance in most developed countries, the majority of R&D is performed by the private enterprise sector, followed by the university sector (OECD, 2000). Furthermore, universities represent the largest and most manifold pool of scientists and researchers within the national innovation system and are the major producers of human capital, through their role of professionally transferring scientific knowledge through education. However, university researchers are driven by their own needs and the incentive systems within which they operate. In academic circles, links with actors outside the university are not as crucial as they are for private firms. Several studies (Meyer-Krahmer and Schmoch, 1998; Fritsch and Schwirten, 1999; Bonaccorsi and Piccaluga, 1994), confirm that the motives of additional funds and knowledge exchange are the underlying reason for most industry-academia-interactions. Other motivations for universities to enter into relations with industry include: decreasing dependence of public contracts, employment opportunities for

postgraduate students, additional facilities and references for publicly financed projects (Schartinger *et al.*, 2000a).

The aim of this chapter is to analyse specific ways in which knowledge transfer takes place between universities and firms. Various surveys are used to analyse the linkages between firms and universities. The results of the specific situation in Austria will be presented in the first part of the chapter, while the second part investigates patterns of knowledge interactions between the enterprise and the university sector.

How important are universities for innovative enterprises in Austria?

Within the scope of the development process, enterprises utilise a variety of information sources. They use this information in different ways, among which the ability to be able to improve their judgement of current market situations, to find solutions for technological problems, to find relevant suppliers, to improve the integration of customer needs, to analyse developments achieved by their competitors, etc. As can be seen from the responses to the Community Innovation Survey (CIS), only in a minority of cases are universities considered to represent an important source of information in the course of the innovation process. In 1996, a mere 3% to 4% of innovative enterprises use public science, *i.e.* universities and public research labs, as an important information source in their innovation projects. Compared to internal sources (*e.g.* in-house R&D, information from marketing departments, enterprises within the own-firm group) and to market stimuli (clients, competitors, suppliers), public science plays no major role in driving innovation activities in the majority of enterprises. This pattern applies throughout the EU Member States.

Table 1. **Sources of information on innovation used by innovative firms in European countries, 1996**[1]

Sources of information	UK	BL	GE	ESP	FRA	IRL	NL	AT	FI	SW	NO	EU
Sources within the enterprise	43	44	57	73	48	56	42	34	40	56	51	51
Clients or customers	54	55	45	53	32	58	14	57	44	69	54	46
Other enterprises within the enterprise group	19	23	39	-	24	46	14	22	18	17	27	26
Fairs and exhibitions	15	19	29	26	10	29	8	31	11	16	16	21
Suppliers of equipment	23	15	22	14	18	24	7	7	13	11	27	19
Competitors	17	24	22	22	9	29	5	17	8	17	19	18
Professional conferences	5	6	11	8	4	14	5	12	1	4	8	8
Universities	4	7	7	3	3	5	1	5	7	5	5	5
Consultancies	2	3	5	7	1	9	1	1	3	2	5	4
Computer-based information networks	3	3	5	-	4	8	1	5	3	2	4	4
Government or non-profit organisations	2	5	3	5	2	7	2	1	5	-	6	3
Patent disclosures	4	2	4	3	2	7	2	2	1	3	1	3

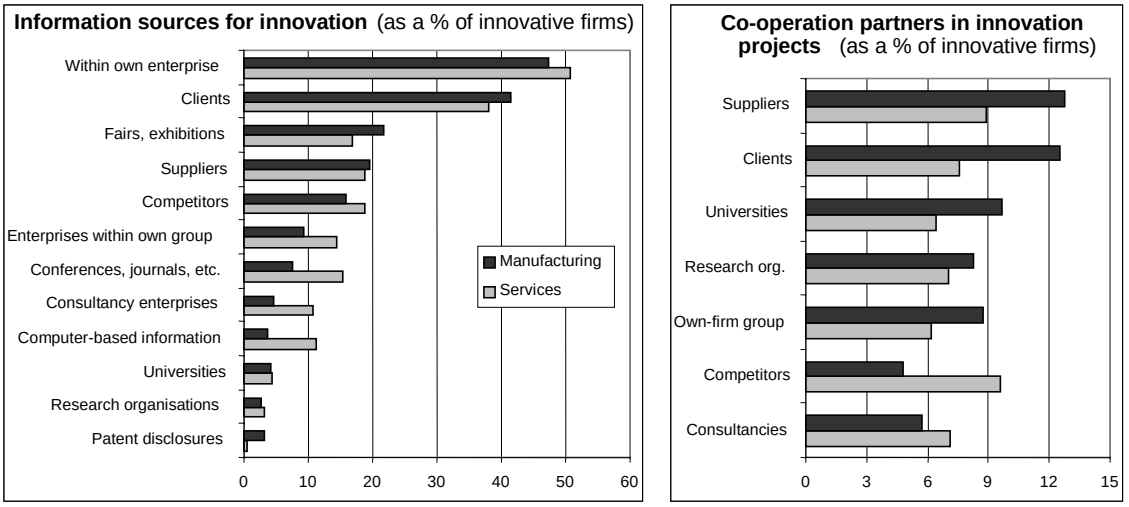
1. Percentage of innovative enterprises rating each source as “very important” in the CIS.
Source: CIS.

When sources of information are ranked by importance, Austria shows consistent results with the general European ranking (Table 1). In Austria, 5% of innovative enterprises rank universities as a highly important source of information for their product and process innovations. In general, the most important sources of information for Austrian enterprises, when it comes to innovation, are not universities, but clearly customers: about 57% of all surveyed Austrian enterprises consider clients as

"very important" (the European Union average is 46%). This is probably due to the high share of small and medium-sized enterprises in Austria. The second most important source is the enterprise itself, as well as related enterprises, fairs and exhibitions, followed by competitors, industry-specific conferences and seminars and, finally, suppliers. Less important are management consultants, computer networks, universities, HTL (secondary school with a focus on technology, engineering, computers, etc.), patent specifications and non-profit research organisations. However, the importance of these sources of information varies depending on the size of the enterprise. The larger the enterprise, the more important the role played by universities, HTL, non-profit research organisations and patent specifications as sources of information. Small and medium-sized enterprises take greater advantage than large firms of sources of information within the conglomerate, as well as of fairs and exhibitions. This pattern leads to the conclusion that small enterprises tend to experience problems in tapping sources of information close to the sciences. If they are part of a conglomerate, they tend to look for this information within the larger construction (Polt *et al.*, 1999).

However, universities and public research labs are more important as a co-operation partner in innovation projects, *e.g.* in actually carrying out certain types of R&D (even if the information source for starting and directing an innovation comes from other sources). Figure 1 reveals that science is of almost the same significance as a co-operation partner in innovation as are suppliers or clients. Nevertheless, only 6%-10% of all innovative enterprises in Europe (in the reference period 1994-96) have carried out innovation activities in co-operation with science; such co-operation may take a variety of forms and need not be restricted to collaborative research.

Figure 1. **Information sources and co-operation partners in innovation: results from the CIS**



Source: Eurostat New Cronos (CIS2), all EU-countries, authors' calculations.

Formal co-operative exercises are one way to use universities as a source of information via face-to-face contacts. In Austria, a growing trend towards formal co-operation between the university and the enterprise sector can be noted. In comparison with the 1990 innovation survey (Leo *et al.*, 1992), more recent studies show an increasing tendency to co-operate and to use the university system as a source of information for innovations. At the beginning of the 1990s, a small number of co-operative agreements between enterprises and universities was observed. Nevertheless, even this is remarkable, considering that Austrian universities are almost exclusively publicly funded. Although there have been cuts in public funding, it is quite difficult to interpret this relatively high co-operation rate with universities and public research institutes in Austria as a consequence of these cuts (*i.e.* that

universities are being "forced" to become more entrepreneurial and commercially oriented). According to Jörg *et al.* (1996), strong co-operation links between specific university departments and commercial enterprises in Austria reflect personal relationships and initiatives of the enterprises more than canvassing by universities to acquire additional funds. However, Jörg *et al.* (1996) also highlight an abstract desire within the university sector for greater co-operation and closer relationships.

A common feature for most of the countries is a strong positive correlation between the size of an enterprise and its collaboration with universities (Table 2). Within the group of co-operating enterprises, nearly half had co-operated with universities during the innovation process. The share increases to two-thirds for enterprises with more than 500 employees.

Table 2. **Co-operation with different types of partners, Austria**

Co-operating enterprises only	Total	10 to 19 employees	20 to 49 employees	50 to 99 employees	100 to 249 employees	250 to 499 employees	500+ employees
				Share in %			
Other enterprises within the conglomerate	22.3	--	9.2	25.2	34.6	43.1	61.7
Competitors	27.3	45.1	25.2	19.7	17.5	8.6	28.3
Clients	46.1	42.7	53.3	54.1	46.6	35.0	36.8
Management consultants	30.9	68.0	20.8	11.5	20.0	10.6	20.5
Suppliers	44.5	46.1	45.0	41.5	42.0	61.8	35.4
Universities and HTL	48.4	28.7	51.3	58.8	49.3	57.8	66.9
Public and private non-profit research institutes	26.1	11.5	31.5	34.9	26.1	36.3	30.7
Share of co-operating enterprises in all enterprises	13.0	9.0	8.0	17.9	22.0	27.4	49.9

Source: Leo (1999), CIS.

As pointed out by Schibany (1998), it is more or less expected that larger enterprises employ highly qualified personnel and are more likely to have in-house R&D facilities. Large science-based enterprises might be better placed to communicate with universities where their codes and their culture are known, while smaller enterprises might face greater difficulties in these respects. In addition, small enterprises often do not have the necessary personnel and financial resources to collaborate with universities. Moreover, the creation of knowledge within the innovation process is not only specific but depends on the development of complementary and sometimes more fundamental fields of knowledge. This may mostly be the case in larger enterprises, which are becoming increasingly "multi-technological" (Pavitt, 1997), incorporating a growing number of fields of knowledge into their endowment.

The establishment of contacts and motives of interaction

As innovative enterprises derive considerable benefits from co-operation with universities, understanding how contacts between universities and enterprises are established is a major concern for science and innovation policy. The findings presented here stem from a survey of a sample of 443 innovative firms which was conducted using the CATI approach (Computer Aided Telephone Interview) in the second phase of the OECD NIS project.[1] This group of 443 firms were the final sample for a postal survey. The survey questionnaire was designed to obtain a broader view of the modes of interaction between the university and the business sector. Ninety-nine firms returned the questionnaire (a response rate of 22.3%).[2]

Table 3 shows that more than half of the contacts between the university and the enterprise sector were established by alumni. This indicates that many graduates now working in enterprises, continue to maintain informal contacts with their former departments. This finding underlines the importance of personal contacts and the crucial role of alumni as gate-keepers to academic research. Taking this into account, it is not surprising that enterprises see themselves as the party which normally takes the initiative in establishing co-operation: 66% of all enterprises surveyed viewed their own initiative as the decisive step towards co-operation. Compared to this finding, mediation through brokering agencies plays only a minor role in the establishment of contacts. Only 10% of firms view mediation as very important.

This indicates that one of the most preferred ways of knowledge exchange between the university and the enterprise sector are personal contacts and informal networks. Such relations especially allow for the exchange of tacit knowledge and provide a trustful environment for co-operation and discussion. Networking on an informal, personal level seems to be a common type of industry-science relation; it enables rapid access to new research results and increases appropriability by controlling access to these networks. Within these networks, industry demand for specific R&D activities is communicated to universities, and professors often directly distribute new findings to the enterprises without claiming IPR (although they do receive indirect remuneration in the form of research equipment and visiting research personnel from industry). This type of interaction seems to substitute for a number of other channels and reduces the need for enterprises to enter into formal collaboration agreements.

Table 3: **Establishing contact**

	Percentage of enterprises responding "important" or "very important"
Initiative of the enterprise	66.6
Contact established by alumni	51.3
Other personal contacts	50.0
Conferences	36.3
Initiative of the university	23.3
Made aware by funds	23.3
Publications	19.7
Brokerage agencies	10.6

Source: Schibany *et al*. (1999).

In Schibany *et al.* (1999), enterprises' motives for co-operation with industry are analysed. A basic finding is that the main motive for co-operation initiated by enterprises, rather than taking advantage of the main function of university research, namely the exploration of new areas of research and access to new research networks, was the capacity of universities to solve problems (Table 4).

Table 4. **Motives and goals for enterprise co-operation with universities**

	Percentage of enterprises responding "important" or "very important"
Capacity for problem solving	72.8
Expected learning processes	69.5
Access to state-of-the-art science	68.3
Access to complementary know-how	66.7
Reduced costs	52.4
Access to additional research capacities	51.3
High quality of university research	51.3
Outsourcing of R&D	42.5
Access to research networks	35.9
Building up of new research areas	25.9

Source: Schibany *et al.* (1999)

Capacity for problem solving was rated as a (very) important motive for co-operation with universities by 73% of the responding enterprises. This involves the transmission of tacit knowledge – the knowledge of methods, designs and techniques which work in given ways with given consequences. It follows that the main transfer mechanism of knowledge between the industrial and academic sectors is through the human factor. This result is confirmed when R&D managers of innovative enterprises are requested to indicate the importance of different types of potential benefits from universities. Table 5 summarises the results (see also Schartinger *et al.*, 2001). The second column of Table 5 shows the share of enterprises which value the different types of potential benefits with 3 (important) or 4 (very important). The second part of Table 5 relates firm size (three size categories) to the mean value of the valuation of potential benefits. Using analysis of variance, we test whether there exist significant differences between the three size categories in terms of their mean values (the null hypothesis is that there is no difference in the mean values between the size categories.) The third part of Table 5 presents information on the valuation of enterprises with own R&D departments (labelled as "yes") *vs.* those enterprises without own R&D departments (labelled as "no"). Again, we use an analysis of variance to test for significance.

Table 5. **General benefits to be gained from universities**

Potential benefits	% of enterprises answering 3 or 4	Mean values on a 1 to 4 scale (1 = not important, 4 = very important)				
		By firm size (number of employees)			Own R&D department	
	n = 99	1-50	51-200	201+	Yes	No
Highly skilled personnel (university graduates)	63.7	2.22***	2.52***	3.26***	3.05***	2.18***
Ideas for new products and processes	47.2	2.53	2.40	2.04	2.19	2.50
General and useful information	42.7	2.32	2.24	2.33	2.29	2.31
Direct support in development process	41.1	2.08**	2.28**	2.67**	2.37	2.25
New instruments and techniques	37.9	2.22	2.20	2.42	2.39	2.17
Results of basic research	33.3	2.19	2.04	1.96	2.18	1.98
Consulting services	32.8	1.86**	1.96**	2.33**	2.02	2.04

*** level of significance (p<0.01), ** level of significance (p<0.05).
Source: Schartinger *et al.* (2001).

As can be seen from Table 5, for firms the following four main channels are the most important types of benefit to be had from universities (in order of importance): employment of educated and highly skilled personnel (university graduates); ideas for new products and processes; provision of general and useful information; and direct support in the development process. The employment of high-skilled university-educated personnel was rated as important or very important for the innovation process by 64% of all enterprises. This finding corresponds to those of most other studies on this issue (Martin *et al.*, 1996) and confirms the widely acknowledged importance of availability of human resources for the innovation process and the role that the universities play in the production of highly qualified labour.

For almost two-thirds of the enterprises surveyed, highly skilled personnel is rated as either important or very important. Furthermore, Table 5 reveals that enterprises with own R&D departments value the benefits of high-skilled personnel to a significantly higher degree than do enterprises without an own R&D department (a mean value of 3.05 *vs.* 2.18). An R&D department allows a company to take advantage of necessary skills, external knowledge in the form of scientific output (publications, seminars, etc.) and determines its absorptive capacity. In a study by Schibany (1998), 41% of all enterprises co-operating with universities had an R&D department. Staff at R&D departments are generally dominated by employees with university-level education. R&D-conducting enterprises have to rely on highly qualified staff to a much greater degree than do enterprises without own R&D departments. There is a clear relationship between firm size and the valuation of high-skilled university-educated personnel: large enterprises have a significantly higher mean value (3.26) than their smaller counterparts (small enterprises have a mean value of only 2.22). Apparently, the demand for qualified R&D personnel increases with firm size; this may be the result of large enterprises being more likely to have an R&D department. Two other types of benefits significantly increase with firm size: *i)* large enterprises value the benefit of universities in directly supporting the development process; *ii)* large enterprises place greater value on the benefits to be obtained from consulting services by universities. It is somewhat surprising that firm size seems to have no significant impact on how enterprises perceive the *results of basic research* to their work. For the majority (66%) of respondents, the *results of basic research* are of little or no relevance. However, about one-third of enterprises find the results of basic research relevant to their innovative activities. This is noteworthy as large science-based enterprises (*e.g.* pharmaceutical firms) appear to be somewhat under-represented in the survey sample.

Almost half of the respondent enterprises indicate that universities are a significant source of ideas for new products and processes. Concerning the other types of benefits, no significant differences between enterprises with and without R&D departments can be reported.

Schibany *et al.* (1999) analyse the main barriers and difficulties to co-operation with universities. The results are clear: 58% of the respondent firms perceive the lack of information on the content of university research as a serious barrier to co-operation. Hence, the real bottleneck for improving the interaction between academic research and industry is poor communication about what universities actually do and what might be relevant for industry. Compared to this, poor equipment or lack of interest (although one-third of the surveyed firms see this as the main barrier) are not the main obstacles to co-operation. Apparently, the various initiatives aimed at providing better information on the research is conducted in different university departments has had limited impact. Enterprises still have difficulties identifying what types of research might be of use to them and whom to contact. The availability of information does not seem to be the real problem; rather it appears that information on university research is not properly translated to respond to industries' needs.

Lack of information about the competency available at the universities can result in information-search costs which the business cannot or does not want to afford. It is neither lack of interest nor lack

of capability which represent the main hindrance to co-operation; rather the problem lies with the lack of knowledge as to what research relevant to an industry is being performed at what university.

The extent of university-industry-interaction at the sectoral level

The following section aims to identify those economic sectors that engage in particularly intensive interactions with universities. The data for this section come from a total survey of university departments in Austria. A postal survey of all university departments in Austria was chosen and conducted in Winter 1998/Spring 1999. For large departments that are divided into sub-departments, the questionnaire was sent to the sub-departments (421 questionnaires were returned by 350 departments, a response rate of 37.2%).[3]

The key questions of the survey focused on different types of interactions between the university and the enterprise sector:

- Personnel mobility in terms of sabbaticals of university researchers in the enterprise sector and the permanent change of university researchers to the enterprise sector.
- Spin-off formations of new enterprises.
- Lectures by business people at universities.
- Training of business people by university researchers.
- Joint supervision of PhDs and Masters' theses.
- Joint publications between the university and the enterprise sector.
- Joint research projects between the university and the enterprise sector.
- Financing of research assistants by the enterprise sector.

A variety of factors contribute to differences in the intensity of knowledge flows between the enterprise and the university sector. These factors can be enterprise-specific (related to whether firms are small/large, uni/multilocal, networked/non-networked, etc.), or sector-specific (determining which types of knowledge are needed, how much knowledge is needed, what is meant by "knowledge", how the acquisition of knowledge is organised, who participates in the acquisition of knowledge, etc.) (Oinas, 1999).

From the sectoral perspective, different sectors of economic activity face different technological opportunities (Klevorick *et al.*, 1993), *i.e.* they differ in the feasibility and sources of advance in their product- and process-relevant technologies. New scientific developments and university research results constitute one source of new contributions to an economic sector's pool of technological opportunities. If university research is analysed in more detail at the level of fields of research, it becomes clear that, although enterprises are becoming increasingly "multi-technological" (Pavitt, 1997), not all research carried out at universities is equally interesting for all sectors of economic activity and *vice versa*. Klevorick *et al.* (1993) find that economic sectors such as the production of drugs or food products rely most strongly on university research. On the other hand, scientific research fields such as computer science or materials science are highly relevant to many sectors of economic activity, while, for example, geology does not bear high relevance to any sectors of economic activity.

It is thus legitimate to analyse the patterns of knowledge interactions between universities and enterprises and their determinants at the levels of sectors of economic activity and fields of university research, since significant variations of the patterns may be expected at these aggregated levels.

In the following, an index of interaction intensity is calculated for different types of knowledge interactions. The intensity of interaction with enterprises *i* in each type *t* and each field of research *r* ($^{t}i_{r}$) was measured by the share of all interactions I of a certain type *t* in field of research *r* ($^{t}I_{r}$) in the total sum of all interactions of type t (^{t}I) in relation to the corresponding share of R&D employees in a given field of research S_r out of all R&D employees *S*. The critical value is one: those economic sectors with an intensity greater than one interact more intensively with university fields of research than average (= than would be expected according to their size).

$$^{t}i_{r} = \frac{^{t}I_{r} / ^{t}I}{S_{r} / S} \qquad (1)$$

Table 6 presents the results for economic sectors at the NACE two-digit level (partly aggregated). The various types of interaction were also partly aggregated: “joint education” comprehends the joint supervision of PhDs and Masters’ theses, lectures held at universities by business people and training activities for business people at universities; “mobility” comprises sabbaticals of university researchers in the enterprise sector and the permanent change of university researchers in the enterprise sector.

The first column shows the percentage share of R&D employees in each sector. The other columns present the interaction intensities calculated as described above. For better visualisation, values above one are shaded. Major differences become apparent in the intensity of interaction between the sectors of economic activity and the university sector. In the manufacturing sector, high R&D intensities do not necessarily correspond with high intensities of interaction in all types of interaction: “Electrical and electronics” reveals a much lower intensity of interaction than would be expected from its size and R&D ratio. The “medical, precision and optical instruments” sector shows an intensity of interaction above average in all depicted types of interactions. Moreover, various sectors show articulate preferences for certain types of interactions: The “machinery and equipment” and “non-metallic mineral products” sectors entertain relations with the university sector mainly via joint projects, the “food and tobacco” sector via the mobility of university researchers and joint educational activities.

In the service sector, “research and development” (which *per definitionem* is also the sector with the highest R&D intensity) interacts with universities mainly via joint publications and the mobility of researchers. “Software services” reveals a distinct preference for mobility, spin-offs and joint educational activities with universities. In total, three sectors of economic activity have an above-average intensity of spin-off formations of new enterprises; these are “medical, precision and optical instruments”, “software services” and “producer-related services”.

Table 6. **ISR intensity broken down by economic sector and type of interaction**

Sector	NACE	Share of R&D employees	Joint publications	Joint projects	Mobility from university to industry	Spin-offs	Joint education
Manufacturing sector							
Food and tobacco	15-16	*0.36*	0.82	0.27	1.42	0.00	1.09
Textiles	17-19	*1.10*	0.00	0.48	0.00	0.00	0.03
Wood and timber	20	*0.33*	0.00	0.00	0.42	0.00	1.24
Paper and print media	21-22	*0.50*	1.22	0.63	1.98	0.00	4.73
Chemicals	23-24	*6.94*	2.38	3.69	2.66	0.22	1.68
Rubber and plastics	25	*0.81*	0.99	25.60	1.25	0.00	0.59
Non-metallic mineral prods.	26	*1.82*	0.36	3.55	0.00	0.00	0.21
Basic metals	27-28	*0.98*	2.58	3.98	0.81	0.00	1.49
Machinery and equipment	29	*2.34*	0.95	1.17	0.92	0.43	0.66
Electrical and electronics	30-32	*9.77*	0.37	0.40	0.17	0.06	0.22
Med./prec./opt. instruments	33	*3.43*	5.75	1.27	3.37	3.81	2.23
Vehicles	34-35, 50	*1.20*	1.03	1.20	0.65	0.00	2.35
Furniture	36	*0.44*	0.91	0.22	0.00	0.00	1.23
Waste management	37, 90	*0.46*	5.39	1.24	1.94	0.00	3.64
Service sector							
Trade	51-52	*0.02*	5.39	0.43	4.25	0.00	2.22
Transport services	60-63	*0.00*	21.57	10.83	27.21	0.00	65.05
Telecommunications	64	*0.09*	2.59	1.39	10.88	0.00	2.68
Financial services	65-67	*0.14*	6.47	1.19	4.42	0.00	9.57
Software services	72	*4.98*	0.86	0.17	4.06	5.33	1.05
R&D	73	*51.28*	2.58	0.47	1.76	0.54	0.83
Producer-related services	74	*0.06*	23.73	2.82	43.20	199.70	50.64

Source: Calculations based on a survey of all Austrian university departments by Schartinger *et al.* (2000a).

In the following, the attempt was made to find correlations between various types of interaction. Table 7 shows the correlation coefficients between the various types of interaction at the level of sectors of economic activity. The results indicate that few significant relations between the various types of interaction can be identified. However, the type of interaction "joint projects" correlates with a wide variety of other types of interactions between the university and the enterprise sector, *i.e.* with the joint supervision of PhDs and Masters' theses, training activities for business people, the mobility of university researchers to industry and the business financing of research assistants at universities. This may be an indicator that joint research projects can trigger other joint activities between universities and enterprises. This is relevant from a policy perspective as decision makers aiming to

enhance interactions between the university and the enterprise sector have to find ways into the system. The present results indicate that the support of joint projects may leverage other joint activities between the university and the enterprise sector. However, it has also to be borne in mind that deliberately attempting to provide incentives for particular types of interactions, may serve to hamper a variety of more diffuse and decentralised knowledge flows from universities to the enterprise sector (Cohen *et al.*, 1998).

Table 7. **Matrix of correlation coefficients between types of interactions at the sectoral level**

	Joint supervision of PhDs, M.Th.	Training of business people at universities	Joint projects	Lectures by business people at universities	Joint publications	Mobility of university researchers	Financing of research assistants	Spin-offs
Joint supervision of PhDs, Masters' theses	1.00	0.23	0.36*	0.12	0.15	0.07	0.47	-0.10
Training of business people at universities		1.00	0.31*	0.58**	0.28	0.18	0.60**	0.07
Joint projects			1.00	-0.01	0.05	0.51**	0.56**	0.08
Lectures by business people at universities				1.00	0.28*	0.34*	0.27	0.03
Joint publications					1.00	0.17	0.19	0.13
Mobility of university researchers						1.00	0.18	0.32
Financing of research assistants							1.00	-0.07
Spin-offs								1.00

** correlation significant at the 0,05 level; * correlation significant at the 0,1 level.
Source: Calculations based upon Schartinger *et al.* (2000a).

Patterns of interaction at the sectoral level

An interaction matrix for 30 fields of research and 25 sectors of economic activity has been produced to allow analysis of the sectoral pattern of knowledge interactions. For each type of knowledge interaction *t*, the share of interactions between research field *r* and sector of economic activity *s* in the total sum of knowledge interactions of type *t* is calculated. The results for two types of knowledge interaction (joint supervision of PhDs and Masters' theses; and spin-off formations of new enterprises) are presented in Annex Tables A1 and A2. An attempt was made to depict the proximity between the research fields and the economic sectors in terms of research intensity of economic sectors and economic orientation of research fields. Sectors of economic activity were listed in order of the share of academic employees in total employment, while research fields were listed in order of the share of graduates employed in the private enterprise sector.

It would be expected that the most frequent interactions would be clustered in the upper left quadrant of the interaction tables. This was only partly confirmed as the interactions tended to cluster on the left-hand side of the tables, indicating that the economic proximity of research fields is important. However, the share of academic employees of an economic sector does not seem to have any visible effect on the pattern of interactions. Other results include:

- The specialisation patterns do not show similarities in the two selected types of knowledge interactions with respect to the frequency of interaction or with respect to the number of economic sectors or fields of research as interaction partners.

- A high share of the interactive activities surveyed by the authors confirms in broad terms what were expected to be proximate interaction partners in terms of the common knowledge background and area of research, although the concrete partners may vary in different forms of interactions.

- It can be inferred that the propensity of research fields and industrial sectors to interact depends on the type of interaction. The range of economic sectors that research fields interact with is highly dependable on the type of interaction. It is apparently of less importance for joint supervisions to take place than it is for spin-off formations of new enterprises that the university department and the private enterprise refer to the same knowledge background. The biology jointly research field supervises PhDs and Masters' theses with ten economic sectors; however, it founded enterprises in only three economic sectors.

- The majority of spin-offs was founded in the producer-related service sector. These findings comply with results from other investigations, *e.g.* by the Austrian Federal Ministry of Science and Transport. Of the 141 enterprises investigated by the Federal Ministry of Science and Transport that were spun off from universities in 1986-98, 77 are comprehended in our survey, 58% of which are established in the producer-related service sector. In the annual report of the Ministry of Science and Transport, this proportion is even higher: 82% of the new enterprises were founded in the producer-related service sector, 13% in the production sector and 5% in wholesale and retail trade. The producer-related service sector includes a wide variety of activities, such as economic, technical and legal consultations and other services. Some research fields (like construction engineering, sociology, electronics, educational science and geodesy) set up 100% of their enterprises in the producer-related service sector.

For interaction matrices on other types of knowledge interactions, see Schartinger *et al.* (2000a).

Conclusions

Placing industry-science relations in the context of the overall innovation system clearly shows that this system has many components and functions. There are, in fact, multiple interactions between the science and industrial systems. When comparisons are made with innovation surveys conducted at the beginning of the 1990s, universities seem to play an increasingly important role for the enterprise sector. From the enterprise point of view, firms' awareness that they could benefit from university research seems to be higher – nevertheless, the transfer of knowledge remains difficult to manage. This applies particularly in terms of the importance of universities as sources of information or as co-operation partners: there is a strong positive correlation between the size of an enterprise and its propensity to collaborate with universities.

When enterprises are asked to state their motives for co-operating with universities in the innovation process, a clear picture of their expectations emerges: what they are looking for is not the results of academic research but rather the capacity to solve problems. This incentive is quite understandable, but nevertheless hard to manage – it involves the transmission of tacit knowledge as well as the bridging of two distinct cultures. The most extensive flows of knowledge from universities to the industry seem to occur through the transfer of human capital: a large proportion of enterprises state that they consider access to skilled graduates to be the benefit from universities that they value most highly.

From a sector-specific perspective, the analysis shows that the list of sectors with the highest intensity of interaction with universities only partially corresponds to common rankings of knowledge-intensive sectors. Huge differences are apparent in the intensity of co-operation between the enterprise sector and the universities. Some sectors have very high intensities in spite of low R&D ratios, while others, which are traditionally considered high-technology industries have only low industry science relations.

When the sectoral pattern of knowledge interaction is analysed, it becomes clear that the propensity of research fields and industrial sectors to interact depends of the type of interaction. The range of economic sectors that research fields interact with is highly dependable on the type of interaction. This adds to the common view of a sector-specific analysis of science industry interactions by taking the type of interaction into account.

The chapter shows increasing interactions between the universities and the enterprise sector via a variety of channels. Industry-science relations have to bridge the gap between the cultures of the two systems. Incentive structures and criteria for success differ between enterprises and universities. However, the existence of distinct cultures is desirable since industry and science have to fulfil two different functions both in an innovation system and in society: the universities have to produce useful science, while industry's role is to produce technologies for commercialisation. Of course, an intermingling of the two cultures is also highly desirable, but it has to be borne in mind that deliberate attempts to provide incentives for some types of knowledge flows and interactions may seriously hamper the flow of more diffuse and decentralised types of knowledge.

NOTES

1. For a detailed description of the project and the results, see Christensen *et al.* (1999) and Schibany (1998).

2. The results of this survey are presented in Schibany *et al.* (1999).

3. For further information, see Schartinger *et al.* (2000b).

Annex

Table A1. **Joint supervision of PhDs and Master's theses by universities (differentiated by field of research) and enterprises (differentiated by sector of economic activity)**

Percentages

Field of research / Economic sector	Engineering	Electronics	Technical chemistry	Medicine, pharmacy	Chemistry	Construction engineering	Mining, metallurgy	Veterinary medicine	Agriculture and forestry	Mathematics, informatics	Physics, mechanics, astronomy	Traffic and transport system	Biology, botany, zoology	Geology, mineralogy	Economics	Statistics	Jurisprudence	Architecture	Spatial planning	Geodesy	Hydrology, hydrography	Meteorology, climatology	Psychology	Educational science	Geography	Historical sciences	Sociology	Linguistics, philology, literature	Fine arts	Political science	Philosophy and theology	Total
Chemicals/pharmaceuticals	0	0.2	0	7.4	4.6	0.1	0.2	0.2	0	0	0	0	0.5	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.5
Machinery and equipment	3.5	0.1	0	0	0	0	0.6	0	0	0.1	0.1	0	0.2	0	0.8	0	0	0	0	0	0.2	0	0	0	0	0	0	0.2	0	0	0	5.8
Electrical and electronics	0	2.7	0	0	0.3	0	0	0	0	1.5	1.0	0	0	0	2.6	0	0.2	0	0	0	0	0	0.2	0	0	0	0	0.1	0	0	0	8.6
Med./prec./opt. instruments	0	0.7	0	1.2	0.5	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0.4	0.1	0	0	0	0	0	0	0	3.3
Vehicles	12.0	0.3	0	0	0.1	0	0	0	0	0.1	0.5	0	0	0	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	19.3
Computer and related activities	0	0	0	0	0	0	0	0	0	1.4	0.2	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	2.1
R&D	0	1.9	0	0.1	0.2	0.2	0.3	0	0	0	4	0	0.3	0	0.4	0.3	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	7.8
Mining	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1
Coke/refined petroleum products	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6
Basic metals	0.2	0.1	0	0	0.2	0.4	4.1	0	0	0	0.5	0	0.6	0	2.3	0	0	0	0	0	0	0	0	0.2	0	0.1	0	0	0	0	0	8.7
Transport	0	0	0	0	0	0	0	0	0	0	0.1	0.5	0.2	0	0.8	0	0	0	0	0.2	0	0.1	0	0	0	0	0	0	0	0	0	1.9
Producer-related services	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0.2	0	0	0	0	0	0	0	0.1	0	0	0	2.3
Agriculture and forestry	0	0	0	0	0	0	0	0.3	0.7	0	0	0	0.2	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3
Textiles	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Paper and print media	0	0	2.4	0	0.2	0	0	0	0	0	0	0	0.2	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.0
Rubber and plastic products	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0.1	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
Energy and water supply	0.2	0.6	0	0	0	0.4	0	0	0	0.1	0	0	0	0.2	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7
Post and telecommunications	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
Banks and insurance	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	1.8	0	0.1	0	0	0	0	0	0	0	0	0.5	0	0.1	0	0	0	2.9
Waste management	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.3	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2
Food and tobacco	0.2	0	0	0	0.4	0	0	1.2	0	0	0	0	0.1	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.6
Lumber industry	0.8	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4
Non-metallic mineral prods.	0	0.1	0	0	0	0	0.2	0	0.2	0	0.1	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2
Furniture	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0.3	0	0	0	0	0	0	0	0	1.1	0	0	0	0	0	0	0	1.5
Construction	0	0	0	0	0	0.9	0	0	0	0	0	0.1	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6
Tourism	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.9
Wholesale and retail trade	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.5
Education	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.7
Rec./cultural/sport. activities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0.1	0	0	0	0.9
Total	17.0	7.9	2.4	8.7	6.4	2.5	5.6	1.7	1.0	4.1	7.3	0.6	2.5	1.9	25.0	0.4	0.2	0	0	0.3	0.2	0.1	0.6	2.2	0.1	0.6	0.2	0.7	0	0	0	100.0

Note: Time period = 1995-98; deviation from 100% due to rounding errors.

Source: Survey of all Austrian university departments by Schartinger *et al.* (2000a).

Annex Table A2. **Spin-off-formations of new enterprises (differentiated by sector of economic activity) by universities (differentiated by field of research)**

Percentages

Field of research / Economic sector	Engineering	Electronics	Technical chemistry	Medicine, pharmacy	Chemistry	Construction engineering	Mining, metallurgy	Agriculture and forestry	Veterinary medicine	Mathematics, Informatics	Physics, mechanics, astronomy	Traffic and transport system	Biology, botany, zoology	Geology, mineralogy	Economics	Statistics	Jurisprudence	Architecture	Spatial planning	Geodesy	Hydrology, hydrography	Meteorology, climatology	Psychology	Educational science	Geography	Historical Sciences	Sociology	Linguistics, philology, literature	Fine Arts	Political Science	Philosophy and theology	Total
Chemicals/pharmaceuticals	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4
Machinery and equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.9	0	0	0	0	0	0	0	0	0	2.9
Electrical and electronics	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4
Med./prec./opt. instruments	1.4	0	0	1.4	0	0	0	0	0	0	4.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1
Vehicles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Computer and related activities	1.4	0	0	0	0	0	0	0	0	7.1	0	1.4	1.4	0	1.4	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
R&D	0	0	0	0	0	0	1.4	0	0	0	1.4	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.3
Mining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coke/refined petroleum products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Basic metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Producer-related services	4.3	2.9	0	2.1	0	8.6	2.9	0	1.4	4.3	2.9	0	1.4	0.7	19.0	0	0	0	0	2.9	0	0	0	1.4	0	0	4.3	0	0	1.4	0	61.0
Agriculture and forestry	0	0	0	0	0	0	0	1.4	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.9
Textiles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper and print media	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubber and plastic products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Energy and water supply	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Post and telecommunications	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banks and insurance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food and tobacco	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumber industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-metallic mineral prods.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furniture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1
Tourism	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
Wholesale and retail trade	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
Education	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rec./cultural/sport. activities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	1.4
Total	7.1	2.9	0	4.3	1.4	8.6	4.3	1.4	1.4	13.0	8.6	2.9	4.3	2.9	21.0	1.4	0	0	0	2.9	2.9	0	0	1.4	0	0	4.3	1.4	0	1.4	0	100.0

Note: Time period = 1995-98; deviation from 100% due to rounding errors.

Source: Survey of all Austrian university departments by Schartinger *et al.* (2000a).

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Chapter 12

COLLABORATION BETWEEN MANUFACTURING FIRMS AND KNOWLEDGE INSTITUTIONS ON PRODUCT DEVELOPMENT: EVIDENCE FROM HARMONISED SURVEYS IN AUSTRALIA, AUSTRIA, DENMARK, NORWAY AND SPAIN

by

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Introduction

A large body of research focuses on the way in which the increasing "globalisation" of economic activity affects the advanced industrial economies. Globalisation is reflected in increased trade flows, higher rates of foreign direct investment, global sourcing and an increased incidence of cross-border inter-firm co-operation. These trends can be linked to the growing importance of knowledge-based competition and are, arguably, both promoting and being facilitated by radical changes in the technologies of information transfer and exchange.

Despite the importance of these trends towards greater economic integration, there is little evidence to suggest that globalisation is eliminating deep-seated differences among the advanced industrial economies. Significant differences can be observed, not only in terms of areas of technological and industrial specialisation, rates of productivity growth and trade performance, but also with respect to inter-firm collaboration/co-operation and networking (CCN). Globalisation has created new bases for competition such as quality and time, although these are necessary but not sufficient conditions for success in a rapidly changing environment. Today, firms' competitiveness depends increasingly on their capability to continuously invent new products and processes that better meet the demands of customers. Local networks and patterns of co-operation with local actors are thus essential in terms of the, often informal, information exchange which exhibits different patterns of national networks and co-operation intensities.

Over the past 10-15 years, there have been a number of key developments in the perception of innovation processes. Today, there seems to be little disagreement over the fact that technological innovation proceeds as a complex interaction between research, design, production and marketing, and takes place in an interactive learning process involving a variety of actors at all levels of the economy (Lundvall, 1992). Moreover, multiple sources of information and pluralistic patterns of collaboration seem to be the rule rather than the exception. Above all, this may be a central characteristic of what the business press heralds as the "new economy".

The concept of a "system of innovation", originally introduced by Freeman (1987), Lundvall (1992) and Nelson (1993), has been widely used in the innovation literature in the past decade and is deeply rooted in the belief that innovation is an interactive process in which agents and organisations communicate, co-operate and establish long-term relationships. The innovation systems concept has been used in both a broad and a narrow sense; the latter notion denoting the knowledge infrastructure and institutions directly relevant for innovation, while the former also encompasses the functioning of a wider set of institutions in the economy as well as informal institutions. Although a variety of systems approaches exist, they all have a common characteristic: their focal interest is the innovation performance of firms and all relevant determinants of innovation. The present chapter focuses on the interaction of firms with knowledge institutions; the discussion of innovation systems is based on the broader definition.

Recent research on innovation systems has found that considerable variation exists among national innovation systems both in terms of the extent to which firms interact with different collaboration partners and in terms of whether collaboration is pursued with domestic or international partners. Investigating patterns of inter-firm collaboration helps to highlight differences between national innovation systems.

Despite an increasing awareness of (and agreement on) the importance of inter-firm linkages and linkages between firms and knowledge institutions in connection with product innovation, few attempts have been made to systematically collect empirical data mapping such relationships to enable cross-country comparisons. In spite of the obvious inherent potential of applying such a perspective, the analysis of innovation systems has only to a limited extent and with a narrow focus pursued systematic international comparisons in these respects. So far, comparative data have been mainly case-study based.

Moreover, the present study focuses on collaboration (including informal collaboration) on product innovation, while previous studies mainly dealt with formal R&D agreements. This is an important difference and has a bearing on our focus. As we know from innovation research that product innovation is something broader than R&D, we would also expect collaboration to be much broader than just R&D collaboration. Therefore, rather than focusing on R&D institutions such as universities, we have taken a broader approach and extend the definition of knowledge institutions to cover not only universities and other research institutions, but also technical institutions, consultants relevant for product innovation, suppliers of technical services, institutions for certification, testing and control.

As the modern conception of innovation emphasises, in many cases firms require support if they are to carry out commercially successful innovations. Typical activities include feasibility studies, development of the prototype, prototype testing, pilot production and marketing of the new product. For all of these activities, knowledge institutions and suppliers of knowledge-intensive services provide specific technical expertise and management support. Examples of technical support include design of the product by an outside designer and testing of a new product. An example of management support is the design of a project management tool for the innovating company, encompassing the whole or large parts of the product development processes.

The lack of studies with this focus and the lack of data in this area have provided the main impetus for a data-gathering initiative, harmonised among a number of countries with a view to undertaking international comparisons. This work has been pursued in connection with the OECD project on inter-firm collaboration in national innovation systems.[1] Austria, Denmark, Spain, Norway and Australia participated in the exercise.[2]

The chapter proceeds as follows. The next section broadens the conceptual framework by showing that, although the benefits of collaborations are generally recognised, there are also reasons for not collaborating. The third section provides a survey of the literature on inter-firm collaboration. The concluding argument in this section is that the literature has focused on studies of formal co-operation/joint ventures, as opposed to taking a broader perspective of collaboration which includes informal collaboration. Previous studies have focused on the role of universities as opposed to the broader set of knowledge generating institutions. Finally, it is argued that previous studies are centred on R&D collaboration rather than on innovation, and that internationally comparable data on this are lacking. The ambition in the present chapter is to focus investigations on these deficiencies. In the fourth section the data sources used in this study are explained in detail. We then go on to present descriptive statistics on the surveys. It is concluded that these statistics alone provide useful insights; however, in order to gain further insights into the multiple forces which drive collaboration between manufacturing firms and knowledge institutions, we need to undertake multivariate analyses. A estimated model is developed in the sixth section, and results from these analyses are discussed in the following section. Finally, in the concluding section, we highlight the implications of our findings for obtaining a better understanding of the issue, and indicate some general policy-relevant considerations.

Rationale for interactions between firms and knowledge institutions

Innovation consists of the creative use of various forms of knowledge in response to market-articulated demands and other social needs. In an interactive model of innovation, knowledge spillovers from other actors multiply the opportunities for innovating through creative recombination. In this model, innovation thus requires more than R&D. The production of goods and services is becoming more knowledge-intensive, but not necessarily more R&D-intensive. Other types of innovative efforts, such as design or market analysis, play an important role in innovation performance. The complexity, costs and risks involved in innovation have spurred the creation of a multitude of partnerships – so-called "networking". New and commercially useful knowledge is the result of interaction and learning processes among various actors in innovation systems (*i.e.* producers, users, suppliers, public authorities and scientific institutions). Knowledge exchange is thus not a unidirectional, but rather a multidirectional, flow, involving many actors from different sectors.

The determinants of innovation and learning have, in recent years, been studied by scholars developing the new "knowledge-based theory of the firm" (Cohen and Sproull, 1995), emphasising four organisational factors which influence the innovativeness of firms (Hämäläinen and Schienstock, 2000):

- *Diversity of knowledge*, which states that the required diversity of knowledge can only be attained when two or more different knowledge sets are combined.

- The development of shared knowledge bases among individuals with different knowledge sets calls for *intensive and long-term communication* between them. This sometimes means that co-operation between firms and knowledge institutions becomes problematic since the individuals' knowledge sets are different, thus making communication, and hence the creation of shared knowledge, difficult.

- *Social capital* includes the shared language and relational dimensions which shape the outcome of innovation processes.

- Finally, inventions do not become successful innovations until they have been combined with many different *complementary assets* and activities and brought to the market (Teece, 1987).

Highly specialised complementary knowledge often lies outside the firm's boundaries and involves the transmission of tacit knowledge – the knowledge of methods, designs and techniques which work in certain ways and with certain consequences. Universities and other knowledge institutions, as major producers of specialised knowledge, are increasingly expected to contribute to this process and to contribute substantially to the competitiveness of industries (Mansfield, 1995, 1997; Mansfield and Lee, 1996).

However, in a broad perspective, science undertaken at universities contributes to innovation in industry in three major ways:

- *By providing highly educated human capital.* The business sector receives inputs from universities in the form of human capital. Although these individuals may require further training, university education lays the foundations for the more specialised industrial training which will be provided by the firm. Nevertheless, the influx of freshly trained graduates brings new knowledge to firms.

- *By developing and providing new knowledge through research which is disseminated through publications and presentations.* However, such "public-good" knowledge needs to be adapted and absorbed before it can be used. The increasingly complex and specialised nature of modern science means that it is becoming increasingly difficult for firms, and , particularly for SMEs, to use potentially fruitful knowledge.

- *By developing and providing new knowledge through research which is disseminated through co-operative research projects or consultancy for the business sector*. However, due to their mission and long-term orientation, universities often do not fit well with the short-term orientation and profit-seeking behaviour of firms. On the other hand, as mentioned above, as firms increasingly specialise on their core resources and capabilities, knowledge institutions are becoming key suppliers of highly specialised complementary knowledge and often act as a bridge to potential partners.

The intensification of the interaction and co-operation between knowledge institutions (universities) and industry (Schmoch, 1999; Hicks, 2000; OECD, 2000) owes much to the following interrelated factors (OECD, 1998).

- Increasing budgetary stringency obliged policy makers to make tough choices in the allocation of funds to the science system. Universities and other public research institutions are forced to seek external sources of income and are thereby encouraged to carry out research work financed by industry. Indeed, there is a clear trend for a growing proportion of HERD to be funded by the business sector, while the total public share is steadily declining.

- At the same time, the "knowledge intensification" (OECD, 1996, 1997) of industrial production makes scientific knowledge more valuable to industry. So-called "science-based technologies" (biotechnology, information technologies, new materials) are defined as those fields which make frequent reference to scientific knowledge. This trend is also shown by the growing number of citations of scientific literature in patent documents (Schibany *et al.*, 1999).

From the industry perspective, there exists a strong incentive for firms to establish external linkages. All firms depend on their knowledge base, which is not uniform but rather consists of different layers of production-relevant knowledge (Schartinger *et al.*, 1999), One layer is the general scientific knowledge base, mainly shaped by universities and knowledge institutions. It varies widely

in its significance for the different sectors of economic activity, but firms use the publicly available stock of knowledge for other purposes than the specific data and conclusions found in research reports. Seen in this light, knowledge institutions serve to expand the technological opportunities open to firms. They do so by contributing to the stock of publicly available knowledge which can then be used by firms to support their innovation process.

The second layer consists of the knowledge bases at the level of sectors of economic activity. It is the underlying dimension according to which industries differ from one another – mainly in their propensity to use sources of knowledge which are external to the firm's innovation process. At this level, knowledge institutions act as a competence pool from which firms can draw to solve complex problems. The third layer constitutes the highly localised knowledge base of individual firms. This base may be informal and tacit, taking the form of the skills specific to individuals or groups of co-operating individuals required to fulfil a limited set of functions in which the firms are competent.

The multi-layered and differentiated knowledge bases of firms in a system suggest that the development of firm-specific knowledge is a complex process which evolves over time through processes of search, use, adaptation and research. Ideally, in each of the layers, firms have to apply the appropriate strategy in order to locate the relevant knowledge and absorb it in their organisation.[3] However, the strength of interactions between the industry and knowledge institutions is dependent on the absorptive capacity of the individual firm as well as that of the industry and the innovation system. Without internal capabilities, the firm is not likely to be an attractive partner in collaborative arrangements or to benefit fully from externally sourced knowledge. Hence, competence requirements vary somewhat according to the type of collaboration: universities differ somewhat from other types of partners in the level of competence required. For example, the existence of a formal R&D department within the firm may facilitate collaboration with universities, but is not necessary for collaboration with other types of knowledge institutions.

The rationales for interaction can be summarised as follows:

- Increased scale and scope of activities of participants.
- Reduction of uncertainty and costs.
- Increased ability to handle technological complexity and complementarities.
- Enhanced learning effects.
- Increased ability to capture external knowledge.
- Reduction of development times.

However, the benefits of CCN cannot be achieved alone. In each case, they have to be balanced against the actual and potential disadvantages of collaboration. These disincentives include the pure costs of CCN: search costs involved in finding the right partner, fear of disclosing strategic information, uncertainty about the benefits of collaboration; and the potential danger of inertia by establishing relationships with one or only a few external partners.[4]

Existing knowledge on inter-firm collaboration

As indicated in the Introduction to this chapter, one of the most important findings from recent innovation research is that innovation is an interactive process. This general characterisation of the

innovation process is by no means new. A classic study is the Sappho Project, which demonstrated the importance of interaction between departments and with customers for innovation success (Freeman, 1982). In the early 1980s, the Uppsala School, inspired by industrial marketing, developed a series of empirical studies of industrial networks that increasingly focused on innovation processes involving informal co-operation between firms (Håkansson, 1987, 1989). A major step forward was the formulation of the so-called chain-linked model, which was explicitly presented as a substitute for the predominating linear model for understanding innovation (Kline and Rosenberg, 1986). The latter model included not only links and feedback from external partners, but also the interplay between different departments within the firm.

The *empirical* analyses of inter-organisational collaboration in high-technology fields pursued at MERIT also pointed to the growing importance of interaction in innovation (Hagedoorn and Schakenraad, 1992). This body of academic research likewise influenced policy makers, who increasingly focused on encouraging interaction between agents as a means of stimulating innovation. This is reflected in the report from the OECD's Technology and Economic Programme (TEP) which emphasised that innovation is an interactive learning process (OECD, 1992). Data from the first round of the Community Innovation Survey (CIS) have been used to show that firms often find their sources of inspiration for innovation in other organisations, and that they seek these sources of inspiration with a multitude of partners rather than with a single external partner (DeBresson *et al.*, 1997). Likewise, the second round of CIS indicated a strong propensity to collaborate. In CIS-II, a question was included on *collaboration* for innovation (rather than on *R&D* as was the case in CIS-I). The replies show that roughly one in three manufacturing companies collaborate in the development of new products/processes. Firms in the Nordic countries seem to be relatively more inclined to collaboration; more than half of them collaborate on innovation. With respect to knowledge institutions, it is interesting to note that the frequency with which firms rate knowledge institutions as being important in the innovation process varies widely depending on the phrasing of the question. It would appear that the inspiration for innovation ("sources") is rarely supply-driven since knowledge institutions rank low in this question. However, when asked to assess the importance of these institutions in carrying the process through, many more firms responded that they were important.

The innovation literature generally studies the manufacturing sector, with innovation in the service sector being largely under-researched. Even in studies of the manufacturing sector, there is a bias towards technology-intensive sectors.

The increasing importance of knowledge-based competition means that companies place greater value on establishing co-operative relations with firms and institutions having complementary competencies. This is one way of staying abreast of the increasingly rapid pace of innovation in a era where knowledge quickly becomes obsolete and where the development of new products calls upon diverse technologies and even different knowledge bases. In line with this argument, one would expect firms to establish links with different types of partners and that these different institutional features would be important to the overall national innovation system. With the growing number of studies of the national innovation systems, our understanding of the role of such institutions has improved. For example, there is useful case-study evidence showing that differences in such national institutions as the professional training system (Lam, 1998) affect the form and effectiveness of these new forms of inter-organisational co-operation and networking. In particular, a large number of studies have focused on the interaction between higher education institutions and firms (as reviewed by Wu and Schibany elsewhere in this volume). As these reviews show, the majority of studies of these links are American. However, our knowledge of the links between knowledge institutions in the broad sense and inter-organisational CCN remains limited. To date, none of the available studies analyse a large number of European countries using a common methodology.

Data

In all international comparisons, an important precondition is a strict definition of the concepts used in data collection, agreement on sampling methods, the exact formulation of questions, etc. Experience gained in previous surveys such as the CIS shows that it has proven difficult to ensure comparability across the participating countries by agreeing upon a common approach and a set of guidelines for empirical work. As one element in harmonising the method for collecting empirical data on patterns of inter-firm collaboration in product innovation, the participating countries have agreed to use CATI (computer-aided telephone interviewing). As the data collection was carried out by telephone, it was not possible (nor totally desirable) to apply the precise definition used in CIS (Box 1 illustrates the differences).

Box 1. **Comparison with the CIS approach**

CIS Survey (OSLO Manual)	**Euro-DISKO Survey**
Between 1994-96, has your enterprise introduced onto the market any technologically new or improved products?	Has your company – alone or in conjunction with others – developed one or more new products within the past two years?
A **technologically new product** is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such *innovation* can involve ...	(If the company has only been involved with the development of other companies' products, the answer is "no".)
A **technologically improved product** is an existing product whose performance has been significantly enhanced or upgraded. A simple product ...	In this survey, **product development** means the development of a tangible product which in its design, its construction, its productive capacity or in any other way is new for the company.
• Technological innovations	We are *not* thinking of small modifications ...
• Innovation activities	Nor does the survey cover developments of new processes ...

In addition to the definition and the agreement to use CATI, a set of common questions were formulated for use as a reference point for the participating countries.[5]

These questions were specified to a set of core questions meant to be a common denominator for the national surveys. In addition to the core questions, individual countries included their own questions. Moreover, some countries undertook the survey at the project level as well; that is, firms were asked to cite their most important product development, and in-depth questions were asked on this product[6]. Despite efforts to harmonise the data collection, a limited number of fully comparable variables were obtained. Even small differences in the phrasing of questions and modifications of response categories may alter the strict comparability. Consequently, the following comparable variables were used:

- Type of partner.
- University, supplier (of materials/equipment), customer (public/private), competitor, technological institutes, institutes for certification, testing and control, consultants, technical advisors.
- Number of partners.
- Foreign/domestic partners.

- Services related to product development.

- Background variables (size, sector).

In interpreting the results from analyses of the data, one should bear in mind that even if two firms mention having collaborated on product development with an external partner, the form of collaboration may be different in the two cases. First, one firm may collaborate *every time* it develops a new product, while the other might have tried to collaborate once over the past two years, regardless of how many products they developed during this period. Second, the duration and intensity of collaboration may vary considerably between instances of collaboration. In some national surveys, questions were asked in order to collect information on this.

In addition to the definition of collaboration, there are at least three other major differences with regard to the data generated in this project and the data obtained from most other surveys. First, the focal point in the present survey is on innovation collaboration and not on R&D collaboration.[7] Second, in CIS, the focus on the use of external information sources primarily concerns the spark to the innovation process, whereas the present survey opens up the possibility to reveal with whom firms collaborate in carrying through the innovation process. Third, the focus on product innovation only and the use of telephone interviews instead of a postal survey makes these surveys more specific.[8]

Table 1 shows the sample distribution and response rate for the participating countries. All samples were selected randomly among the manufacturing firms with ten or more employees.[9] The participating firms in the countries represent the broad population of the firms in terms of industry and size. While the response rate of a postal survey means the number of filled-in questionnaires received, the response rate of a telephone interview includes the willingness of the respondent to answer even the first question (willingness to do the interview, Yes/No). With the exception of Austria, which had a response rate of 92%, the response rates range between 62% and 74%, which is satisfactory.[10] The overall rate is 73%.

Table 1. **Sample distribution and response rate**

Country	Number of firms contacted	Number of firms responding	Response rate
Australia	1 003	622	62%
Austria	1 006	927	92%
Denmark	1 500	1 022	68%
Norway	1 081	797	74%
Spain	594	400	67%
All countries	5 184	3 768	73%

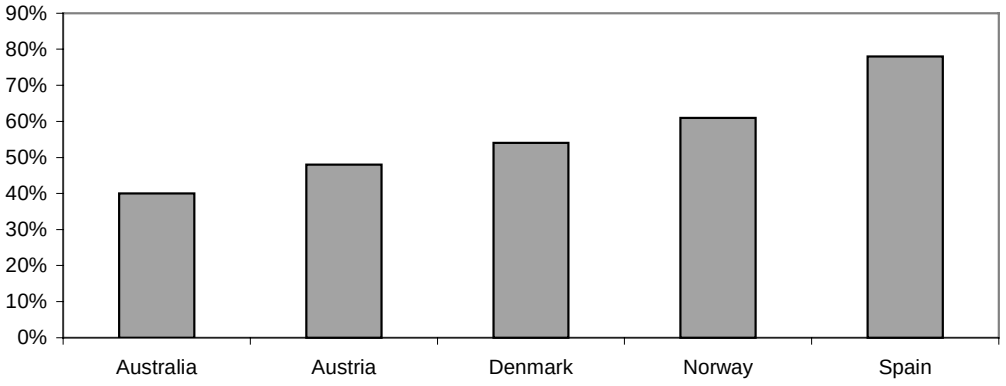
Descriptive statistics on the results of the surveys

The CIS and EuroDISKO surveys carried out in Australia, Austria, Denmark, Norway, Spain and the East Gothia region of Sweden, bear evidence to the fact that firms frequently collaborate on product innovation. As mentioned above, it should be stressed that the data show the share of firms which within a two-year period tried at least once to collaborate on product innovation. This does not mean that all firms collaborate each time they develop a new product.[11]

As depicted in Figure 1, Australia has the lowest percentage of innovating firms in the sample. Forty per cent of the firms had developed one or more new products within the last two years. In Austria, 48% of firms had developed one or more new products while, in Denmark, Norway and

Spain, the percentages are 54%, 61% and 78%, respectively. Thus, a large dispersion exists between the participating countries.[12] Compared to CIS-II, the innovation frequency is almost reversed for the countries. In CIS-II, Danish manufacturing firms have the highest percentage with 71%, followed by Austria with 67%, while the frequency in Norway and Spain is only 48% and 29%, respectively.[13]

Figure 1. **Percentage of firms innovating in participating countries**
Unweighted



Source: Harmonised EuroDISKO survey.

Table 2 shows the distribution of collaboration partners in participating countries, size, industry and Pavitt sectors. Of the 40% of Australian firms that have developed one or more new products, 86% collaborated with one or more partners on at least one of their product innovations within the last two years. In Austria, the share was 62%, in Norway, 80% and in Spain, 83%, while in Denmark, 96% of firms had collaborated on at least one of their product developments.[14]

At the general level, the propensity to collaborate rises only slightly with firm size (from 77% to 86%), although there are differences across countries. The results are as would be expected; in general, large firms engage more often in product innovation.[15] Hence, it can be expected that they are more likely to collaborate with one or more external partners. Also, external relations are often interpersonal. Since it has more employees, there is a greater likelihood that a large firm has at least one collaborating partner (the survey covers both formal and informal collaborative arrangements). Collaboration by industry also indicates that high-technology firms make slightly greater use of collaboration partners, *i.e.* science-based 85% *vs.* 77% for supplier dominated firms.

There is considerable variation across countries with regard to the frequency of collaboration with different types of collaboration partners. As is the case in other surveys, it is clear that key partners in all countries are customers (both private and government), and suppliers of materials and components. As noted above, the interactive character of the innovation process is emphasised in recent literature on innovation, and our results strongly support that perception. These partners are not simply market traders, they play an active role in decisions about which products are brought to the market.

Table 2. **Distribution of collaboration partner(s) in participating countries, by size, industry and Pavitt sectors**

Percentage, unweighted

	Collaborating in general	Knowledge institutions	University & research orgs.	Customers: private	Customers: govt.	Supply of mat. and comp.	Supply of equip.	Comp.
By country								
Australia	86	64	17	64	15	52	26	7
Austria	62	64	41	56	33	62	29	20
Denmark	96	67	17	71	21	75	45	13
Norway	80	74	55	58	18	62	38	31
Spain	83	91	60	53	25	58	49	15
By size								
10-19 empl.	78	62	22	62	21	62	38	18
20-49 empl.	81	67	27	64	21	61	33	14
50-99 empl.	80	73	38	64	24	63	41	16
100-199 empl.	84	78	49	58	21	70	44	21
200+ empl.	87	81	55	63	26	68	42	22
By industry[1]								
Food, beverages and tobacco	75	67	38	56	10	67	50	18
Textiles, wearing apparel, leather	80	76	30	63	33	73	37	21
Wood and wood products	57	66	29	47	11	71	37	18
Paper prod., printing and publish	84	66	35	62	25	62	45	33
Refined petrol. prod. & chem. and man-made fibres etc.	83	78	62	56	29	56	35	21
Rubber and plastic	81	58	33	78	18	72	41	14
Other non-metallic mineral prod.	77	79	46	53	24	60	47	13
Processing of basic metals	80	70	38	67	20	64	39	20
Machinery and equipment nec.	85	74	37	66	21	71	44	10
Electrical and optical equipment	86	82	46	62	35	58	32	25
Transport equipment	87	80	51	63	22	70	42	28
Furniture, manufacturing nec.	84	72	24	58	26	74	35	18
By Pavitt sector[1]								
Supplier-dominated	77	73	28	57	27	74	37	19
Scale-intensive	80	69	39	63	19	66	44	21
Specialised supplier	85	74	37	66	21	71	44	10
Science-based	85	80	52	60	32	57	33	23
All	81	73	32	62	22	64	39	18

Note: Firms can have more than one collaboration partner.
1. Australian data not included due to a different industry classification.
Source: Harmonised EuroDISKO survey.

Although, quantitatively, these partners play a significant role, other partners should be considered as well. One of the most striking differences is with respect to knowledge institutions and more specific universities and research centres, which are shown separately in the second column. Spanish firms frequently resort to the services of both types of partners (91% for knowledge institutions and 60% for universities and research centres). This too is the case for Norwegian firms (74% and 55%, respectively) and Austrian firms (64% and 41%). However, the universities and research centres are not favoured as collaboration partners by Danish and Australian firms (17% for universities and research centres, but 67% for knowledge institutions).

A possible explanation for this might be found in differences in institutional set-ups. One of the reasons why firms in Denmark might use universities and public research institutions as collaborating partners less frequently than do product-innovating companies in other countries could be the broad range of technological services offered by the intermediate technological service organisations which are part of the Danish GTS system (Approved Technological Service System). Also, as pointed out by Sanz-Menéndez *et al.* (1998), the relevance of universities and public research centres as central actors in innovative networks is also determined by the institutionalisation of research and development in a country. In Spain, which is dominated by public policies aimed at fostering and subsidising or supporting collaboration between public institutions and business organisations, it is not surprising to find that universities and public research centres are the most frequently used collaboration partners. This strong policy orientation has been confirmed by the fact that some 67% of Spanish firms involved in product development have received public support for what they identify as the most relevant project in the company.[16]

In Norway, the high percentages may be explained by: *i)* the relatively large number of research institutes; and *ii)* the number of policies which promote interaction between knowledge institutions and firms, but also between knowledge institutions and research institutes. The aim is to facilitate accessibility to relevant information by Norwegian firms; an example is the co-ordination between the Research Council of Norway and the Governmental Business and Regional Development Agency, whereby the former takes care of the financial aspects while the latter oversees the development of ideas, commercialisation, etc.

Collaboration with universities and public research centres is lower in Australia (17%) than in the other participating countries, with the exception of Denmark. The relatively low share may be explained partly by the institutional structure and partly by the likely (related) perception of the survey question posed. As Basri explains:[17]

> "The 17% average conceals an asymmetric distribution, with strong collaboration with universities in such fields as chemicals and machinery but low or zero collaboration in fields such as food, textiles or printing and publishing. Australia also has a range of largely publicly funded research institutions that are not part of the university structure. Agencies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Nuclear Science and Technology Organisation (ANSTO) and the Defence Science and Technology Organisation (DSTO) play a critical role in Australia's knowledge institutions system. Industries such as agriculture and food possess shared-cost research institutions known as RDCs (Research and Development Corporations), in which industry and government share research costs. There are 15 such corporations. Given the complex structure of these agencies, it is unclear if firms viewed collaborative relationships with such institutions in terms of "university and public sector research institutes" partners or as "knowledge institute" partners. This distinction is important since "knowledge institutions" (64%) are seen as important collaborative partners for new product development in Australia. It certainly seems as though collaborators in the food industry (a major Australian

sector) considered their partners as "knowledge institutions" rather than "universities and public sector research institutes."

Since more than 70% of government R&D funding in Austria is devoted to the higher education sector (the highest percentage in the OECD), it is difficult to interpret the relatively high co-operation rate with universities and public research institutes in Austria as a consequence of cuts in R&D funding (*i.e.* that universities are being "forced" to become more entrepreneurial and commercially oriented). According to Jörg *et al.* (1996), Austria demonstrates strong co-operation links between certain university institutes and commercial firms, reflecting personal relationships and initiatives of the firms. According to Jörg *et al.* (1996), there is also a desire within the university sector for greater co-operation and closer relationships.

An interesting result from Table 2 is that collaboration with knowledge institutions, and especially with universities and research institutes, are highly correlated with firm size; this is not the case for the other types of partners. As pointed out by Schibany (1998), this seems to be an expected result given that larger enterprises tend to employ more highly qualified personnel and are more likely to have in-house R&D facilities. Large science-based firms might be better prepared to communicate with universities since they are familiar with their codes and their cultures, while smaller firms might have greater difficulties in this respect. In addition, small firms do not always have the personnel and financial resources needed for collaborative projects with universities.

As is the case in the other countries, suppliers of technological services in Austria rank low as foreign collaboration partners. It is interesting to note that in all countries, technological services (suppliers of technological services, other private technical consultants and marketing and management) seem to be acquired largely from national sources. A possible explanation could be that expert knowledge, problem-solving know-how, etc., is at the very core of the "products" of knowledge-intensive services. An inherent problem associated with "buying" information is the fact that the value of the information is unknown until the purchase is completed. Accordingly, the choice of supplier is crucial to the product received. In a business which is rather opaque, firms might prefer to stick with national collaboration partners, with the added advantage that language barriers, cultural differences, etc., are reduced.

The table shows that, as would be expected, high-technology firms collaborate more often with knowledge institutions, and particularly with universities and research institutes.

Model description

The descriptive statistics revealed interesting features on inter-firm CCN in the five countries. However, we wished to analyse in more depth the nature of CCN and the possible combined effects of variables explaining CCN. Therefore, we developed a model to analyse the link between collaboration on product development with knowledge institutions and other variables. It should be strongly emphasised that the model was constructed under the restriction that the data enable analyses for all five countries. This pragmatic model is not ideal; in practice, a better model in terms of improved and more concise variables could be built for individual countries or for a couple of countries (for example, incorporating collaboration intensity, different degrees of innovation intensity, etc.).[18]

As mentioned above, we aggregated the categories universities, consultants, etc., and denoted these as "knowledge institutions" in order to have a common reference point and to increase the number of observations. Moreover, our knowledge of university-industry links has recently improved as a consequence of the growing interest in this issue. Nevertheless, we made our estimations on the specific sub-group of firms collaborating with universities and research organisations to verify if any

differences were revealed. In our model estimations, we tried different independent variables, one of which was firm size. With regard to sector, we use both the Pavitt sectors and the usual industry NACE 2 classification. We constructed a variable based on frequencies of partners, *i.e.* whether the firm has above or below the average number of collaboration partners. In addition, we tested in order to verify whether collaboration with a foreign partner is associated with collaboration with knowledge institutions.

What were the expected results? With regard to *firm size*, we would expect this to be strongly related to collaboration with knowledge institutions. The reasons for this are fairly straightforward and are clearly stated in the literature: greater knowledge base, more product development, more employees, more financial resources, etc. A specific feature of CCN with universities is the difficulties experienced by small firms in coping with differences in culture, time horizons, objectives, etc. As mentioned above, these differences are well recognised; however, they do not hinder collaboration for large firms to the same extent as they do for small firms. The culture, resources, time perspective, etc., of a large firm are more likely to match those of a university. We would therefore expect stronger results for calculations on CCN with universities and firm size compared to the results from calculations on the broader concept of knowledge institutions.

Tests for *sectoral classification* of the firm are expected to render results indicating greater collaboration in high-technology sectors. In the Pavitt terminology, we know from earlier research that high-technology firms are more frequently found in the category of specialised suppliers, especially firms belonging to the science-based industries. This above-average tendency to collaborate with knowledge institutions in the high-technology sectors is to be expected since it can be argued that product development in these sectors is more likely to be of a radical nature. Such radical innovations frequently require the involvement of knowledge institutions for collaboration on technical matters, patenting, etc. We would expect these two hypotheses to be even more clearly confirmed in the case of CCN with universities.

One would expect that firms which have the capacity to collaborate with an *above-average number of partners* also collaborate with knowledge institutions. Or that product developments in the group of firms which collaborate with knowledge institutions would be more supply-driven than for other firms? This would most likely demand a range of different partners since the inputs required for such innovations are often very complex. Related to this, if this hypothesis is true, then *suppliers should be relatively more important compared to customers* (customers are generally the most important and frequent partner). An additional explanation of why suppliers are likely to be important is that consultants, maintenance, etc., are often provided by suppliers.

If it is true that the knowledge-based economy is becoming increasingly international, then it would be expected that *firms which collaborate with knowledge institutions would have at least one foreign partner* (of some kind). The reasons for this may be linked to internationalisation in general, but also to the fact that firms may benefit from the assistance of national bodies set up to help domestic firms develop their export activities. Likewise, a firm trying to penetrate foreign markets, perhaps through collaboration with a local market player, may need to obtain certification and approval.

Finally, in addition to globalisation effects, we would also expect the existence of *country-specific* effects, mainly due to the fact that national institutional set-ups are likely to differ.

Results of the analysis

Collaboration with knowledge institutions

On the basis of the above, two models are estimated. The first describes a firm's ability to collaborate with knowledge institutions including universities and research institutes, while the second models collaboration with universities and research institutes only. As independent variables, the firm's interactions with other types of partners, firm-specific characteristics and country effects, are applied.

There is a certain amount of inconsistency between the industry classification used in the five countries. Australia uses the ANZSIC classification, while the other countries use NACE codes. In order to test for industry differences, model I in Tables 3 and 4 present data for the four countries for which industries are classified according to NACE. Data for Australia are not included in this model. Model II includes data for all countries although, due to different industry classifications, the industry variable is excluded in this model.

The data set covers 3 766 firms from Australia, Austria, Denmark, Norway and Spain. Of these, 2 040 (54%) firms have developed new products and 1 658 have at some time during a two-year period developed products in collaboration with external partners (81% of product-developing firms). 1 185 have collaborated with knowledge institutions (72%) and 606 with universities and research institutes (37%). Since both variables are binary (yes/no), the procedure for estimating the models are logistic regressions.[19] Table 3 shows the results for collaboration with knowledge institutions in a broad sense.

Firms with an above-average propensity to collaborate with other partners are 2.7 times more likely to collaborate with knowledge institutions.[20] Thus, the hypothesis that knowledge institutions become a bridge to other partners is proven true. On this basis one can put forward the hypothesis that the development of these products may be more supply-driven and complex.

Although the result concerning firms collaborating with at least one foreign partner is insignificant, there is a tendency towards the case that firms which collaborate with at least one foreign partner are more likely to collaborate with knowledge institutions. Furthermore, firms which collaborate only with suppliers are 1.5 times more likely to interact with knowledge institutions than firms which collaborate only with customers. Thus, there is evidence (although weak) that the development of products is supply-driven and complex ; although this only holds true for the first model where the Australian data is excluded.[21]

The parameter estimates for firms with 10-19 employees and 20-49 employees, have negative and significant signs while firms with 50-99 and 100-199 employees are insignificant compared to the benchmark category of 200 employees or more. The odds ratio indicates that firms with 10-19 employees are 2.6 times less likely to collaborate with knowledge institutions, while those with 20-49 employees are half as likely to collaborate with knowledge institutions compared to firms employing more than 200 workers. Thus, as expected, collaboration with knowledge institutions is positively related to firm size.

The large number of observation in the analysis enables industry differences to be traced. Using Pavitt's taxonomy as a reference point, there is no sign of differences in the propensity to collaborate with knowledge institutions, although the right sign is present for scale-intensive and specialised suppliers.[22]

In terms of country effects, Austrian firms are less likely to collaborate with knowledge institutions than are Norwegian firms, while the opposite is the case for Spain. No significant estimates can be traced in the case of Australia and Denmark. Norwegian firms are almost twice (1.7) as likely to co-operate than Austrian firms, while Spanish firms are three times more likely to use knowledge institutions than firms in Norway. As mentioned above, this is mainly due to the institutional set-up and thus the national systems of innovation.

Table 3. **Logistic regression on collaboration with knowledge institutions**

Dependent variable: collaborated with knowledge institutions – yes/no

	Model I			Model II		
Independent variables	Estimates	Std. error	Odds ratio	Estimates	Std. error	Odds ratio
Constant	1.496**	0.111	4.465	1.301**	0.096	3.680
Propensity to collaborate with other partners – under/equal average, benchmark: above	-0.990**	0.178	0.372	-0.941**	0.167	0.390
No collaboration with a foreign partner, benchmark: at least one foreign	-0.236	0.145	0.790	-0.220	0.133	0.802
Collaboration with suppliers/customers – benchmark: suppliers only						
Did not collaborate with suppliers or customers	0.665*	0.265	1.945	0.706**	0.236	2.026
Collaborated with customers only	-0.396*	0.191	0.673	-0.321	0.173	0.726
Collaborated with both customers/suppliers	-0.053	0.187	0.948	0.136	0.172	1.145
Number of employees – benchmark: 200+						
10-19 empl.	-0.968**	0.214	0.380	-0.862**	0.196	0.422
20-49 empl.	-0.715**	0.206	0.489	-0.564**	0.187	0.569
50-99 empl.	-0.407	0.240	0.666	-0.340	0.218	0.671
100-199 empl.	-0.129	0.226	0.879	-0.149	0.211	0.861
Pavitt – benchmark: science-based						
Supplier-dominated	0.001	0.225	1.000			
Scale-intensive	-0.307	0.182	0.735			
Specialised suppliers	-0.025	0.228	0.975			
Country – benchmark: Norway						
Denmark	-0.211	0.167	0.809	-0.233	0.164	0.792
Austria	-0.519**	0.183	0.595	-0.519**	0.181	0.595
Spain	1.139**	0.256	3.124	1.186**	0.251	3.274
Australia				-0.245	0.200	0.783
Log likelihood	1 506.38			1 764.82		
Correct predicted	74.7%			72.6%		
N	1 447			1 658		

Collaboration with universities and research institutes

This section deals with a more narrow definition of knowledge institutions in terms of universities and research institutes which in many studies provides the point of departure. Although interactions with these institutions are not new, in the last decade, the study of these interactions has

become more frequent and systematised. This growing interest stems from the fact that governments and policy makers increasingly regard knowledge from universities and research organisations as an under-utilised technological resource which may help firms to gain competitive advantage.[23] Moreover, much of the literature comes from the United States, where universities are managed in a more entrepreneurial manner, while universities in Europe are administrated according to public regulations (Schmoch, 1999). Thus, an European analysis provides an interesting point of comparison.

When the dependent variable is changed to deal with firms collaborating with universities and research organisations only, not only do the results become even stronger for firm-specific variables such as size and sector but the estimates for the five countries are more dispersed. Table 4 shows that all size categories vary significantly from the benchmark category of firms with more than 200 employees. Thus, collaboration with universities and research organisations is shown to be even more closely related to firm size, *i.e.* firms with 10-19 employees are approximately three times less likely to collaborate with universities and research organisations than firms with more than 200 employees.

Supplier-dominated firms like *textiles, wearing, apparel, leather* and *furniture, manufacturing nec*, but also scale-intensive firms such as *paper production, printing and publishing and rubber and plastics*, collaborates significantly less with universities and research organisations than firms in the science-based sector.

The country variable shows the largest effect. Danish firms are more than six times less likely, Australian firms five times less likely and Austrian firms half as likely, to collaborate with universities and research organisations compared to Norwegian firms, while no significant differences in the country variable can be detected for Spain.

As was the case with the estimations for knowledge institutions, the same results exist for firms with an above-average propensity to collaborate with other partners. Thus, firms with a high propensity to collaborate with other partners and firms collaborating with at least one foreign partner are more likely to collaborate with universities and research organisations. Likewise, firms collaborating with at least one foreign partner are more likely to collaborate with universities and research organisations. On the other hand it is not possible to verify the hypothesis concerning supplier collaboration.

Table 4. **Logistic regression on collaboration with universities and research institutes**

Dependent variable: collaborated with knowledge institutions yes/no

	Model I			Model II		
Independent variables	Estimates	Std. error	Odds ratio	Estimates	Std. error	Odds ratio
Constant	1.496**	0.111	4.465	1.301**	0.096	3.680
Propensity to collaborate with other partners – under/equal average, benchmark: above	-0.990**	0.178	0.372	-0.941**	0.167	0.390
No collaboration with a foreign partner, benchmark: at least one foreign	-0.236	0.145	0.790	-0.220	0.133	0.802
Collaboration with suppliers/customers – benchmark: only suppliers						
No collaboration with suppliers/customers	0.665*	0.265	1.945	0.706**	0.236	2.026
Collaborated with customers only	-0.396*	0.191	0.673	-0.321	0.173	0.726
Collaborated with both customers/suppliers	-0.053	0.187	0.948	0.136	0.172	1.145
Employees – benchmark: 200 or more						
10-19 employees	-0.968**	0.214	0.380	-0.862**	0.196	0.422
20-49 employees	-0.715**	0.206	0.489	-0.564**	0.187	0.569
50-99 employees	-0.407	0.240	0.666	-0.340	0.218	0.671
100-199 employees	-0.129	0.226	0.879	-0.149	0.211	0.861
Pavitt – benchmark: science-based						
Supplier-dominated	0.001	0.225	1.000			
Scale-intensive	-0.307	0.182	0.735			
Specialised suppliers	-0.025	0.228	0.975			
Country – benchmark: Norway						
Denmark	-0.211	0.167	0.809	-0.233	0.164	0.792
Austria	-0.519**	0.183	0.595	-0.519**	0.181	0.595
Spain	1.139**	0.256	3.124	1.186**	0.251	3.274
Australia				-0.245	0.200	0.783
Log likelihood	1 506.38			1 764.82		
Correct predicted	74.7%			72.6%		
N	1 447			1 658		

Summary and conclusions

The analysis described in this chapter is based upon one of the very few truly comparative, quantitative data sets on CCN in different countries. The main results are reported in Christensen and Rogaczewska (1998). Compared to that report, the present analyses have been broadened, both in scope (with the inclusion of more countries and a broader concept of knowledge institutions) and method (multivariate analyses). From analyses of the data using multivariate methods, we found additional interesting conclusions compared to those arrived at using frequency analysis alone. We will point to four such conclusions, which were not fully reflected in the OECD (1998) synthesis report (which was based on frequency analysis and four countries only).

First, firms collaborating with knowledge institutions are more likely to have multiple partners. This may reflect the fact that knowledge institutions function as bridging institutions to other partners. Moreover, since suppliers are relatively more important for firms collaborating with knowledge institutions, one may hypothesise that product innovations in these firms are more complex and supply-driven. However, we have no solid proof of this.

Second, firms collaborating with knowledge institutions are more likely to collaborate with at least one foreign partner. This may complement the pattern described above of multiple partners for such firms. It would appear that these firms conform to a greater extent to the characteristics of firms in what has been labelled the "new economy" – extensive networking and an international orientation.

Third, we found that a Pavitt classification of the firms showed over-average propensity to collaborate with universities and research institutes among science-based firms and specialised suppliers.[24]

Fourth, it is evident that variances of estimations are greater for analyses of CCN with universities compared to knowledge institutions. This may indicate that CCN with universities is confined to a more narrow, specialised segment of manufacturing industry. Attempts to boost collaboration to other segments that may not be able to participate, or do not see any economic benefits to be gained from participation, in such collaborative agreements may turn out to be counter-productive.

Fifth – and perhaps less of a new conclusion compared to earlier results – we found clear country effects to show that national innovation systems are indeed different, and that the institutional set-up of a country provides a framework for the propensity to collaborate on innovation.

Speed and complexity are the terms that best describe the way in which the innovation process has developed over the last few years. Both of these factors have policy implications. First, and related to the argument presented in the paragraph above, the speed of technological development may call for the development of more flexible innovation policies. In this development, policy makers must be very clear as to which areas require a permanent public presence in the market, for example in the general technological counselling infrastructure, and which areas – perhaps those related to the development of specific technological fields – might benefit from temporary public stimulation of CCN. Second, the complexity of the innovation process is no longer related only to the fact that many innovations are based in different knowledge bases (Pavitt, 1998). As described in this chapter, it also has to do with the fact that firms rely on multiple partners in their innovation processes. Therefore, stimulation of CCN among different types of partners in the innovation system may be an efficient means to spur industrial development.

Given the fact that innovation and collaboration are key for the industrial developments of tomorrow, it is interesting to better understand how collaboration can be stimulated. This has become

a major policy issue. However, the design of policy measures to stimulate CCN must be considered carefully. Although ,we comply with the general conclusion that CCN benefits innovation, not all CCN is beneficial and there is no linearity or even simple regularities in the outcomes to be achieved by increasing CCN (if it were at all possible to measure such outcomes with any precision). Thus, CCN requires resources, and productive learning may be much stronger with some partners than others (whose contribution may even prove counter-productive). This is not to say that policies should be guided by the traditional market failure argument. Market failure as a rationale for innovation policy has generally been abandoned both theoretically and by advanced policy makers. Rather than focusing upon failures, policies are now more concerned with how policy may be used to stimulate knowledge flows in the system. Therefore, the challenge for policy makers is to think carefully about the design of policies and the quantitative measures that are appropriate to spur CCN and innovation. A further argument as to why policy formulation in this area should not be too simplistic is that national innovation systems differ, even between countries which are similar in many other respects. CCN policies should therefore be adapted to the environment in which they are to operate.

Comparing propensities to collaborate between countries, we find marked differences. However, the normative interpretation of these differences is particularly difficult. What in one institutional setting might be less than optimal may in another setting be too much. In other words, national innovation systems are above all national. One country's propensity to collaborate should not be used uncritically as a benchmark for other countries. In fact, pursuing such a strategy could introduce tensions into the system. This point needs to be borne in mind in any cross-country comparison of the share of firms collaborating with universities and the share of firms collaborating with knowledge institutions in the broader sense. If all national innovation systems were alike, these ratios would tend to be equal, which is certainly not the case.

The results direct our attention towards the role of knowledge-intensive services in the innovation process. The data indicate that manufacturing firms have become redoubled their use of knowledge-intensive services. The data from our own surveys as well as the CIS data both show that somewhere between 30%-50% of the firms surveyed had established co-operative links with consultancy, technological service firms, universities, etc.

At the core of the "products" of knowledge-intensive services lie specialised expert knowledge, research and development abilities, problem-solving know-how, etc. (Strambach, 1997). In this vein, it can be argued that knowledge-intensive services provide a diversity of specialised expertise, which (if the firms succeed in utilising this knowledge) enhances firms' abilities to adjust more rapidly to a continuously changing environment posing new threats and challenges. The demand for knowledge-intensive services can thus be said to illustrate the strong need for new learning and change within firms and organisations. Further, as revealed by in-depth interviews in the Danish DISKO survey and as pointed out by Sanz-Ménendez *et al.* (1998), technological services such as testing and control institutes play another important role: since they are external to the firm, they provide legitimacy in terms of the quality of the technological and innovative activities of the firm. Furthermore, even if certification, etc., may seem trivial issues, such services function as an entry point to more advanced services. Thus, factors such as technological skills and legitimacy of technological actions and initiatives place knowledge-intensive services at the heart of the development process.

This points to the need for industrial policy which pays greater attention to knowledge-intensive services and proactively encourages the use of such services as a way of enhancing the organisational and technological transformations of firms. Innovation policy must be alert in at least two respects: an inherent problem associated with buying information is that the value is not known until the actual purchase. Equally, the choice of supplier is crucial to what the firm actually receives. Needless to say, this choice is very difficult and could be facilitated by government guidance as to the specific kinds of knowledge that firms can buy from specific suppliers. An important policy task is to increase the

transparency of the market for knowledge-intensive services. An important element in encouraging the use of knowledge-intensive services would be to build trust among potential users. As pointed out by Lundvall and Borras (1997), quality control, *i.e.* the instruments and institutions necessary to monitor the quality of knowledge-intensive services, could be a crucial mechanism in achieving this. Another important policy task is to ease the *accessibility* of (especially small and medium-sized) firms to knowledge-intensive services by promoting networks and partnerships which active involving firms and specific knowledge-intensive services in the definition of strategic innovative actions.

One strategy for policy learning within this field is to increase exchange of cross-country experiences. This is already taking place with national civil servants studying CCN schemes in other countries. However, the processes are fragmented and to some extent constrained by, for example, language differences. They would benefit from studies of systematic, research-based foundations.

Annex

SURVEY METHODOLOGY

Population

The DISKO survey defined the population of companies as those:

- Listed under the heading Manufacturing, NACE codes 15-36.
- With more than 10 employees.

Recommendation on sampling

Target of approximately 400 manufacturing companies that:

- Have introduced a new product on the market within the last three years.
- Have engaged in some form of collaboration with external parties.

The variables

- Development of new or improved physical product within the last three years
- Development of new service, related to the physical products, conditional on new physical product
- Collaborative links (0/1),

⇒ list of collaborators from the DISKO survey

⇒ distinction between foreign and domestic and public/private customers

⇒ rating on a 4-point importance scale of the indicated collaborators

In addition to the core questions, individual countries included their own questions. Moreover, some countries undertook the survey on the project level as well; that is, firms were asked to mention their most important product development, and in-depth questions were asked on this product.

NOTES

1. More recent comprehensive approaches used to survey collaboration by innovative firms include the CIS (First and Second Community Innovation Surveys) and the PACE Survey (Policies, Appropriability and Competitiveness for European Enterprises).

2. Sweden undertook a survey similar to that carried out in the other countries. However, it covered only one region of Sweden and the data are only included in this chapter as *ad hoc* references.

3. It is important to emphasise that this is a truly ideal, theoretical situation. In practice, access to external knowledge is often based on ad hoc, personal contacts rather than on systematic search. Likewise – although this has surely improved with the increased focus upon knowledge management – firms rarely have a strategy concerning how external knowledge is disseminated internally. These two conclusions are derived from qualitative studies in Denmark on interactions among a selection of the manufacturing firms in this study and knowledge institutions as their external partner. The firms were interviewed by telephone, followed up by a personal interview and the CCN partner was identified and interviewed, thus allowing the researchers to assess both parties' perceptions of the co-operation.

4. See, for example, Hansen (1999). This author argues that weak ties within organisations have an advantage in the search position compared to strong ties when sharing codified and independent knowledge, while weak ties lead to problems in transferring tacit and dependent knowledge.

5. The main categories of questions refer to: type of partner, reason for and importance of collaboration with the specific type of partner, duration and intensity of collaboration, mobility of labour during collaboration, services related to product development.

6. Indeed, individual countries have much richer databases compared to the common database built for this project. Thus, even more interesting analyses could be undertaken if the number of countries were reduced.

7. A second CIS survey, building on the methodological and analytical lessons learned from the first phase (1991-93) was launched in 1997. Here, the question on R&D collaboration has been replaced with one on innovation and collaboration.

8. A more detailed explanation on the methodology which underlies the data collection in the Danish survey (which functioned as a role model for the other surveys) is available at http://www.business.auc.dk/disko/disko-attach/disko2.pdf.

9. The Australian survey included firms with less than ten employees.

10. In the East Gothia region of Sweden, the response rate was 70% (of a total of 954 firms contacted).

11. The Danish DISKO survey showed that 59% of the firms in more than half of the cases collaborate with external partners in the process of product development.

12. In the East-Gothia region of Sweden, the percentage was 37%.

13. One explanation could be that Euro-DISKO deals only with product innovations, while CIS-2 also takes process innovations into account.

14. In the East Gothia region of Sweden, 70% of manufacturing firms collaborated on product innovation.

15. However, the development of new products per employee is not higher than for small firms. In the Danish DISKO survey, the number of product developments per employee was 0.3 for firms with 10-19 employees and 0.1 for firms with more than 50 employees.

16. However, as pointed out by Sanz-Méndez *et al*. (1998), due to the original composition of the data set used for the sampling of the empirical analysis, the percentage is very surprising and lower than was expected.

17. We are grateful to Ester Basri of University of Western Sydney for providing this information on Australian features

18. In fact, the data have been used in a wide range of national reports and academic papers.

19. A logit/probit estimation would have given the same results.

20. Calculated as the inverse of the odds ratio.

21. Although the models showed no sign of multi co-linearity between the independent variables, the three variables concerning partners are to some extent interrelated (although not seriously). However, if only one of the variables is included in the estimation procedure, they all become significant with the right sign as expected.

22. The NACE 2 classification shows that the *food, beverage and tobacco, paper products, printing and publishing, chemicals and man-made fibres, etc*., and *rubber and plastics* industries, are all less than half as likely to collaborate with knowledge institutions compared *to electrical and optical equipment* which is selected as the benchmark category.

23. See Cohen *et al*. (1997) for a review highlighting the importance of interactions with universities in the sense that such interaction enhances firms' sales, R&D and patenting productivity.

24. This is, however, not the case when analysing knowledge institutions in the broad sense.

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Chapter 13

UNIVERSITY-INDUSTRY RESEARCH CO-OPERATION IN CHINESE TAIPEI

by

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Introduction

The economy of Chinese Taipei was traditionally based on labour-intensive industries requiring little sophisticated technology. Industrial firms had minimal motivation to invest in research and development (R&D) and relied on cost advantages to compete. In addition, companies did not co-operate with either research institutes or universities. Nevertheless, the situation has changed markedly in the past few years. As countries such as Thailand and China have followed in the footsteps of Chinese Taipei and developed industries based solely on cost advantage, many of Chinese Taipei's traditional firms have lost their competitive advantage and must now reinvent themselves if they are to remain viable. The government is assisting this transformation; for example, the Ministry of Economic Affairs has set up the New Product Development Fund to support industrial firms willing to develop risky products for which there is a sizeable potential market. Furthermore, in 1993, the National Science Council (NSC) set up a committee to encourage research co-operation between universities and industry. These efforts are expected to significantly influence the technological upgrading of industry in Chinese Taipei.

Nevertheless, university-industry (U-I) research co-operation is a new concept for most of Chinese Taipei's universities and corporations. Enhancing university-industry research co-operation is difficult unless the benefits are clearly understood by the various actors. Consequently, this study aims to explore the following important questions:

- What motivates universities and industrial firms to become involved in research co-operation?
- What are the major factors affecting university-industry research co-operation?
- How do universities and industrial firms communicate regarding research co-operation?
- What are the major influences on the performance of university-industry research co-operation?
- What is the role of government in improving research links between university, and industry?

Review of the literature

University-industry interactions: current situation and future trends

Since universities and industrial firms have different cultures and different objectives, many countries have implemented laws specifically designed to promote co-operation between universities and industry. For example, the Japanese Government has enacted the "Promotion Act for the Promotion of U-I Technology Transfers", the major focus of which includes: *i)* increasing research funding to universities – funding for universities accounts for 44% of the Japanese R&D budget; *ii)* lowering barriers to university research with a view to repositioning universities as key centres both for cultivating human resources in S&T and for conducting R&D; and *iii)* promoting technology transfer from universities to industry by calling upon the universities to establish "technology licensing offices" (Fujisue, 1998).

Similar actions have also been adopted in Europe. In December 1987, Italy established the Association of Research and Continuing Education to promote and manage co-operation between universities and industry, with particular emphasis on continuing education for engineers. This association is the first formal organisation overseeing government-university-industry co-operation in Italy (Cantoni, 1997).

The widely acclaimed US National Co-operative Research Act was passed in 1984. Since that time, the US Government has devoted considerable attention to the role of universities in transferring technology and promoting economic development. Nevertheless, until 1990, the resources of US universities continued to be under-utilised by industry. Many scholars regard "cultural differences" as the major reason for this under-utilisation.

The major goals of universities are the pursuit of new knowledge and the maintenance of academic freedom, while industry is more focused on short-term profits. Lee (1996) investigated the opinions of 1000 professors at 115 universities, and found the following:

- University researchers with a technical background are more likely to support university-industry co-operation than those without a technical background. Meanwhile, researchers who oppose U-I co-operation mostly do so on the basis that U-I interactions may interfere with the research and university autonomy.

- The share of public funding in university research has been gradually decreasing, causing universities to approach industry for research funds, and thus affecting how university faculty members conduct research and co-operate with industry.

- Incentives and motivations, such as including patents and technical reports in decisions about tenure, affect how university researchers interact with industry.

- Compared with the 1980s, in the 1990s university researchers and faculty members began to adopt an increasingly positive attitude towards university-industry research co-operation.

Baldwin and Link (1988) studied American research alliances and found that the number of members in university-led research alliances always exceeds that of alliances led by other entities. The reason for this is that university research is more generic and less specific, and thus stimulates the interest of a greater number of enterprises. In terms of incentives to encourage university-industry interactions, the US National Science Foundation (NSF) has established a "Distinguished Young Scholar Fellowship", the winner of which is awarded research funds by the NSF on the condition that

he/she obtains matching funds from industry. Another approach is to sponsor university researchers to undertake short-term residential programmes in industrial firms during sabbaticals or breaks.

A closer examination of the situation at the global level reveals that while many countries have recently tried to promote university-industry co-operation, the actions taken have differed according to their particular situations.

Types of university-industry co-operation

Perters and Fusfeld (1982) point out that university-industry interactions can be formal or informal and that the length of co-operation can range widely – from under one hour to more than 30 years. Steward and Gibson (1990) classify university-industry interactions in four major categories: *i)* classroom; *ii)* publication; *iii)* research; and *iv)* financial links. The same study goes on to identify 72 types of links through which professionals from industry and universities interact. Atlan (1987) divides the major university-industry interactions into six categories: *i)* general support; *ii)* contract research; *iii)* research centres and institutes; *iv)* research consortia; *v)* industrial affiliate programmes; and *vi)* business incubators.

According to the above descriptions, different types of co-operation can be used to integrate the resources of universities and industry and stimulate scientific and technological development. In Chinese Taipei, five modes of U-I interaction can be defined. The first comprises *co-operative research projects*, which are mainly supported by the National Science Council (NSC). The NSC generally requests that university researchers find partners from industry, and the industrial firm normally puts up only a small part of the total funds for co-operative research, with the remainder being provided by the NSC. The second type of interaction involves *industrial corporations contracting a research project to a university*. In general, industry sets the research objectives, and the university then conducts the research. In the third interaction mode, *university researchers conduct technical services for industry*, while the fourth type of interaction covers situations in which *industrial firms hire university professors as consultants*. Finally, the fifth variety of interaction involves a *university providing technical training for industrial professionals*. Among these five approaches, the first and second modes are closely related to research and technological development and will be emphasised in this chapter.

The NSC initiated the University-Industry Research Co-operation (UIRC) programme in 1991. As of January 1998, a total of 140 companies and 14 universities had participated in 84 U-I projects. The NSC provided some USD 50 million to support the programme, supplying roughly 80% of the programme's research funds (Wu, 1999). Generally, the intellectual property rights (IPR) of the co-operative research results belong to the NSC. However, if a company provides more than 30% of the total funding for a project, it will be offered either exclusive or early licensing rights. For contract research, companies usually have to provide the totality of the required funds and in return can expect to receive the IPR of the research results, an important boost to competitiveness.

Motives for university-industry research co-operation

The motives for university-industry research co-operation are believed to significantly affect the nature of the co-operation, in turn affecting its degree of success. Therefore, studies of U-I co-operation have long focused on the underlying motivations. Table 1 lists the major motives of industrial firms seeking co-operation with universities. While businesses mainly aim to exploit technology, additional benefits can also be realised, such as cost reductions and access to highly skilled potential employees.

Table 1. **Major motives spurring industrial firms to co-operate with university**

Motives	Related research
1. Obtain knowledge of basic research and emerging technologies	Roessner *et al.* (1998) Geisler *et al.* (1991) Elsevier (1989) Tseng (1990)
2. Obtain direct technical support	Roessner *et al.* (1998) Geisler *et al.* (1991)
3. Increase interactions with other organisations or technical staff	Roessner *et al.* (1998) Meyes (1988) Smilor (1987)
4. Reduce costs and risks	Elsevier (1989) Chen (1985) Liu (1983) Tseng (1990)
5. Shorten learning curves	Smilor (1987) Liu (1983)
6. Obtain access to expensive facilities at universities	Elsevier (1989) Liu (1983)
7. Gain vital knowledge about competitors	Elsevier (1989)
8. Stimulate creativity for R&D	Elsevier (1989) Spark (1985) Liu (1983)
9. Recruit promising students as future employees	Roessner *et al.* (1998) Spark (1985) Elsevier (1989) Liu (1983) Tseng (1990)

The motivations of the universities appear simpler than those of business. In most countries, as governments face mounting budget pressures, universities begin to turn to industry for research funds. In addition, some university professors are so oriented to real-world problems in their research that it is quite natural for them to seek co-operation with industrial firms. Table 2 lists the major motives underlying universities' desire to co-operate with industry.

Table 2. **Major motives for university to co-operate with industry**

Motives	Related research
1. Increase sources of research funding	Dierdonck and Debackere (1988) Geisler *et al.* (1991) Elsevier (1989) Tseng (1990)
2. Provide opportunities to learn about new industrial practices	Dierdonck and Debackere (1988) Geisler *et al.* (1991)
3. Seek opportunities to use facilities of private enterprises	Elsevier (1989)
4. Enhance understanding of business value and stimulate innovation	Spark (1985)
5. Provide students with opportunities for jobs	Elsevier (1989) Tseng (1990) Wu (1998)
6. Gain access to industry funds with less red-tape	Geisler *et al.* (1991)

The importance of communication…

Maximising the benefits to be gained from co-operative research imperatively calls for greater *communication* between universities and industry. A number of studies highlight that both the frequency and type of communication have a significant impact on the success of U-I research co-operation. For example, Wu (1993) showed that distance necessarily affects U-I research co-operation, but that the barriers imposed by distance can be reduced through frequent communication. Vedovello (1998), in a study of a science and technology park located in southern New England, found that 20 out of 21 companies had interactions with local universities. Nevertheless, geographical factors may not be critical in Chinese Taipei, given the small size of the island. Communication can be categorised as: residential programmes at universities, residential programmes in firms, meetings and discussions, documents and letters, telephone, and computer networks. Although this issue is critical to any study of technology transfer and co-operation, few studies have been carried out in Chinese Taipei, particularly for university-industry interactions. This chapter therefore includes an overview of the frequency and types of communication.

…and of commitment

Based on case studies of university-industry co-operative research, Wu (1998) indicates that *commitment* of behalf of both universities and industry is a key factor in the success of U-I research co-operation. From the industry perspective, the following questions arise: *i)* Within the company, do the researchers who contact the university systematically change? *ii)* Is the co-operative research project strategically important to the firm? *iii)* Does the company have an internal programme running in parallel to the university research? The commitment of university researchers is also likely to be critical to the success of co-operative research projects.

Research design and methods

Research objects and questionnaire surveys

This study focuses on two types of university-industry research co-operation: NSC's UIRC and contract research. For the former, the sample comprises the 70 UIRC projects that ran from 1993 to June 1999. Obtaining the data and information necessary to survey of this type of project was straightforward since it was readily available from the National Science Council. Separate questionnaires were sent to the contact persons who oversaw the project at the university and the firm, respectively. In the case of the contract research, since the projects were not always registered at the university, and since the university's administrative office was sometimes reluctant to disclose information about contact persons or type of research project, it was difficult to obtain the information necessary for questionnaire surveys. Therefore, this study focuses on research projects based in four major universities (Table 3). Twenty-five questionnaires were mailed to professors in these universities; each recipient was asked to send the questionnaires(s) to their industry partner(s).

Table 3. **Research projects of universities (except NSC's UIRC)**

Universities	Number of samples
Taiwan University	25
Chao-Tung University	25
Chung-Hsing University	25
Cheng-Kung University	25
Total	100

Of 379 surveys sent out, 78 were returned. Deducting ten incomplete surveys leaves a total effective sample of 68 returned questionnaires: 45 from universities and 23 from industrial firms. The total effective rate of return is 18%, 26.5% from universities and 11% from industrial firms (Table 4).

Table 4. **Number of questionnaires mailed out and returned**

	Mail to university	Mail to industry	Return from university	Return from industry	Effective questionnaires from university	Effective questionnaires from industry
NSC UIRC project	70	109	25 (35.7%)	17 (15.6%)	21 (30.0%)	15 (13.8%)
Contract research	100	100	27 (27%)	9 (9%)	24 (24%)	8 (8%)
Total	170	209	52 (16.2%)	26 (12.4%)	45 (26.5%)	23 (11.0%)

The questionnaire is based on a nominal scale, and uses Likert's 1-5 scale to measure motives, types of communication, commitment and performance. For some constructs, Cronbach's α coefficient is used to verify the internal validity. Nunnally (1978) indicates that the measurement has high validity if the α coefficient is greater than 0.7. Wortzel (1979) also notes that the value of 0.7-0.98 indicates a high validity. For those constructs with an α coefficient of less than 0.7, each item is analysed separately.

Research framework

According to the literature review, the major influences on the performance of university-industry research co-operation include motivations, type of communication, commitment from both sides. Some additional mediating factors, such as the type of co-operative research, individual experiences of previous U-I interactions, and the level of technology involved, are believed to influence the performance of U-I research co-operation. The research framework is shown in Figure 1. Table 5 lists the major research variables and items included in the study and questionnaire.

Figure 1. **Research framework**

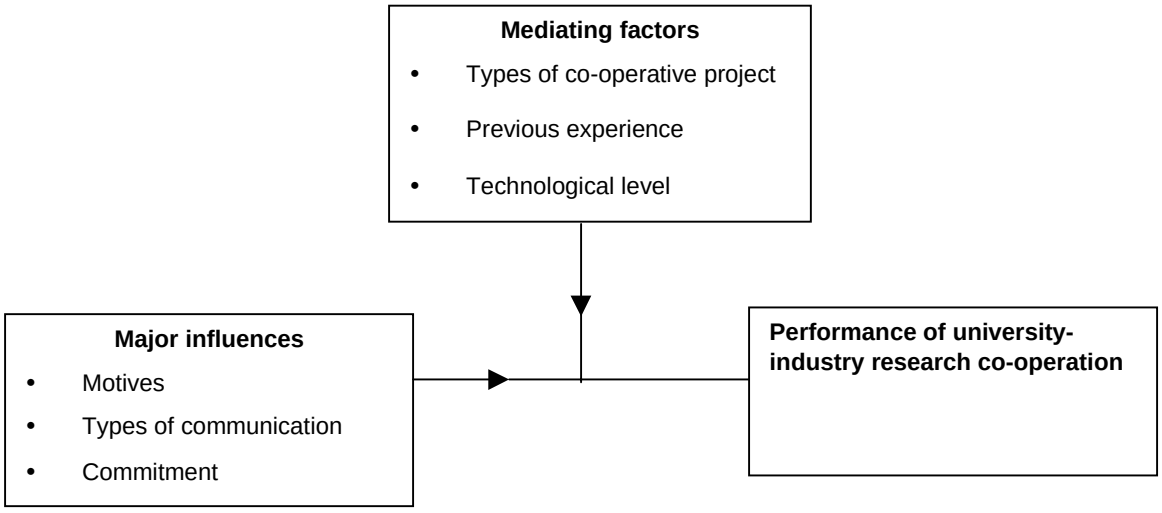


Table 5. **Research variables and items included in questionnaire**

I. Major influences

1. Motives:
   (1) University
      - Increase sources of research funding
      - Gain access to industry funds with less red-tape
      - Increase the application or commercialisation of university research
      - Participate in "real" projects
      - Gain access to specific equipment from industry
      - Provide students with opportunities to study real-world problems

   (2) Industry
      - Reduce R&D costs
      - Obtain leading-edge research and technological know-how
      - Solve specific problems
      - Overcome the shortage of technical staff
      - Gain access to expensive equipment at universities
      - Recruit good students
2. Communication types:
      - Residential programme in the firm
      - Residential programme at the university
      - Meetings and discussions
      - Documents and letters
      - Telephone
      - Computer network
3. Commitment:
   (1) University
      - Effort and involvement by university researchers
      - Degree of commitment the university perceives on behalf of the firm

   (2) Industrial firm
      - Degree to which the co-operative project is appreciated
      - Frequency with which the corporate researchers are changed
      - Degree to which the firm provides facilities and equipment
      - Degree of commitment the firm perceives on behalf of the university

II. Mediating factors

1. Types of co-operative project:
   (1) NSC UIRC project
   (2) Non-NSC contract research
2. Previous UIRC experience:
   (1) With experience
   (2) Without experience
3. Technological level:
   (1) Basic research
   (2) Applied research
   (3) New product development
   (4) Technical support
   (5) Engineering improvement

III. UIRC performance

1. Performance and satisfaction (industry)
2. Performance and satisfaction (university)

Data analysis tools

SPSS/SAS is the main software package used to analyse the data. The major statistical methods and their uses are as follows:

- *Pearson coefficient:* to analyse how each variable relates to performance.
- *t-test:* to test differences of mean values for comparable variables, such as NSC's UIRC *vs.* contract research, university vs. industry, and so on.
- *Cronbach's α:* to check internal reliability.

Analysis of research results

This study investigates the motivations behind and the practices involved in university-industry research co-operation and the correlation of these factors with the success of U-I co-operation. Separate surveys were sent to university professors and industrial firms; thus the results are analysed separately.

Motives for university-industry research co-operation

Table 6 lists the mean values of each of the motives behind university co-operation with industry. The factor with the highest mean value is "desire for further application and commercialisation of university research", followed by "willingness to participate in practical research". The motivation factor that is generally considered to be the most significant; namely, "increasing sources of research funding", ranks only third. The survey results reveal that university professors are in fact practice-oriented and that the popular view of professors "living in ivory towers" is a misconception.

Table 6. **Perceived mean value of the motives for U-I interactions by academic researchers**

Motives	Mean	S.D.
1. Further apply or commercialise university research	4.38	0.65
2. Participate in "real" projects	4.11	0.78
3. Increase sources of research funding	3.93	0.86
4. Provide students with opportunities to study real-world problems	3.51	1.10
5. Gain access to industry funds with less red-tape	3.00	1.22
6. Need particular equipment from industry	2.64	1.21

Table 7 lists the mean value of the motivations for industry to seek co-operation with universities. The desire to obtain knowledge on leading-edge research and emerging technologies ranks highest, closely followed by the desire to solve particular problems encountered in their industrial operations. These findings are fairly predictable as it can be difficult for industrial firms in general, and SMEs in particular, to conduct basic or leading-edge research. Most firms therefore rely on universities for basic research or emerging technologies, while others seek help in solving specific problems involving advanced or specialised knowledge.

Table 7. **Perceived mean value of the motives for U-I interaction by industrial researchers**

Motivation	Mean	S.D.
1. Obtain leading-edge research and technological know-how	4.00	0.90
2. Solve specific problems	3.96	0.77
3. Overcome the shortage of technical staff	3.87	0.76
4. Recruit good students	3.30	1.06
5. Reduce R&D costs	3.13	1.10
6. Obtain access to expensive equipment at universities	2.61	1.12

Types of university-industry communication

Tables 8 and 9 list the mean values of the major types of communication between universities and industry from the perspectives of the universities and industry, respectively. The two sides appear to attribute more or less the same importance to the six types of communication. Face-to-face meetings and the telephone are the two most popular methods of communication between university and industrial researchers. Surprisingly, residential programmes in either a company or a university, which are popular in many other countries, are seldom used in Chinese Taipei. Communication via the Internet and video-conferencing systems is not yet widely used, perhaps partly due to the small size of the country.

Table 8. **Mean values attributed by academic researchers to different types of communication**

Communication types	Mean	S.D.
1. Meetings and discussions	4.00	0.83
2. Telephone	3.82	1.07
3. Documents and letters	3.00	1.21
4. Computer network	2.69	1.20
5. Residential programme in the firm	2.49	1.25
6. Residential programme at the university	2.33	1.19

Table 9. **Mean values attributed by industrial researchers to different types of communication**

Communication types	Mean	S.D.
1. Meetings and discussions	4.26	0.75
2. Telephone	3.91	0.60
3. Documents and letters	3.57	0.66
4. Computer network	3.00	1.28
5. Residential programme at the university	2.39	1.08
6. Residential programme in the firm	2.09	1.16

Commitment

In terms of the commitment of university researchers to co-operative research, this study investigates two areas: *i)* university researchers' views regarding their own commitment and effort;

and *ii)* university researchers' thinking about the efforts of their industrial counterparts. The results indicate that university researchers see themselves as more committed than their industry partners (Table 10). On the other hand, Table 11 lists the mean values of the commitment of corporate researchers. The results indicate that industry researchers make roughly the same judgements regarding the commitment of academic and industry researchers.

Table 10. **Perceived commitment by academic researchers**

Corresponding commitment	Number of samples	Mean	S.D.
1. University researchers' own commitment	45	4.49	0.63
2. Industrial researchers' commitment	45	3.84	0.95
T-test for the difference between (1) and (2)	t-value	D.F.	P-value
	4.517	44	0.000**

Note: ** =statistically significant.

Table 11. **Perceived commitment by industrial researchers**

Corresponding commitment	Mean	S.D.
1. Degree to which the co-operative project is appreciated	4.30	0.56
2. Frequency with which the corporate researchers are changed	3.61	0.94
3. Degree to which the firm provides facilities and equipment	4.17	0.58
4. Degree to which the firm perceives the commitment of the university	4.19	0.72

Note: Number of samples: 23.

Performance of university-industry research co-operation

Universities and corporations have different objectives for interacting with each other; it may be useful to examine the performance of co-operative research separately. The results are shown in Tables 12 and 13, respectively.

Table 12. **Performance of university-industry co-operation, as perceived by academic researchers**

Perceptual performance	Mean	S.D.
1. Overall satisfaction	4.02	0.62
2. Realisation of objective	3.91	0.73

Note: Number of samples: 45.

Table 13. **Performance of university-industry co-operation, as perceived by industrial researchers**

Perceived performance	Mean	S.D.
1. Realisation of objective	3.83	0.78
2. Enhancement of technological capabilities	3.83	0.49
3. Cost reductions	3.30	0.70
4. Transfer of results into profits	3.39	0.66
5. Incorporation of results into the R&D system	3.78	0.67
6. Overall satisfaction	3.83	0.72

Note: Number of samples: 23.

Overall, university researchers appear to be more satisfied than industrial researchers, although industrial researchers are satisfied in certain areas, such as the enhancement of technological capabilities and the incorporation of the results of university research into the wider R&D system. However, industrial researchers are less pleased on other counts, such as reducing costs and transferring research results into profit.

Performance vs. *motives, types of communication and commitment*

The Cronbach α coefficients of group items for measuring the performance of UIRC from the perspective of both the university and the firm are greater than 0.7. Therefore, their mean values will be taken as an indicator of overall performance. Table 14 lists the Pearson coefficients between performance and motives, types of communication, and commitment for university researchers. The data show that the performance values of university researchers with higher motives of application and commercialisation, is positively correlated. As far as types of communication are concerned, the data indicate that university researchers who use university residential programmes, face-to-face meetings and telephones as their primary communication tools also perform better. Regarding commitment, performance is enhanced if university researchers meet with commitment from industrial firms.

Table 14. **Correlation of motives, types of communication and commitment with performance**
As perceived by academic researchers

		Pearson correlation
Motivation	1. Increase sources of research funding	0.188
	2. Gain access to industry funds with less red-tape	0.241
	3. Further apply or commercialise university research	0.316*
	4. Participate in “real” projects	0.151
	5. Need for particular equipment from industry	0.274
	6. Provide students with opportunities to solve real-world problems	0.143
Type of communication	1. Residential programme in the firm	0.213
	2. Residential programme at the university	0.342*
	3. Meetings and discussions	0.469**
	4. Documents and letters	0.214
	5. Telephone	0.421**
	6. Computer network	0.124
Commitment	1. Effort and involvement by university researchers	0.132
	2. Degree to which the university thinks the industrial side is committed	0.630**

Note: Number of samples = 45; *:p<0.05 **:p<0.01.

Table 15 lists the Pearson correlation coefficients of performance with motives, types of communication, and commitment, based on the perceptions of industrial researchers. The data demonstrate that a higher mean value of motivation for solving a particular problem may enhance performance. Regarding communication methods, the survey yields some surprising results: the use of documents and letters as the major communication mechanism is actually negatively correlated to performance (although the correlation is not statistically significant). As for commitment, industrial researchers are of the view that if they could provide better facilities and if the university researchers were more committed, performance would be significantly improved.

Table 15. **Correlation of motives, types of communication, and commitment with performance**
As perceived by industrial researchers

		Pearson correlation
Motives	1. Reduce R&D costs	0.040
	2. Obtain leading-edge research and technological know-how	0.323
	3. Solve specific problems	0.416*
	4. Overcome the shortage of technical staff	0.126
	5. Obtain access to expensive equipment at universities	-0.129
	6. Recruit good students	0.174
Type of communication	1. Residential programme in the firm	0.264
	2. Residential programme at the university	0.121
	3. Meetings and discussions	0.319
	4. Documents and letters	-0.072
	5. Telephone	0.371
	6. Computer network	0.000
Commitment	1. Degree to which the co-operative project is appreciated	0.331
	2. Frequency with which the corporate researchers are changed	0.024
	3. Degree to which the firm provides facilities and equipment	0.584**
	4. Degree of commitment the firm perceives from the university	0.741**

Note: Number of samples = 23; *:p<0.05 **:p<0.01.

Type of co-operation as a mediating factor

This study investigates two major types of university-industry co-operative research, namely the NSC UIRC project and contract research. Whether motives, types of communication, and commitment differ between these two types of research is an important question. Table 16 lists the results based on the replies from university researchers, and indicates that the motive of commercialisation and application of UIRC projects significantly exceed that of contract research. This is because NSC requires university participants in the UIRC programme to be application-oriented. On the other hand, the motivations for contract research may depend on the major purpose of the firm, whether it is solving a particular problem or gaining access to leading-edge technical know-how. Regarding the correlation between the major influences and performance for the NSC UIRC projects and contract research, the study finds that when the participants are motivated by further commercialisation and application, performance is enhanced. When the objectives of both sides are more consistent,

performance is obviously enhanced. On the other hand, the results show no difference between UIRC projects and contract research in terms of motivations. This finding implies that NSC financial subsidies may not have a significant impact on the motivations behind U-I co-operation. The results also indicate that the motivation to solve a specific problem is highly correlated with performance for contract research, but not for NSC UIRC projects.

Table 16. **T-test for the difference between NSC UIRC projects and contract research**
As perceived by university researchers

Number of NSC UIRCs: 21 Number of contract research projects: 24		T-value
Motives	1. Increase sources of research funding	-0.549
	2. Gain access to industry funds with less red-tape	-0.484
	3. Further apply or commercialise university research	2.460*
	4. Participate in “real” projects	-0.510
	5. Need particular equipment from industry	1.628
	6. Provide students with opportunities to study real-world problems	-0.467
Type of communication	1. Residential programme in the firm	0.887
	2. Residential programme at the university	0.249
	3. Meetings and discussions	1.466
	4. Documents and letters	-0.245
	5. Telephone	0.758
	6. Computer network	-0.608
Commitment	1. Effort and involvement by university researchers	0.824
	2. Degree of commitment the university perceives from the firm	0.083
Performance	1. Overall satisfaction	0.734
	2. Obtain the objective	0.350

Note: Degree of Freedom: 43; *: $p<0.05$ **: $p<0.01$.

Previous experience as a mediating factor

The results of the survey of university researchers (Table 17) indicate that, depending on whether or not they have previous experience of U-I research co-operation, researchers differ in their use of documents/letters and the telephone as communication tools. The mean value (3.75) of researchers without experience in using documents/letters as a major tool of communication with industrial researchers is significantly higher than that of researchers with previous experience (2.73).

Table 17. **T-test for the difference between university researchers with and without experience**

Number of samples (with previous experience): 33 Number of samples (without previous experience): 12		T -value
Motives	1. Increase sources of research fund	-1.505
	2. Gain access to industry funds with less red-tape	-1.104
	3. Further apply or commercialise university research	-0.757
	4. Participate in “real” projects	1.015
	5. Need particular equipment from industry	-1.195
	6. Provide students with opportunities to study real-world problems	-0.876
Type of communication	1. Residential programme in the firm	-1.682
	2. Residential programme at the university	-1.743
	3. Meeting and discussion	-0.813
	4. Documents and letters	-2.698*
	5. Telephone	-2.740**
	6. Computer network	-0.203
Commitment	1. Effort and involvement by university researchers	-0.606
	2. Degree to which the university thinks the industrial side is committed	-0.656
Performance	1. Overall satisfaction	-2.103
	2. Obtain the objective	-1.427

Note: Degree of freedom: 43; *: $p<0.05$ **: $p<0.01$.

Regarding the use of the telephone, the mean value (4.50) of researchers without previous experience of U-I research co-operation significantly exceeds that of university researchers with experience (3.58). This could imply that university researchers lacking previous experience are unfamiliar with industrial firms, and thus need to communicate more with industry. Concerning performance and overall satisfaction, it seems surprising that the mean value (4.33) of researchers without experience exceeds that (3.91) of those with experience. This might indicate that researchers without experience are more willing to participate in first-time co-operation with industrial firms, thus enhancing performance and satisfaction. The results of the correlation between major influences and performance, illustrated in Table 18, indicate that the motive of “further applying and commercialising university research” is highly correlated with performance and satisfaction for researchers without experience. This relationship may imply that university researchers with previous experience of co-operative projects have clear objectives and motivations for “further application and commercialisation”. However, the motivations of researchers without experience may be less clear-cut. As for the type of communication, while the use of “meetings and the telephone” as communication tools is correlated with performance for researchers with previous experience, the correlation is insignificant for inexperienced researchers. Instead, for inexperienced researchers the use of “residential programmes at university and industrial firms” is correlated with performance. Apparently, university researchers with previous experience use meetings and even simply telephone calls to communicate effectively with industrial researchers and attain their goals. However, inexperienced researchers may require “residential programmes” for effective results, owing to the better, more frequent and longer-term communication. The correlation of performance with commitment is statistically significant for all researchers, regardless of their level of experience.

Table 18. **Correlation of performance with motives, communication types and commitment**

		Pearson correlation coefficient of university researchers' (a, b) performance with:	
		a: with previous experience (no. of samples: 33)	b: without previous experience (no. of samples: 12)
Motives	1. Increase sources of research funding	0.116	0.277
	2. Gain access to industry funds with less red-tape	0.121	0.507
	3. Further apply or commercialise university research	0.393*	0.000
	4. Participate in "real" projects	0.267	0.046
	5. Need particular equipment from industry	0.155	0.560
	6. Provide students with opportunities for real-world problems	0.062	0.303
Type of communication	1. Residential programme in the firm	0.015	0.588*
	2. Residential programme at the university	0.189	0.594*
	3. Meetings and discussions	0.577**	-0.145
	4. Documents and letters	0.132	0.067
	5. Telephone	0.344*	0.480
	6. Computer network	0.080	0.277
Commitment	1. Effort and involvement by university researchers	0.080	0.244
	2. Degree of commitment the university perceives from the firm	0.590**	0.784**

Note: *: $p<0.05$ **: $p<0.01$.

The results of the survey of the perspectives of industrial researchers (Tables 19 and 20) indicate that the mean value (3.81) of experienced industrial researchers significantly exceeds that (3.00) of inexperienced researchers regarding the use of documents/letters as communication tools. This would suggest that industrial researchers utilise "documents/letters" to communicate effectively with university researchers, and rely on documents to keep track of the progress and outcomes of the U-I co-operative projects; however, documents and letters are used to a much lesser extent by inexperienced researchers. Regarding "the degree to which the co-operative project is appreciated by the corporate management", the results indicate that researchers without previous experience (mean value: 4.71) have to follow the project far more closely than do more experienced researchers (mean value: 4.13). "Obtaining leading-edge research and technology know-how" is found to be positively correlated with performance in the case of experienced researchers, while "using expensive university equipment" is negatively correlated with performance. Experienced industrial researchers could probably enhance leading-edge research and knowledge themselves; although the expectation of gaining access to expensive university equipment is unrealistic. The correlation between performance and commitment is positive for both experienced and inexperienced researchers.

Table 19. **T-test for the difference between industrial researchers with and without previous experience**

Number of samples (with previous experience): 16 Number of samples (without previous experience): 7		T-value
Motives	1. Reduce R&D costs	1.213
	2. Obtain leading-edge research and technological know-how	-1.002
	3. Solve specific problems	-0.176
	4. Overcome the shortage of technical staff	1.266
	5. Gain access to expensive equipment at universities	0.913
	6. Recruit good students	-0.790
Type of communication	1. Residential programme in the firm	-1.344
	2. Residential programme at the university	-0.950
	3. Meetings and discussions	1.106
	4. Documents and letters	3.238*
	5. Telephone	-0.454
	6. Computer network	0.000
Commitment	1. Degree to which the co-operative project is appreciated	-2.619*
	2. Frequency with which the corporate researchers are changed	0.598
	3. Degree to which the firm provides facilities and equipment	-1.435
	4. Degree of commitment the firm perceives from the university	-0.486
Performance	1. Realisation of objective	-1.313
	2. Enhancement of technological capabilities	-1.131
	3. Cost reductions	-0.552
	4. Transfer of results into profits	-1.617
	5. Incorporation of results into R&D system	-1.029
	6. Overall satisfaction	-1.435

Note: Degree of freedom: 21; *:p<0.05 **:p<0.01.

Table 20. **Correlation of performance with motives, types of communication and commitment**

As perceived by industrial researchers

		Pearson correlation coeff. of university researchers' (a,b) performance with:	
		a: with previous experience (no. of samples: 33)	b: without previous experience (no. of samples: 12)
Motives	1. Reduce R&D costs	0.170	0.067
	2. Obtain leading-edge research and technological know-how	0.540*	-0.031
	3. Solve specific problems	0.229	0.641
	4. Overcome the shortage of technical staff	-0.068	0.677
	5. Gain access to expensive equipment at universities	-0.574*	0.612
	6. Recruit good students	-0.149	0.482
Type of communication	1. Residential programme in the firm	-0.261	0.602
	2. Residential programme at the university	-0.139	0.286
	3. Meetings and discussions	0.105	0.660
	4. Documents and letters	0.496	-0.417
	5. Telephone	0.080	0.638
	6. Computer network	0.167	-0.279
Commitment	1. Degree to which the co-operative project is appreciated	0.019	0.563
	2. Frequency with which the corporate researchers are changed	-0.264	0.284
	3. Degree to which the firm provides facilities and equipment	0.206	0.852*
	4. Degree of commitment the firm perceives from the university	0.734*	0.803*

Note: *:$p<0.05$ **:$p<0.01$.

Technological level as a mediating factor

This study divides the technological level into five categories: basic research, applied research, new product development, technical support, and engineering improvement. However, the study finds that most of the samples collected belong to applied research (24 samples) and product development (14 samples). The numbers for the remaining samples, from basic research, technical support and engineering improvement, are all less than five. The analysis will thus focus on applied research and product development. From the perspective of industrial researchers, the results show no difference between applied and development projects. This means that the motives, communication types and commitment level are not affected by whether the co-operative project is applied research or development-oriented. Results for the correlation between the major influences and performance indicate that performance is highly correlated with the motivations "further application and commercialisation of the research results" for applied research projects, but not for product development projects. In terms of type of communication, the use of face-to-face meetings and discussions are closely correlated with performance ($p<0.001$). The results of the samples of industrial perspectives are similar, and indicate a difference between applied research and development projects regarding the use of face-to-face meetings and discussions. This could imply that industrial firms perceive a risk that intellectual properties and trade secrets could be leaked during co-operative projects with universities on new product development. In contrast, the commitment of university researchers is correlated with performance, whether in applied research or development projects.

Suggestions for improvement

In addition to behavioural surveys, suggestions by both university and industrial researchers regarding ways of improving the university-industry linkage were investigated; the results are listed in Table 21. University researchers would like to see increased government financial subsides for U-I co-operative research projects and recommend the setting up of co-operative research centres oriented towards industrial technologies. Industrial researchers would prefer that the intellectual property rights resulting from co-operative research be delegated to industrial firms; like university researchers, they also favour the establishment of co-operative research centres located on university campuses.

Table 21. **Suggestions by university and industrial researchers**

Suggestions	No. of university respondents who agree	% of university respondents who agree [1]	No. of industrial respondents who agree	% of industrial respondents who agree [2]
1. Increase financial subsidies for UIRC	30	66.7%	16	69.6%
2. Set up "Patent and Licensing Offices" on campus	16	35.6%	9	39.1%
3. Establish U-I Co-operative Research Centre for Industrial Technologies	26	57.8%	19	82.6%
4. Delegate intellectual property rights to universities	15	33.3%	3	13.0%
5. Delegate intellectual property rights to firms	10	22.2%	20	87.0%
6. Government to provide incentives	6	13.3%	1	4.4%

1. University sample size: 45.
2. Industrial sample size: 23.

Research results

Research co-operation between universities and industrial firms in Chinese Taipei has become an important issue since the early 1990s. Although the concept is new to many researchers, from both universities and industry, some impressive results have already emerged due to the efforts of the National Science Council, Ministry of Education, industrial firms and universities. This study found that "further applying and commercialising university research", "participating in real-world practices" and "increasing sources of research funds" are the three major motives of university researchers in co-operating with the industry. On the other hand, the three major factors motivating industrial firms to co-operate with universities are "obtaining leading-edge research and technological know-how", "solving a specific problem" and "overcoming the shortage of technical staff". In terms of types of communication, the research findings indicate that both parties regard "face-to-face meetings and discussions" as the most important communication tool. Furthermore, both see their partner's commitment as a key determinant of performance and satisfaction in U-I co-operation. Concerning the correlation of performance with the major influences, the results indicate that the motivations "further applying and commercialising university research", communication types of "meetings", "telephone calls" and "residential programmes", and commitment are correlated with performance from the perspective of the university. From the industry viewpoint, the motivations of "solving a specific problem" and commitment are highly correlated with performance.

Regarding mediating factors, research indicates that previous experience and technological level affect U-I co-operation and performance. University researchers tend to use "meetings" and "telephone calls" in order to communicate with their industrial counterparts, although those without previous experience prefer to use "residential programmes" for more effective and longer-term communication. As for the level of technology, the analysis shows that "meetings" are highly correlated with performance in the case of applied research projects. However, "meetings" are insignificant for product development projects. In addition, the results indicate that participation in co-operative projects which benefit from government subsidies does not affect performance. From the perspective of industrial researchers, the results show that all three mediating factors also have some impact on U-I co-operative behaviour and performance. For contract research, the motivation of "sharing facilities and equipment" is correlated with performance, but the correlation is insignificant for the NSC UIRC projects. In addition, the motivation of "obtaining leading-edge research and technological know-how" is highly correlated with performance for researchers with previous experience, but the correlation is insignificant for those lacking previous experience. On the other hand, the use of "meetings and discussions" is correlated with performance and satisfaction for applied research projects, but not for product development projects.

Conclusion and policy implications

Conclusion

Although university-industry research co-operation is fairly new in Chinese Taipei, the number of co-operative research projects appears to be on the increase, and some of the projects have produced exciting results. This study investigates two major types of U-I co-operative research, NSC UIRC and contract research, and analyses the opinions of academic and industrial researchers.

The intention to apply and commercialise research and to conduct practical research are the two major motives spurring university researchers to co-operate with private corporations. On the other hand, obtaining leading-edge research knowledge and solving specific problems are the major motivations pushing industrial firms to seek co-operation with universities. As for communication methods, both universities and industry prefer face-to-face meetings. In addition, both parties believe commitment and facilitation to be the biggest influence on UIRC failure or success.

Regarding the performance of UIRC, the results of samples of university researchers' perceptions indicate that the degree of motivation applied to research results and commercialisation is correlated with performance. In the case of industry, the degree to which the firm desires to solve a specific problem is also correlated with performance.

As for the mediating factors, concerning the types of co-operation, the results indicate that university researchers are not affected by the type of co-operative research. However, for contract research, the degree to which firms provide facilities is correlated with performance. Furthermore, levels of experience and technology (mainly applied research and development) could also affect the U-I co-operative behaviour and performance. Based on survey results, this study finds that governments can significantly improve the link between university and industry.

Policy implications

The analysis shows that both industrial and university researchers recognise the role of government in university-industry research co-operation. Some policy implications can be drawn, as follows:

Policy makers should not consider financial subsidies as a panacea of U-I research co-operation

According to the research results, NSC UIRC projects and contract research do not differ in terms of the motives underlying co-operative research. Consequently, government funding for U-I co-operative research may not be critical.

Policy makers should consider differences in motivations among researchers

The data analysis and results reveal that these motivations may significantly impact the performance of U-I research co-operation. Policy makers should be able to identify key individuals or organisations to support U-I co-operative research.

Policy makers can help set up intermediary organisations to facilitate university-industry linkages

Universities and industrial firms exist for different purposes and many barriers impede research co-operation among researchers. Communication and co-operation can be expected to become smoother if intermediary organisations are established, such as a patent and licensing office or a U-I co-operative research centre.

Policy makers should consider delegating intellectual property rights to universities or firms

Intellectual property rights have always been a very important subject. In Chinese Taipei, in 1998, the Legislative Yuan enacted a Science and Technology Basic Law which allows universities to own the intellectual property rights to the results of co-operative research. However, a more flexible system which shares ownership with industry would be more beneficial to both sides.

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PART IV

POLICY

Chapter 14

THE ROLE OF GOVERNMENTS IN NETWORKING

by

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Introduction: general considerations on the role of governments in networking

Governments have become increasingly aware of the growing importance of co-operative networks. In recent times, they have developed various policies aimed at facilitating the creation and efficient functioning of inter-firm networks. In general, such policies were developed on an ad-hoc basis rather than based on a thorough analysis of their economic rationale, one reason for this being that research on networks to date has – with a few exceptions – paid relatively little attention to policy. Recent research on innovation systems has stressed the importance of networks for the innovation process, but has generally been rather vague about the role for government.

Due to the limited research on network-facilitating policies, policy makers today have at their disposal little information about: *i)* the conditions under which network arrangements prove more efficient than alternative organisational solutions; *ii)* the types of problems or "failures" that typically occur when setting up and operating networks; and *iii)* which of these problems can be resolved most efficiently by government.

In today's economies in which companies increasingly focus on their core competences and in which the creation and exchange of knowledge among an increasing number of specialised institutions plays an important role, new types of economic interactions are coming into being. Although the process of adjusting to these new interactions can be costly and cumbersome for the economic agents involved, many of these processes are resolved through self-organisation. In particular, the problems associated with co-operation and networking can often be solved efficiently by large firms (re-incorporation into hierarchies) and self-organised institution building (*e.g.* membership of business associations).

Bearing these caveats in mind, there is reason to believe that public policy can, and should, address networking. The costs of setting up and running a network tend to fall primarily on the organisations actively promoting it; they stem from the process of finding the right partners, negotiating, creating behavioural rules for co-operation and building the necessary shared resources. For most of these processes, often no market exists or else it is incomplete. However, the benefits of an efficient network tend to accrue to all of its members. This is also true for the costs of actually

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running a network. Partners might want to "free-ride" on the transaction costs born by the co-ordinators of a network. Thus, networking obviously has a public good or externality dimension; the private benefits from network formation may not cover the private costs for some partners, although the social benefits are likely to be substantial. Firms will only engage in networking if the perceived private benefits of setting up a network exceed its private costs. Therefore, there may be room for efficiency-enhancing government intervention to address the aforementioned awareness, information, search and transaction cost problems associated with networking.

These problems occur at different stages of the networking process; thus, the role to be played by public policy differs accordingly. The stages include:

i) *Awareness* of a networking possibility.

ii) S*earch* for partners.

iii) Building *trust* and a shared knowledge base.

iv) *Organising* the network.

v) Ensuring *complementary resources*.

vi) *Active* co-operation.

Failures seem to be more prominent in the early stages of network formation and operation (search, setting-up, trust formation, etc.); in the final stages they can be solved by the network participants themselves. The role of policy must change accordingly: it should not continue to support networks once they are established and their benefits have become obvious to participants. At this stage, all participants should have found and put in place mechanisms for contributing fairly to the costs and sharing the benefits. Rather, the role of governments should shift to one of avoiding the "lock-in" phenomena of established networks and the detrimental effects that established networks can have on competition in product markets.

Country case studies on network policies

To review recent developments in network policies and to depict how they tackle these problems, the OECD Focus Group on Innovative Firms and Networks carried out policy case studies for Austria, Denmark, Finland, Greece, Hungary, Italy, Switzerland and Chinese Taipei (Table 1).[1] For an overview of the network-oriented policies covered by the policy case studies see Table A1.1 in the Annex to this chapter.

These case studies looked into the ways in which these countries approached network policies. They were carried out using a common format in order to obtain comparable (although mainly qualitative) information. The format is described in detail in the Annex to this chapter and could be used and further developed in future case studies. The Austrian case is provided in the Annex to this report as an example for such policy case studies.

Table 1. **Overview of network-oriented policies: a selection from the country case studies**

Focus of programme		Awareness of the possibilities offered by networking	Search for partners	Building trust and a shared knowledge base	Organising the network	Ensuring provision of comple-mentary resources	Active co-operation	Type of programme
Country	*Name of programme*							
Austria	**K**plus	**X**		**X**		**(X)**		Targeting science-industry linkages
	Ki_{nd}/K_{net}			**X**			**(X)**	Targeting science-industry linkages
	Export cluster	**X**	**X**	**X**		**(X)**		Addressing export-oriented networks of enterprises
Switzerland	Promotion of applied research by CTI – standard projects					**X**	**(X)**	Promoting ISR networks via financing the salaries of researchers at public institutions
	CTI – thematically oriented support projects (see below)							Mix of various programmes with differing thematic focus
	General reform of specialised colleges					**(X)**	**(X)**	General reform, with special focus on technology transfer and co-operation with the private sector
	SOFTNET	**X**			**(X)**		**X**	Enhancing ISR in the software sector
	MEDTECH	**(X)**					**(X)**	Technology transfer in medical technology
	Start-up							Enhancing the number of start-ups from the higher education sector
Denmark	Centrecontract-scheme	**X**			**(X)**	**(X)**	**X**	Intensification of co-operation between universities, private firms and technological service institutes
	Technology incubators		**(X)**			**X**		Provision of state-financed seed-capital to innovative entrepreneurs
	Business-to-business-scheme		**(X)**				**X**	Supporting the development of a private business sector in the Baltic region, with a special focus on SMEs

Focus of programme		Awareness of the possibilities offered by networking	Search for partners	Building trust and a shared knowledge base	Organising the network	Ensuring provision of comple-mentary resources	Active co-operation	Type of programme
Country	*Name of programme*							
Finland	National workplace development	**X**		**X**	**X**	**X**		Launching new network facilitation activities and projects
	Centre of expertise programme	**X**	**X**	**X**	**X**	**X**	**X**	Programme-based regional networking strategy involving various institutions
	Wood Wisdom	**X**	**X**	**X**	**X**		**X**	Finnish cluster programmes
	Well-being cluster	**X**	**X**	**X**	**X**	**X**	**X**	Finnish cluster programmes
Greece	Action for SMEs	**(X)**					**X**	Promotion of collaboration among firms
	SYN					**X**	**X**	Fostering co-operation among universities/research labs and industry
	EKVAN						**X**	Promotion of research joint ventures
	Int. Coop. R&D						**X**	Promotion of international R&D co-operation
	Human Networks	**X**		**X**				Promotion of interaction and networking between researchers and industry
	Techn.Parks			**X**	**X**			Promotion of industrial clustering and enhancing interactions among firms
	Liaison Offices		**X**	**X**		**X**		Exploitation of university research
	EBETA	**X**				**X**		Establishing links between academic research and industry
	Innovation Centres	**X**	**X**					Network of intermediaries with a range of services, especially for SMEs

Focus of programme		Awareness of the possibilities offered by networking	Search for partners	Building trust and a shared knowledge base	Organising the network	Ensuring provision of comple-mentary resources	Active co-operation	Type of programme
Country	*Name of programme*							
Hungary	Applied R&D						**(X)**	Development of new products, services and processes
	Maecenas		**X**					Conference participation, conference organisation, payment of membership fees in international S&T organisations
	Regional Innovation						**(X)**	Promoting local/regional R&D by SMEs (in co-operation with county offices of Chambers of Commerce or their consortia)
	Liaison Office	**X**	**X**					Fostering Hungarian participation in the 5th EU RTD FWP
	Consortium Building		**X**		**X**			Fostering Hungarian participation in the 5th EU RTD FWP
	Integrator						**X**	Improving the technological capabilities of SMEs, enabling them to become suppliers
	Co-operative Research Centres			**X**	**X**	**X**	**X**	Fostering long-term academy-industry co-operation
	Thematic networks	**X**	**X**		**X**			Fostering Hungarian participation in the Thematic Networks funded by EU FP5
Italy	National research programmes	**X**		**X**	**X**	**X**	**X**	Thematic R&D programmes, including collaborative R&D projects
	SMECOO	**X**		**X**	**X**	**X**	**X**	Fostering co-operation among SMEs
	UNISME					**X**		Mobility of researchers to SMEs
	INNOREG					**X**		Fostering regional co-operation in R&D, technology transfer and innovation diffusion and training

Focus of programme		Awareness of the possibilities offered by networking	Search for partners	Building trust and a shared knowledge base	Organising the network	Ensuring provision of comple-mentary resources	Active co-operation	Type of programme
Country	*Name of programme*							
Chinese Taipei	UIRC	**X**			**X**	**X**	**X**	Enhancing university-industry linkages
	Incubator Program	**X**				**X**		Enhancing university-industry linkages
	TCFST		**X**		**X**	**X**		Enhancing university-industry linkages

(X) = partly/indirectly addressed.

Some generalised observations from the policy case studies

The case studies provided some interesting examples of policy initiatives and programmes. Although only scattered evidence can be gathered on the basis of a limited number of cases, it would appear that some trends in network-oriented policies can be discerned and some good practice examples identified. Of course, the conclusions drawn are tentative and will need to be substantiated by further empirical research.

Policies to foster collaboration, co-operation and networking are extremely varied, as is the rationale put forward to justify the adoption of such policies. As would be expected, the majority of the programmes are not based on thorough *ex ante* assessment of the potential market failures in networking but rather on ad-hoc judgements about the respective problems. However, the more recent programmes often have a more elaborate foundation. This variety is also a reflection of the different perceived strengths and weaknesses of the various national innovation systems (NIS). Despite this variety, we attempt to generalise some observations:

Many countries have identified collaboration, co-operation and networking-oriented policies as important technology and innovation policy instruments. Different types of programmes and initiatives have emerged. In addition, in terms of funding, the monies provided for these types of policies have increased in recent years. Many of the programmes and initiatives mentioned in the country case studies are very recent and most will remain in operation in the years to come. In particular, programmes and initiatives which explicitly address networking are a rather new phenomenon although, in some countries (*e.g.* in the National Research Programmes of Italy and Switzerland), policies traditionally included aspects of collaboration, co-operation and networking as one dimension among others.

Most of the policy initiatives fall into one (or more) of the following categories:

- Programmes addressing the problems of *co-operation between scientific institutions and enterprises* (increasingly with a stronger emphasis on encouraging more radical innovations).

- Programmes addressing the *problems encountered by SMEs in forming and linking to networks* (with a stronger focus on near-market co-operation in innovation, *e.g*. encouraging product innovation or entry into new markets).

- Programmes addressing the *geographic dimension of a network* (some of these policies have a strong regional dimension, while others are aimed at linking the actors in a country to international networks).

The *scope of these policies also seems to have widened* beyond the support of collaboration and co-operation in R&D to include innovative activities in a broader sense (*e.g.* support for export-oriented networks of firms in Austria and product-innovation-oriented networks in other countries). This holds true especially for the SME-oriented programmes, which often involve a technology transfer dimension.

Yet, *R&D-oriented initiatives still are at the centre of the policy focus,* and are receiving increased attention with the numerous attempts to foster science-industry relations, many of which specifically address the university-industry relationship (as in Chinese Taipei).[2] Policy initiatives addressing this specific interface can be found in practically all OECD countries (examples include the competence centre and industrial network programmes in Austria, Denmark and Hungary, which tie together scientific institutions and enterprises in long-term, institutionalised networks). Sometimes, the

R&D-oriented initiatives include aid to SMEs in collaboration, co-operation and networking and to ensure an international dimension of networking (*e.g.* the Hungarian Programmes supporting the preparation of proposals for the European Framework Programmes for RTD).

A number of programmes – especially the more recent ones – share some design characteristics. Among the more recent policy initiatives, many *encourage or demand some form of formal organisational structure* (ranging from "associations" to the foundation of limited companies), although the participants are able to choose the form they see as most appropriate. Thus, such programmes have minimum formal requirements, but also a degree of flexibility. By this means, they seek to encourage the formation of long-term, sustained relationships and aim at the creation of organisational frameworks which aid in building trust between the network partners. On the other hand, the design of the internal relations of the networks is mostly left to the participants. There is a wide-spread perception that government or public funding institutions should not try to "micro-manage" the relations in a network. In some cases, organisational and administrative help and informational resources are provided as services to the networks.

The practice with regard to the selection of technological areas is more diverse. Some countries continue to organise their programmes in a "top-down" manner, around pre-defined technological areas, while in many other countries a "bottom-up" definition of these areas prevails. From the policy case studies and from other examples of network-oriented policies, it would appear that *many governments have recently become far more aware of the perils of using a top-down approach to selecting "strategic industries" as targets for network-oriented policies* and have turned more and more to programme designs that encourage and support self-organising networks.

It is still too early to identify the *overall effect* of the programmes (their effectiveness and efficiency, both taken alone and in comparison with other policy measures). Most of the programmes were implemented only a few years ago and judgement will have to wait at least until evaluations are available. Only for very few of the completed programmes, are evaluations available. Given the nature of the programmes, most of the real impact will only emerge some years after completion (development of the networks into fully fledged clusters, commercialisation of pre-competitive research projects, etc.) – and will be hard to measure anyway since many of the hoped-for effects include intangibles (*e.g.* "behavioural additionality" such as sustained networking, learning effects with regard to efficiently organising networking, etc.). At present, scattered evidence stemming from a few evaluations, current programme monitoring or in some cases from first impressions after the programme start-up seem to indicate that: *i)* most of the programmes seem to have tackled important perceived weaknesses of the respective innovation system; *ii)* some have even introduced novel programme designs and conduct; *iii)* the programmes seem to attract a rather wide spectrum of participants and indeed seem to have triggered co-operation or established a new quality of co-operation. However, not all of the policies, programmes and initiatives are unqualified successes. Rather, there seem to be several conditions that have to be met for a programme to be successful.

Since network creation and the establishment of trust relations takes time, *the programme should encompass sufficiently long periods of support* (*e.g.* in the Austrian and Danish cases, three to seven years), or should provide frameworks with some institutional stability (as is, for example, the case with the EU Framework Programmes) so that networking can become a "repeat game". Programmes which had initiated projects of a shorter duration had only limited success, *i.e.* initiating collaborations on a limited scale or initiating networks that could not be sustained (*e.g.* in Greece and Italy).

Appropriability of results has to be designed properly in order to give firms the incentive to participate. This is especially a problem where the results of collaborative research accrue to government (as is the case of the Italian and Chinese Taipei programmes designed to foster science-

industry relations). On the other hand, positive externalities should be a genuine goal of government intervention. Some programmes attempt to secure these positive externalities by actively disseminating the results of R&D networks or by transferring technologies to SMEs (as is the case in the EU's Framework Programme).

Policies need to be tailored to the different needs, incentives and capabilities of the participants. The existing adoption capabilities of participants have to be taken into account. Especially in programmes fostering science-industry collaborations and networks, the gap between the scientific institutions and the enterprises (SMEs) should not be overly high (a good example is provided by one of the Greek programmes). Also, the greater difficulties of network formation in some types of more innovation-oriented, near-market types of networks should be kept in mind. These networks tend to involve a greater number of partners and are less pre-competitive. In particular, it would appear that SMEs seem to experience greater difficulties in establishing relations of trust.

The new generation of programmes supports self-organisation of participants, they are "incentive-compatible", and are increasingly organised as competitions. Such programmes provide management, administrative and organisational support as well as a framework for sustained co-operation (either in the form of projects funded for sufficiently long periods of time or in the form of the establishment of intermediary organisations). As has been stressed above, governments refrain from "micro-management" of the network, which is left to the participants.

In the face of the growing variety of technology and innovation policy instruments, there is a pressing *need for greater co-ordination between these instruments* and the formulation of a coherent technology and innovation policy strategy. The problem is one of co-ordination and complementarity:

- Between different programmes addressing networking in one country at the same time.
- Between these programmes and policies at the international (*e.g.* EU Framework Programmes and structural funds), or the regional level.
- Between cluster-/network-oriented policies and other types of technology policy (*e.g.* general SME-oriented polices, institutional reforms at universities and the higher education institutions, etc).

To sum up, there have been encouraging developments in the design of network-oriented policies. However, much remains to be done, both in terms of research on the topic, which has to be further developed to provide sound reasoning and empirical analysis of the effects of network-oriented programmes to support policy makers, and on behalf of policy makers, who need to be aware of the complexities involved in designing such policies. Finally, we can echo a conclusion which was reached with respect to public funding of private R&D in general (Guellec and van Pottelsberghe, 2000): *policies have to provide a stable environment in terms of funding and institutional setting*. Frequent changes in policy goals, competing or uncoordinated initiatives and unstable financing of programmes are even more detrimental to network-oriented policies than they are for technology and innovation policy in general.

NOTES

1. Some of these policy case studies are available on the Web site of the NIS project. Additional case studies on network-oriented policies can be found in European Commission (2000).

2. For a recent overview of science-industry-related policies in Austria, Belgium, Finland, Germany, Ireland, Italy, Sweden, the United Kingdom, the United States and Japan, see Polt *et al.* (2001).

Annex

OUTLINE FOR THE POLICY CASE STUDIES

The case studies were designed to contain information on the following aspects of network-oriented policies:

- *Documentation of the programme(s).* In the form of policy documents related to the programmes, descriptions of the programmes, progress reports, and available assessments and evaluations.

- *General features of the programmes.* Target groups, volume (in monetary terms), duration, institutional setting and organisation, instruments used (subsidies, consultancy, infrastructure etc.).

Table A1.1. **Suggested scheme for classification for the programmes to be used in the case studies**

Type of programme / Angle of intervention	Programmes targeting science-industry linkages (for example)			Programmes fostering SME co-operation (for example)	Programmes oriented towards regional networks/ clusters (for example)
	Prog. 1	Prog. 2	Prog. 3	Prog. 4	Prog. ...x
Awareness of the possibilities of networking	X	X		X	X
Search for partners		X			
Building trust and a shared knowledge base	X	X			
Organising the network	X			X	
Ensuring providing complementary resources			X		
Active co-operation			X	X	

A programme might have more than one angle of intervention. Presenting the programmes this way would allow a comparison to be made between the different profiles of the programmes.

Characteristics of networks

- *Vertical and horizontal*. Vertical networks connect firms or production activities along the value-added chain; horizontal networks connect individuals and organisations in functional areas, *e.g.* research, production, logistics or marketing. In recent years, networks have also been created between private and public sector organisations.

- *Geographic scope*. Networks can be local, regional, national, international or global.

- *Organisational structure*. Network relationships may be informal, flexible and trust-based or formal and rigid.

- *Duration*. Project teams and virtual corporations are formed to achieve a short-term goal; strategic alliances, joint ventures and business associations typically have longer-term objectives.

- *Boundaries*. In most cases, there are no clear boundaries between a network and its environment. The membership of a network is not always clear and may change over time. This suggests that networks are open constructs. However, access to networks may be restricted and exit costs may be quite high. Hence, networks differ in terms of their degree of openness.

- *Architecture and balance of power*. In principle, networks are defined as an association of autonomous actors with equal rights. However, dependency among the participants may be more or less symmetric. A number of small companies can form a network of partners with equal rights and mutual assistance, or one or more "flagship" firms may lead the network, controlling the other partners.

- *Stability and trust*. In general, networks are a structure of loosely linked actors, making it easy for new members to join and for established partners to leave. The membership may thus change quite rapidly and relationships may be relatively unstable. Hämäläinen and Schienstock (2001) characterise networks by close interdependency and high-trust relationships – two factors that contribute to stability.

Perceived and/or actual benefits

Although co-operation occurs in different forms and may have different motives, a number of general assumptions underpin networks. Collaboration and networks lead to positive gains for internal activities and may have positive welfare effects under specific conditions; that is, partners can obtain benefits they would not gain independently. However, the benefits and effects of co-operation depend on the perspective. Industrial arrangements may differ depending on market organisation, the environment for innovation, strategic interaction between firms and the objectives and organisation of inter-firm collaborative agreements. As no two firms are alike, strategies and competencies are not the same even in the same industry. The following benefits of networking appear to be important:

- *Increased scale and scope of activities*. The results of collaboration may be applicable to each firm's market and thus expand their customer base. A firm's capability may be considerably extended if it can achieve synergy between different technological competencies.

- *Shared costs and risks*. Costs for major innovations, such as a new generation of semiconductors or aircraft, have risen rapidly and are now beyond the means of any single firm. The high costs and risks of innovation can be shared under a collaboration agreement.

- *Improved ability to deal with complexity*. Many key technological developments are complex and draw on a wide range of scientific and commercial knowledge. This reinforces the need for co-operation with participants in different fields of expertise. The close integration of firms also helps to deal with the complexity of multiple sources and forms of technology.

- *Enhanced learning effects*. Owing to continuous and rapid market and technological changes, firms are pressured to improve their learning capacities. Collaboration provides possibilities for learning about new technologies, methods to create future technologies and ways in which technologies may affect the existing business. It can also teach companies to change their organisational approach.

- *Positive welfare effect*. Internalising positive externalities through collaboration on R&D may result in increased efficiency and an increase in overall R&D expenditure.

- *Flexibility and efficiency*. In establishing overheads and production capacity, vertically integrated firms forsake the flexibility that networks provide for reallocating resources immediately. Networks also facilitate interaction between large and small firms so that the resource advantages of the former are linked to the behavioural or creative advantages of the latter. This efficiency-enhancing effect of networks is linked to the nature of technological knowledge. Much knowledge is tacit - *i.e.* difficult to codify – and firm-specific. It is therefore difficult to transfer through market mechanisms. Collaboration makes it possible to transfer such knowledge on the basis of mutual trust.

- *Speed.* Speed is often essential for taking advantage of emerging opportunities. A network can put together a package of resources to meet challenges in a customised response that, in its flexibility and scope, may be beyond the capacity of an integrated firm. Rapid product development may, for example, depend on reliance on outside suppliers. The ability to commercialise products thus rests on the exploitation of the knowledge of other firms. Networks not only determine access to information, but also support learning among firms.

Market/systemic failure the programme aims to address; rationale and motivation for the programme

- Awareness.

- Informational failures/asymmetries.

- Investment in complementary assets.

- Institutional failures/trust.

Problems identified/likely future (or built-in) failures of the programmes

- [open question]

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Chapter 15

CONCLUDING REMARKS

by

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Introduction

This chapter briefly summarises the main findings of the previous chapters. It singles out a few key messages from the different strands of research undertaken by the Focus Group. More detailed accounts of the work of the Focus Group are presented in the recent OECD *Science, Technology and Industry Outlook* (OECD, 2000), in other OECD documents (see, for example, Christensen and Rogaczewska, 1998) and on the NIS homepage of the OECD (http://www.oecd.org/dsti/sti/s_t/index.htm).

The Focus Group approached the topic of networking from both the theoretical and the empirical angles, applying a wide range of methodological tools. It addressed also the policy implications of its main analytical findings (see Chapter 14).

Theoretical foundations

The contributions in this volume are mostly, although not exclusively, based on evolutionary and institutional approaches of economic theory. This is understandable as it is mainly the various recently developed approaches (such as the "knowledge-based theory of the firm") that have placed innovation and networking at the centre of their analysis. Institutional approaches analysing phenomena such as trust and "social capital" are especially important for the analysis of networks. Nevertheless, it was observed that, although the reasoning of different theoretical approaches on networks is rather different, they often arrive at similar conclusions. For example, both neo-classical and evolutionary theory lead one to expect that collaboration will raise the level of R&D closer to its socially optimal level; that large enterprises are more likely than SMEs to participate in networks and accrue higher benefits and lower costs, and so on. In our view, it would be fruitful to take a pragmatic stance drawing on all the insights offered by the different approaches.

Empirical findings

The majority of the papers in this volume are empirical studies on the different dimensions of networking – their current patterns, their developments and, to some extent, their effects. To this end,

existing databases were used extensively and analysed in novel ways. These include the Community Innovation Survey (CIS) or CIS-type national innovation surveys, the CORDIS database on collaborative R&D projects in the realm of the EU Framework Programmes, and other CORDIS-based but more elaborate national databases. A number of studies rely on national surveys of various aspects of networking, but empirical data are scattered and internationally comparability is therefore limited. Therefore, in the previous phase of the study, in order to provide a third main database upon which the studies could draw, the Focus Group constructed its own database by carrying out a co-ordinated survey (the "EURO-DISKO"), which is – to our knowledge – the first such international survey of its kind (see Christensen and Rogaczewska, 1998).

Each database has its own advantages and shortcomings: the questions used in the CIS do not allow an in-depth analysis of networks, but rather look at different information channels and stimuli for innovation. The CORDIS database – as is the case for other databases on research joint ventures (RJVs) such as the MERIT database on strategic research alliances – focuses only on R&D co-operations and therefore leaves out an important part of the picture. On the other hand, the EURO-DISKO focused solely on product innovation and does not provide a comprehensively coverage of networking in the various stages of innovation process.

These shortcomings in data availability necessarily restrict the possibilities for analysis and may also introduce a certain bias in empirical research; for example, since RJVs are the best documented form of co-operation and networking, most of the existing empirical literature naturally has an "R&D" bias. Also, there is a bias towards manufacturing firms, as R&D activities in manufacturing are comparatively well documented. Only recently, has empirical research covering networking in innovation in a broader sense been intensified and the scope broadened to include services. Where surveys specifically addressing the networking phenomenon were carried out, these were done in national contexts and restricted to specific dimensions of networking (*e.g.* the university-industry interface), often producing results that are interesting but which are not internationally comparable.

The studies collected in this volume point to an apparent increase in the importance of networking, both in terms of the numbers of such interactions as well as in their importance for the innovation process. As technological change becomes more rapid and complex, and dissemination and sourcing of information is facilitated by the emergence of new technologies, many firms have taken the decision not to create all knowledge internally. Some such knowledge can be acquired in the market. However, there are no markets for certain kinds of knowledge; in particular, a significant part of firms' productive knowledge is tacit or collective, and therefore not easily transferable; other parts are firm-specific or strategic and thus are not for sale. The incentives for collaboration depend on both the characteristics of the underlying knowledge and the characteristics of the possible organisational arrangements. In order to make use of another firm's knowledge, a firm needs to possess sufficient internal competencies, *i.e.* absorptive capacity which has a cumulative nature.

In the past decades, the determinants and incentives to engage in networking have been influenced by two fundamental forces: the increasing specialisation and growing uncertainty of economic activities. These twin forces have increased the dissimilarity of productive resources, the transaction and co-ordination costs of economic activities, and the diversity of knowledge in value-adding systems. Combined with the rapid structural change of modern economies, increasing specialisation and uncertainty have challenged the information-processing capacities and cognitive frames of economic agents. These changes tend to favour more powerful organisational arrangements and, hence, raise the comparative advantage of hierarchies and networks in comparison to the market mechanism.

Despite this shift, networks are not always the best arrangement for complex economic interactions. Markets and corporate hierarchies have their own strengths and weaknesses which give

them comparative advantages in some industry environments. Although a networking strategy induces faster learning, it does not always translate into profitable innovations. There are organisational characteristics which shape the comparative advantage of markets, hierarchies and networks in organising particular value-adding activities. These organisational characteristics are determined by the level of:

- Similarity of resources and knowledge required by interdependent activities.
- Level of transaction costs between such activities.
- Co-ordination needs of interdependent activities.
- Nature of innovation processes.

The relative importance of each of these determinants depends on the particular structure of the respective innovation system and its actors.

While one can depict a general rise in the importance of networking in innovation, at the same time, a great variety of types of networks can be identified. Networks can be distinguished according to the following main characteristics:

- *Composition of partners.* Findings indicated that, as a general trend, horizontal networks (*i.e.* networks connecting individuals and organisations in functional areas such as research, production, logistics or marketing) are becoming more prominent *vis à vis* the more traditional forms of vertical integration, although the latter continue to play a key role. Another general trend is the observation that forms of "comprehensive" or "complete" networking (*i.e.* networks comprising a wide variety of different actors, such as suppliers, users, scientific organisations of various kinds, business-oriented services, public bodies, etc., also seem to be gaining in importance. This is in line with the increasing division of labour in the production and diffusion of knowledge which calls for networking of heterogeneous partners.

  On the other hand, not withstanding these observations on general trends, some specific patterns of networks could be depicted, depending on the technological regime and the predominant innovation mode (*e.g.* science-based, fully network-integrated high-technology firms; IT-oriented network-integrated developers; market-oriented incremental innovators with loose external links; cost-oriented process innovators with strong external links along the value chain, to name but a few). As these forms of networks span across industries and sectors and are not determined by specific industries, traditional branch- and sector-oriented policies might be misplaced. Rather, policy should be of a more horizontal nature and focus on the type of interaction and networking.

  In the same vein, an analysis of the patterns of knowledge interactions between universities and enterprises and their determinants in different sectors shows huge differences in the intensity of interactions. Various economic sectors indicate clear preferences for certain types of interactions. Moreover, some economic sectors, which are traditionally considered as high-technology industries have only low industry-science relations, and vice versa. This kind of analysis emphasises that the propensity of research fields and economic sectors to interact is highly dependent on the type of interaction.

- *Geographic scope.* Networks can be local, regional, national, international or global in scope, depending on the type of network and the specific activity within a network. For example, the increase in the importance of scientific knowledge in the innovation process, has served to increase the amount of internationally available codified information. In addition, ICT has significantly reduced the costs involved in the search and transmission of information. At the same time, informal contacts based on face-to-face communication have been repeatedly reported as being the most important channel for co-operation between universities and industry. Thus, networks with a strong local and regional focus and based on close personal relations are supplemented rather than replaced by international networks and electronic interaction.

  A number of the papers indicate that the propensity to collaborate exhibits country differences which can be explained with differences in the national institutional set-ups which provide the framework for the propensity to collaborate on innovation. The infrastructure provided by the "knowledge institutions" of a national innovation system encompasses not only universities and research institutions but also consultants or suppliers of technological services. Co-operation with knowledge institutions during the innovation process seems to take place predominately in a national setting.

- *Organisation and relations within the network.* Network relationships vary considerably, ranging from highly informal, flexible and trust-based relations to more formal and rigid connections. One main finding is that the build-up of trust and social capital is a necessary ingredient for sustained networking. In particular, strategic alliances, joint ventures and business associations typically have longer-term objectives and are geared towards longer duration. The boundaries of networks change over time. However, access to networks may be restricted and exit costs may be quite high. Hence, networks differ in terms of their degree of openness.

- Here, the task for public policy is quite difficult: on the one hand, there is room for policy in aiding the building of trust by supplying appropriate legal frameworks such as IPRs, by overcoming information asymmetries and helping reducing search costs. On the other hand, policy also needs secure the openness of network formation and guard against "lock-in" of established networks. The task is further complicated by the observation that governments should refrain from micro-management of networks and instead restrict themselves to the creation of appropriate incentives and frameworks.

The benefits of networks

Both from the theoretical point of view and from empirical studies, one can conclude that collaboration and networks lead to positive gains for internal activities and may have positive overall welfare effects – under specific conditions. That is, partners can obtain benefits they would not have been able to gain independently. However, the benefits and effects of co-operation depend on the concrete setting. Institutional arrangements may differ, depending on market organisation, the environment for innovation, strategic interactions among firms and the objectives and organisation of inter-firm collaborative agreements. As no two firms are alike, strategies and competencies are not the same, even within the same industry. The following benefits of networking have been underlined in the papers included in this report:

- *Increased scale and scope of activities*. The results of collaboration may be applicable to each firm's market and thus serve to expand its customer base. A firm's capability may be

considerably extended if it can achieve synergy between different technological competencies.

- *Shared costs and risks*. The costs associated with major innovations, such as a new generation of semiconductors or aircraft, have risen rapidly and are now beyond the means of any single firm. The high costs and risks of innovation can be shared under a collaboration agreement.

- *Improved ability to deal with complexity*. Many key technological developments are complex and draw on a wide range of scientific and commercial knowledge. This reinforces the need for co-operation with participants in different fields of expertise. The close integration of firms also helps to deal with the complexity of multiple sources and forms of technology.

- *Enhanced learning effects*. Owing to continuous and rapid market and technological changes, firms are under pressure to improve their learning capacities. Collaboration provides possibilities for learning about new technologies, methods to create future technologies and ways in which technologies may affect the existing business. It can also teach companies to change their organisational approach.

- *Positive overall welfare effect*. Internalising positive externalities through collaboration on R&D may result in increased efficiency and an increase in overall R&D expenditure. However, this is due to a critical spillover level at which the co-operative and non-cooperative R&D levels will coincide. If spillovers are above this critical level, co-operation in R&D will result in higher R&D investments and will thus have a positive welfare effect.

- *Flexibility and efficiency*. In establishing overheads and production capacity, vertically integrated firms forsake the flexibility provided by networks for reallocating resources immediately. Networks also facilitate interaction between large and small firms, so that the resource advantages of the former are linked to the behavioural or creative advantages of the latter. This efficiency-enhancing effect of networks is linked to the nature of technological knowledge. Much knowledge is tacit - *i.e.* difficult to codify – and firm-specific. It is therefore difficult to transfer through market mechanisms. Collaboration makes it possible to transfer such knowledge on the basis of mutual trust.

- *Speed.* Speed is often essential for taking advantage of emerging opportunities. A network can put together a package of resources to meet challenges in a customised response that, in its flexibility and scope, may be beyond the capacity of an integrated firm. Rapid product development may, for example, call for reliance on outside suppliers. The ability to commercialise products thus rests on the exploitation of the knowledge of other firms. Networks not only determine access to information, but also support learning among firms.

Convincing as most of these benefits sound, we believe that they materialise only under certain conditions. Networks cannot not be seen as a panacea to the challenges of economic development. They can have inherent weaknesses ("network failure"), *e.g.* lock-in, barriers to entry and distortion of market competition, etc. Although the empirical findings seem to confirm some of the benefits that the theory would lead one to expect (*e.g.* increased innovation intensity of network partners, higher rates of product innovation, etc.), the evidence is not unambiguous. For example, in comparing the different types of networks with respect to their economic performance, no significant differences could be found (see Chapter 3 of this volume). Here, more empirical studies are needed.

Tasks for future research on networks

Progress has been made in recent years – not least through the work of this Focus Group – in terms of both theoretically capturing and empirically tracing the network phenomenon. As should be clear from the previous chapters, much remains to be done, both in terms of theoretical and conceptual clarification as well as in empirical research on the different types of networks, their patterns of development and their effects on economic performance. As we have explained above, the data question is especially pressing. To enable a better understanding of the network phenomenon, it is crucial to improve the data situation. This could be done in several ways.

First, questions that allow a better picture of the patterns and intensity of networking should have a more prominent role in the innovation surveys. Partial improvements have been incorporated in the upcoming round of innovation surveys, but there is room for substantial improvement.

Second, specifically designed surveys analysing networking in its various aspects should be carried out periodically in an internationally co-ordinated manner. The EURO-DISKO survey is a starting point in this direction, and could serve as the basis for further research. However, it needs to be further refined and broadened in terms of its coverage of the stages of the innovation process and its geographical scope. Third, while some progress has been made in depicting *patterns* of networking and their developments – at least with respect to some aspects of the networking phenomenon – there is a lack of empirical studies on the *effects* of networking and the effectiveness of various forms of networking. There are some developments in the evaluation literature, namely in connection with the evaluation of the EU's Framework Programmes, that try to capture these effects in terms of measurable economic output, changes in firm behaviour, and broader impacts on society; but, again, this is restricted to a specific type of networking and does not cover the phenomenon as a whole. This is especially important for the assessment of network-oriented policies. In terms of descriptions of such polices, some progress has been made (*e.g.* in the context of the "Trend Chart" project of the EU). What is still lacking in this field is a truly comparative analysis of these policies, based on more elaborate and commonly applied methodology for the evaluation of their effects. Here, a great deal needs to be done, both in terms of the operationalisation of concepts such as additionality (especially "behavioural additionality"), and in the measurement of both intangible effects of networks and their broader externalities.

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Annex

POLICY CASE STUDY: AUSTRIA

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Introduction

In this case study, three examples of Austrian programmes aiming at the encouragement, fostering and facilitation of network formation[1] are presented:

- The **K**plus programme of the Ministry of Transport, Innovation and Technology.
- The K_{ind}/K_{net} programme.
- Programmes funded by the Ministry of Economic Affairs and Labour targeting the formation of "export-clusters".

These programmes are representative examples of a shift in Austrian technology policy towards programmes aimed at fostering linkages in the Austrian national innovation system. It has long been claimed that the linkages between enterprises, on the one hand, and between the science system and enterprises, on the other, constitute major weaknesses of the Austrian innovation system (for detailed characterisations of the Austrian innovation system, see, for example, Hutschenreiter *et al.*, 1996, Technologiepolitisches Konzept, 1996, Hutschenreiter *et al*., 1997, Polt *et al*., 1999,[2] and the *Green Paper on Austrian Research Policy*, 1999).

The Austrian enterprise sector can roughly be characterised by the following features: a comparatively large share of SMEs, a small number of multinational corporations of Austrian origin, and a considerable share of foreign-owned firms, especially among R&D-intensive sectors like pharmaceuticals, biotechnology, electronics and software production. In terms of innovative activities, Austrian firms perform fairly well (with a high share of innovative enterprises), although their focus is predominantly on incremental innovation, mainly along existing technological trajectories. Only a minority of firms have the capabilities for research-intensive, "breakthrough" technological innovation. In terms of industry structure, resource- and scale-intensive sectors occupy the major share of Austrian industry (see Polt *et al*., 1999). The Austrian science system is characterised by the large share of the universities in public R&D expenditure, the small amount of university R&D financed by firms and the small number of public research centres.

Thus, there are considerable barriers to co-operation between these very different types of actors in the enterprise sector, as well as between those actors and the science system (Schibany, 1998).

Against this background, the fostering of co-operative relations in the national innovation system has become a focal point of recent Austrian research, technology and innovation policy.

Case Study 1: The Kplus Programme

Background information on the programme[3]

The programme was started in late 1998, when the former Ministry of Science and Transport – now Ministry of Transport, Innovation and Technology (BMVIT) – entrusted the *Technologie Impulse Gesellschaft* (TIG), a specialised funding institution, with the responsibility for managing the programme. These responsibilities included: carrying out specific information activities, organisation of selection processes, and establishment and monitoring of the competence centres.

The selection process of the centres introduced a novelty into Austrian technology funding schemes insofar as it is a *competitive process* between different proposals. Calls for proposals are launched regularly. There is no pre-selection of technological/scientific areas or types/status of project proposers. The consortia which bid for the grants are formed in a self-organised way between business and academia. Proposals are evaluated on the basis of:

- Their scientific and technological quality.
- Their ability to "cluster" existing scientific and economic competence into "critical masses".
- The estimated economic benefit for Austrian companies.
- The quality of the business plans.

The main instrument of the evaluation process is peer review. The following 12 competence centres are operative or have been selected for funding.

General features of the programme

Focus. **K**plus funds collaborative research facilities which are jointly run by enterprises and research institutions (universities, government research labs, etc.). Research carried out in the centre should be pre-competitive. Individual projects run by the centre should involve multiple partners.

Target groups. Industrial enterprises and research institutions which carry out high-quality research with strong potential for economic application.

Volume. To ensure the formation of critical masses, some "target size" indicators are used: centres should have an annual funding of ATS 30-60 million (EUR 2.2-4.4 million) and some 25-50 staff.

Table 1. **K**plus **– Competence centres**

	Status	Programme funding		Total project costs		Duration (years)	Number of partners	*Of which:* enter-prises	Unit	Public research centre
		ATS million	EUR million	ATS million	EUR million					
Advanced Computer Vision (ACV)	Operational	91.92	6.6	153.2	11.10	4 (+3)	15	11	3	1
Carinthian Tech Research (CTR)	Operational	79.8	5.8	133	9.66	4 (+3)	10	6	4	0
Applied Electrochemistry (ECHEM)	Operational	113.4	8.2	189	13.73	4 (+3)	43	37	4	2
Forschungszentrum Telekommunikation Wien (FTW)	Operational	129	9.4	215	15.62	4 (+3)	17	14	3	0
Leichtmetall-Kompetenzzentrum Ranshofen (LKR)	Operational	94.8	6.9	158	11.48	4 (+3)	15	12	2	1
Materials Centre Leoben (MCL)	Operational	100.8	7.3	168	12.21	4 (+3)	26	17	7	2
Software Competence Centre Hagenberg (SCCH)	Operational	94.8	6.9	158	11.48	4 (+3)	21	14	7	0
Centre for Virtual Reality and Visualization (VRVis)	Operational	77.4	5.66	129	9.37	4 (+3)	13	8	5	0
Mechatronic Centre Linz (MCL)	Operational Dec. 2000	93.6	6.8	156	11.3	4 (+3)	29	24	3	2
Wood Chemistry and Composites Competence Centre Austria (WOOD)	Operational	100.8	7.3	168	12.21	4 (+3)	12	7	4	1
Competence Centre for Bio-Molecular Therapeutics (BMT)	Operational	102	7.4	170	12.37	4 (+3)	11	6	5	0
Knowledge Management Centre Graz (KNOW)	Operational Dec. 2000	89.4	6.5	149	10.84	4 (+3)	16	11	3	2
Total		1 167.7	84.7	1 946.2	141.43		228	167	50	11

Source: T.I.G.

Duration. Centres are established for a period of four years, with the possibility of extension (following an interim evaluation) for a further three years. There is no *a priori* limit for the duration of the programme, although at the outset it was estimated that there would be a ceiling of some 20-25 centres in Austria.

Institutional setting and organisation. There is considerable leeway in the organisation of internal relations between the partners. Most centres are organised as limited companies. A minimum of five industrial participants are required, in order to avoid “single-firm centres” and unfair preferential treatment which might have undesirable effects on competition.

Instruments used: In addition to the subsidies, some assistance is provided in the preparation of the proposal and the establishment of the organisation of the centre. Management advice is also provided throughout the duration of the project. Subsidies are provided in the form of grants, with up to 35% coming from T.I.G. Enterprises bear a minimum of 40% of the costs, the remaining 25% stem from other public sources.

Type and focus of the programme

The main objective of the programme is to establish long lasting co-operative relations between enterprises and scientific institutions. "Awareness of the possibilities of networking" is provided by the PR activities of the programme (*e.g.* road shows). Given the long-term goals of the programme, the main focus is on "building trust and a shared knowledge base". Although it does not provide complementary resources, the programme has the target of ensuring the pooling of resources to form "critical masses". In terms of the "organisation of the network", some basic requirements are set, although no active role is taken by T.I.G. The "search for partners" is left to the network members themselves (Table 2).

Table 2. **Suggested scheme for classification for the programmes to be used in the case studies**

Type of programme / Angle of intervention	Programmes targeting science-industry linkages (for example)			Programmes fostering SME co-operation (for example)	Programmes oriented towards regional networks/ clusters (for example)
	Prog. 1	Prog. 2	Prog. 3	Prog. 4	Prog. ...x
Awareness of the possibilities of networking	X	X		X	X
Search for partners		X			
Building trust and a shared knowledge base	X	X			
Organising the network	X			X	
Ensuring providing complementary resources			X		
Active co-operation			X	X	

Characteristics of networks

Vertical and horizontal. Networks can (and do) take both forms.

Geographic scope. At the present time, the centres are national, although international/global scope is not excluded.

Organisational structure. After an initial phase (18 months), during which the partners can organise themselves as associations, they are expected to set up a limited company.

Duration. The duration is much longer than for normal R&D projects (four years for the initial term) and can be extended to a total of seven years.

Boundaries. As the main objective is to ensure stable and long-term relations between participants, access of new participants is limited but possible (and has occurred). Nevertheless, the boundaries seem to be rather fixed and the barriers to entry relatively high.

Architecture and balance of power. The establishment of the relationship is a self-organised process, hence the centres are free to define their relations as they wish.

Stability and trust. As the establishment of long-term relations is the main goal of the programme, stability and trust are the primary targets.

Perceived and/or actual benefits

As the programme is still in its initial phase and results will take time to materialise, the following describes the *expected* benefits:

Increased scale and scope of activities	Both are expected benefits
Shared costs and risks	Both
Improved ability to deal with complexity	Yes
Enhanced learning effects	One of the mayor goals
Positive welfare effect	No explicit goal, but might arise in some projects, given their nature
Flexibility and efficiency	Expected benefit
Speed	Not an explicit goal. Rather long-term, pre-competitive research is fostered.

Market/systemic failure the programme aims to address

The programme explicitly or implicitly addresses a number of potential market failures (uncertainty/risk, appropriability, information asymmetries, institutional failures). However, it's main focus is on institutional failures and the reduction of uncertainty/risk. The awareness problem is also addressed, although the issues of information asymmetries tend to be left to the "bottom-up" process of network formation and organisation.

Identified/potential problems

- Although the thoroughness of the process of screening, monitoring and selection of the projects is expected to lead to the selection of "high-quality projects", it is also associated with some administrative burden.
- In the selection process, the peer-review approach has some limits.
- The reliance on the self-organisation capabilities of industry and academia could lead to unwarranted exclusion effects.

Case Study 2: The K_{ind}/K_{net} Programme

Background information on the programme[4]

The programme was born at the end of 1997, when the Minister for Economic Affairs announced the plan to foster co-operation between enterprises and science institutions. The plan became effective as of May 1999 in line with the Guideline issued by the Minister for Economic Affairs. Selection of the centres/networks and funding began in the second half of 1999. Two types of collaboration are

distinguished: K_{ind} are competence centres, K_{net} are genuine networks. So far, the following seven networks/centres are operative or are about to start up.

Table 3. **K_{ind}/K_{net} – Networks and centres**

	Type	Status	Programme funding		Total project costs		Duration	Number of main partners[1]	*Of which:* enterprises
			ATS million	EUR million	ATS million	EUR million			
Competence Centre for Car Acoustics	K_{ind}	Operative	75	5.5	133	9.7	1999-03	3	2
Competence Centre for Mechatronic and Automation	K_{ind}	Operative	64	4.7	117	8.5	1999-03	8	5
Competence Network: Energy from Bio-mass	K_{net}	Operative	34	2.5	60	4.4	1999-03	5	3
New Media Competence Centre	K_{ind}	Start phase	33	2.4	55	4.0	2000-04	5	4
Competence Centre for interactive e-business	K_{ind}	Start phase	66	4.8	110	8.0	2000-04	10	5
EC3 Electronic Commerce Competence Centre	K_{ind}	Start phase	56	4.1	93	6.8	2000-04	8	4
Competence Network on Aerospace Composite Materials	K_{net}	Start phase	90	6.5	150	10.9	2000-04	11	8
Total			418	30.5	718	52.3		50	31

1. Excluding associated SMEs.
Source: Ministry for Economic and Labour Affairs (BMWA).

General features of the programme

Focus. K_{ind} (industrial competence centres) supports the establishment of R&D centres jointly run by enterprises and research institutions (universities, government research labs, etc.), while K_{net} supports the co-operation of geographically dislocated/dispersed research facilities along common themes.

Target groups. All industrial enterprises with an own R&D department, research institutions. SMEs without own R&D can participate as "associate" partners at the level of individual projects. The centre/network should have a transfer component (*i.e.* technology transfer activities are encouraged). Planned technology transfer activities are a positive criterion for selection.

Volume. Three centres are in operation, for which ATS 150 million (EUR 6.5 million) were provided in 1999 (project costs totalled ATS 276 million or EUR 20 million). Four centres are currently (2000) in the preparation phase, with the start of fully fledged projects expected for 2001.

Duration. 1999-2002 (period of initial funding; with projects expected to run until 2006). The funding period is limited to four years, with the possibility of a three-year extension.

Institutional setting and organisation. The co-operation can take various forms, ranging from loose "associations" to the establishment of a formal RJV as a limited company.

Instruments used. Subsidies in the form of grants, up to 60% of total (eligible) project costs. Enterprises bear a minimum of 40% of the costs. Of the 60% of public funding, a maximum of 40% can come from the programme, the rest being provided from other public (*e.g.* regional) sources.

Type and focus of the programme

The main objective of the programme is to lay the ground for the formation of industrial clusters by providing a durable framework for co-operation which should lead to the "building of trust and a shared knowledge base" (Table A.1.1). "Awareness activities" and "search for partners" are not an explicit activity of the programme. The programme plays no active role in organising the network, although it does outline some minimum formal requirements. Otherwise, the organisation is left to the participants. Neither does the Ministry take an active role as a partner in the centre/network, although some regional governments do.

Characteristics of networks

Vertical and horizontal. So far, the networks have been mainly of a horizontal type, although vertical networks are not ruled out.

Geographic scope. Existing and planned centres/networks have a regional (the Austrian provinces have a stake in some of the centres, while others tend to have a regional "core") and a national focus (mainly the networks, which have to have distributed research facilities). At the moment, there is no network with an international or global dimension, although this is not ruled out by the funding guidelines.

Organisational structure. Flexible, although different forms are prescribed by the programme. In reality, the majority of centres/networks take the form of a limited company, some function as loose "associations".

Duration. The duration is much longer than for normal R&D projects (four years for the initial term) and can be extended to a total of seven years.

Boundaries. Access to the centre/network, once formed, is possible, but is subject to the agreement of the existing network members. Where enlargement takes place, the amount of funding available to the centre/network can be increased.

Architecture and balance of power. The establishment of the relations is a self-organised process, hence existing and planned centres/networks demonstrate a great variety of linkages.

Stability and trust. Since the establishment of industrial clusters is the main goal of the programme, stability and trust are the main target variables. There is a barrier to entry preventing the numbers of participants becoming too large and there is a barrier to exit (sunk costs – which vary from one participant to another); thus it would be expected that number of participants will not fluctuate wildly. One problem – at least in the start-up phase of the programme – has been to secure the stability of funding. Due to budget restrictions, the start up of some – already selected – centres/networks had to be put on hold until sufficient funds became available. This might have caused some uncertainties among potential applicants.

Perceived and/or actual benefits

Since the programme is in its initial phase and results will take time to materialise, the following table describes only the *expected* benefits:

Increased scale and scope of activities	Both are expected benefits
Shared costs and risks	Expected, but not specific to the programme
Improved ability to deal with complexity	Neither a major goal nor a major expected outcome
Enhanced learning effects	One of the primary goals
Positive welfare effect	Expected through technology transfer activities
Flexibility and efficiency	Expected benefit
Speed	Expected benefit

Market/systemic failure the programme aims to address

Among the potential market failures that could be addressed by the programme (uncertainty/risk, appropriability, information asymmetries, institutional failures), its main focus is on institutional failures and its main target is to provide a durable framework with the aim of building up trust. Awareness and information asymmetries are not addressed by the programme; rather, the formation of the centres/networks is left to a "bottom-up" process.

Identified/potential problems

- Among programme managers, stability of finance is seen as crucial (the programme virtually came to a halt in 2000, as the provision of public funds was unclear). Stop-and-go finance decisions could be detrimental to the stability of the networks. Stability of finance and policy has also been shown to exercise a positive influence on the effects of public funding of private R&D (Guellec and van Pottelsberghe, 2000).

- Another (potential) problem lies in the pure "bottom-up" character of the process, which might run counter to "SWOT-based technology policy".

Case Study 3: Export cluster formation

Background information on the programme

In late 1997, the Austrian Government launched an initiative to improve the export performance of Austrian enterprises ("Exportoffensive"). Based on the findings of a study from Arthur D. Little (ADL, 1997), a specific sub-programme for "export cluster" formation was established as part of this larger initiative. Although the programme is labelled as a "cluster" programme, it is actually designed to encourage the creation of networks. Only in the medium- to long-term, is it expected that genuine clusters might emerge from sustained co-operation.

So far, the following 20 "export clusters" initiated by the Austrian Economic Chamber (WKÖ) and three "export clusters with operators",[5] initiated by the former Federal Ministry of Science and Transport (BMWV) are operative or have been selected for funding:

WKÖ: "Export clusters" (without operators)	Members	Period of support
Austrian Agricultural Cluster	13	1998 – 2000
Austrian Water Cluster	35	From 1998
Bioenergy Austria	44	From 1999
C-O-I – Cluster Object International – Hotel equipment	19	1999 – 2000
ICON – Industrial Construction Network	10	1998 – 2000
Food Cluster	10	1998 – 2000
Food Cluster South Austria	15	From 1998
Cluster "Austrian Environment" (Waste treatment)	25	From 1999
Airport Development Group	23	From 1999
AMEM Austrian Marine Equipment Manufacturers	20	From 1999
Austrian Building & Construction	14	From 1999
Centric	19	From 1999
Cluster Elektronic	4	1999 (dissolved in 2000)
EGA – Engineering Group Austria	10	2000
ENSO – Energienetwork South-East	26	From 1999
Export-Cluster ‚Vorarlberger Wood House'	14	From 1999
IMC – International Medical Cluster	12	From 1999
Signatur	7	From 2000
Bio Concept	6	From 2000
ADWC – Austrian Danube Water Co-operation	11	From 2000
Almaco	20	From 2000
Total: 21 (20 operative)	***357***	***1998 – 2000***

Source: Wirtschaftskammer Österreich (WKÖ).

BMWV/BMWA: "Export clusters with operators"	Members	Period of support
AHC Austrian Health Care Systems & Engineering GmbH (operative since 01/01/1999)	21	1998
APET Austrian Power & Environment Technology GmbH (operative since 08/09/1999)	12	1999
ATC Austrian Telecom Corporation GmbH (operative since 13/09/1999)	11	1998 – 1999

Source: Federal Ministry for Economic Affairs and Labour (BMWA).

According to the Federal Ministries Act (BMG), the competency for "export clusters with infrastructure operators" was transferred from the (former) Federal Ministry for Science and Transports (BMWV) to the Federal Ministry of Economic Affairs and Labour (BMWA) on 1 April 2000. Since then, BMWA has been responsible for the co-ordination and guidance of all Austrian infrastructural export clusters.

ARE, AHC, APET and ATC are organised as limited companies and respectively comprise enterprises as well banks and industry-specific operators. The clusters with operators act as internal and external co-ordinators, thus ensuring the accessibility of jointly developed know-how for international clients.

General features of the programme

Focus. The programme attempts to help the formation of clusters of export-oriented enterprises. The support addresses both the organisation of the cluster (cluster management, information management), marketing activities (presentations at trade fairs, lobbying), market and feasibility studies, etc.

Target groups. All exporting – or potentially exporting – Austrian enterprises, although as far as export clusters of WKÖ are concerned, special attention is paid to the participation of SMEs. In fact, some 85% of current participants are SMEs.

Volume. In total, the "export offensive" has a volume of ATS 332 million (EUR 24 million), of which some ATS 30 million (EUR 2.3 million) accrue to the "cluster formation" sub-programme. In terms of the WKÖ export clusters, "cluster formation" projects are eligible for funding of up to ATS 2.5 million (EUR 0.2 million) for a period of two years (which can be extended in exceptional circumstances). In contrast, the three BMWV/BMWA export clusters with operators received less than the ATS 1.25 million (EUR 0.09 million) per cluster originally budgeted for the build-up period (initiation phase: AHC and APET up to one year; ATC 1.7 years). Participants provide funds in the form of membership fees, which vary widely among the clusters (and often even within the clusters between larger and smaller enterprises).

Duration. The programme started in 1998 and is scheduled to run until the end of 2000. Individual projects receive funding over a two-year period (a few have an extended duration of three years). After this initiation phase, the clusters are expected to continue on the basis of their own funding. In contrast, all three BMWV/BMWA-clusters had to be built up within two years, *i.e.* between 1998 and 1999. As the programme originally provided for export clusters to be set up within one year (although the programme itself ran for two years), the creation of AHC and APET was finished within one year (although the establishment of ATC required 1.7 years).

Institutional setting and organisation. With respect to the WKÖ clusters, funding is provided by the Ministry of Economic and Labour Affairs, while the programme is organised by the Austrian Economic Chamber (WKÖ). As far as the three "export clusters with operators" are concerned, the initiation phase of AHC, APET and ATC was organised and financed with less than ATS 1.25 million (EUR 0.09 million) per cluster by the former Federal Ministry of Science and Transport (BMWV). The three BMWV/BMWA export clusters with operators have been self-financing since their foundation in January 1999 (AHC) and September 1999 (APET, ATC).

Instruments used. Subsidies, in the form of grants, are provided to finance the activities of the WKÖ clusters (cluster management, marketing activities, etc.). Some complementary resources are provided in the form of free use of the network of the foreign trade commission of the WKÖ. As all three BMWV/BMWA "export clusters with operators" have been self-financing since September 1999 at the latest, the legal entities AHC, APET and ATC have not received any subsidies (*e.g.* in the form of grants) for their activities since their respective creation dates.

Type and focus of the programme

The main objective of the programme is to assist companies entering new export markets. Time horizons are relatively short, *i.e.* the goal is rapid commercial success. The financial contribution of public funding is limited, although the angle of intervention is fairly wide, targeting "awareness of the possibilities of networking", "search for partners", "building trust and a shared knowledge base" and providing some input/help with regard to the "organisation of the network". Most of these activities

come under the responsibility of the cluster manager. Some complementary resources are also provided in the form of support from the *Aussenhandelsstellen* (foreign trade commission) of the federal economic chamber (WKÖ). Only "active co-operation" is not covered, as neither the chamber nor the Ministry are part of the cluster (Table 1).

Characteristics of networks

Generally, the clusters fall into two categories: "information and marketing platforms" and "sales clusters". While the former focus on information exchange, information management and marketing activities, the latter act either as "virtual system suppliers" (*e.g.* for large-scale infrastructure facilities like airports) or as a consortium selling a specific product.

Vertical and horizontal. Co-operations can (and do) take both forms.

Geographic scope. Clusters are predominantly present at the regional and national level, although their range of activities is global. Due to competition and cartel laws, the BMWV/BMWA export clusters with operators do not operate within the EEA, the United States or Canada.

Organisational structure. Each network has to have a formal structure, although many organisational forms are possible (six different forms are currently operative). The appropriate form depends on the type of activities the cluster focuses on. The clusters designed to provide information exchange and act as a marketing platform, are mainly organised in looser forms (*e.g.* as associations, working groups). Clusters which act as "virtual systems suppliers" (*e.g.* for infrastructure) or which focus on direct sales activities are predominantly organised as limited companies (44%). The three BMWV/BMWA export clusters with operators are organised as limited companies.

Duration. The funding period for the launch of the WKÖ cluster is limited to two years. The export cluster programme provided for clusters to be built up within one year. This time restriction was respected by AHC and APET, although the creation of ATC took 1.7 years. None of the BMWV/BMWA export clusters with operators received funding of more than ATS 1.25 million (EUR 0.09 million) in total.

Boundaries. There are boundaries since formal membership (involving the payment of membership fees) is required, but the network remains fairly open. Access can be granted subject to approval by the members (rules for access differ among the different organisational settings). With regard to the BMWV/BMWA export clusters with operators there are no restrictions to potential members willing to join the clusters (although an "entrance fee" can be charged).

Architecture and balance of power. The establishment of the relationship is a self-organised process, hence the networks are free to define their linkages as they see fit. In practice, some clusters have found it difficult to achieve an appropriate "balance of power".

Stability and trust. In this type of network, stability and trust are constantly challenged by the diverging (short-term) interests of the participant firms. This is particularly evident in the clusters with the greatest numbers of members, a high share of SMEs and a large number of competitors trying to co-operate. In some cases, it took a long time to establish trust, in others this process has yet to be been completed. Some of the clusters may even disintegrate. Thus, the task for the cluster manager is extremely delicate. As recent experience with the conduct and performance of the various clusters has shown, the cluster manager plays a key role as a "go-between". The success of the cluster hinges mainly on his/her performance in this role.

Perceived and/or actual benefits

As the programme is still in the initial phase and results will take time to materialise, the following table sets out the benefits *expected* by the programme administrators:

Increased scale and scope of activities	Not necessarily in the form of new products/ processes, but in terms of access to new markets
Shared costs and risks	Both
Improved ability to deal with complexity	Expected benefit, once the networks have become stable
Enhanced learning effects	No explicit goal, but a likely by-product of co-operation
Positive welfare effect	No explicit goal, direct effects for the firms are the main target. Might arise in some projects.
Flexibility and efficiency	Among the expected benefits (in the form of quick reaction to new market opportunities)
Speed	See above

A study monitoring the performance of the programme and the participants of the WKÖ export clusters (without operators) found that the clusters were very much geared towards "information exchange" and "project acquisition", which were seen to be the main benefits to be gained from participation (scoring 27.5% and 23.8%, respectively). Only for a small minority of firms were joint R&D, impulses for product development or joint training seen as motives for participation (with scores of 7.2%, 8.4% and 4.8%, respectively) and actual benefits (2.5%, 2.5% and 0%, respectively). This is not surprising given the orientation of the programme and the short period of time that has elapsed since the foundation of most of the clusters. Nevertheless, it would be expected that these dimensions of co-operation will be enforced in those clusters that emerge as stable configurations. "Co-operation with other enterprises" improved for 63% of participants – despite some manifest problems in some clusters.

Market/systemic failure the programme aims to address

The programme attempts to address a number of potential market failures, predominantly those arising from information failures/asymmetries/deficiencies and institutional failures. Information deficiencies include a lack of information about potential co-operation partners as well as about foreign markets. SMEs are especially prone to these types of market failure.

Identified/potential problems

- The programme's main focus is to initiate co-operation and to encourage joint use and provision of services, thereby building trust among members. As the number of participants in the networks can be high, the creation of trust can be difficult and time-consuming. It is envisaged that some of the clusters might even fall apart before real take-off owing to the diverging interests of partners.

- The programme had fixed ceilings for the funding and duration for each cluster, irrespective of the heterogeneity which can be found between them. A more flexible approach to duration and funding might have been beneficial for some of the WKÖ clusters, especially those dealing with complex products and/or involving a large number of participants.

- The programme was hit by budgetary constraints. Stable provision of funding would help to establish stable relations at an earlier stage.

- For some of the WKÖ clusters, the possibility of a longer funding period or follow-up funding would have a positive effect on the sustainability of the clusters. As of today, no such extension of the programme is envisaged.

Networking policy in Austria: summary and conclusions

Policies addressing networking and cluster formation have received increased attention in recent Austrian technology and innovation policy. The programmes described above are good examples for these initiatives (which cover also cluster formation at the regional level). In terms of financing, the funds provided for such policies have increased in recent years.

Two of the programmes address a specific weakness of the Austrian innovation system; namely, the perceived lack of co-operation between the science system (including universities and public research facilities) and the enterprise sector. The third initiative addresses the export performance of SMEs. The programmes share some characteristics:

- They do not "pre-select" areas, fields of technology or branches. The definition of the topics takes place through a "bottom-up" process.

- They encourage or demand some form of formal organisational structure, although the participants have a choice as to which form they consider to be most appropriate to their particular needs. Thus, they have minimum formal requirements, but also some flexibility.

- The design of the internal linkages within the networks is left to the participants.

The differences between the programmes are mainly to be found in:

- The more long-term perspective of **K**plus and K_{ind}/K_{net} in comparison to the "export cluster" programme. This difference is also reflected in the duration of funding.

- The apparently greater difficulties of network formation in the "export cluster" programme. This should not come as a surprise since these networks on average involve a greater number of partners and are more market-oriented and less pre-competitive than the two other programmes. It is natural for the large numbers of competing SMEs to experience greater difficulties in establishing relations of trust.

The **K**plus programme has introduced a formalised competitive process for the distribution of funds, which is a novel feature for Austrian technology and innovation programmes.

The overall effect of the programmes on the Austrian innovation system cannot be identified at this stage. The programmes are relatively recent and judgement will have to wait at least until the first round of intermediary evaluations. Given the nature of the programmes, most of the real impact will only emerge some years after completion (*e.g.* sustained networks, development into fully fledged clusters, commercialisation of pre-competitive research projects, etc.)

At present, it can be said that the programmes seem to have tackled important weaknesses of the Austrian innovation system and have introduced a novel approach to programme design and conduct.

In addition, the programmes seem to attract a rather wide range of participants and indeed appear to have triggered co-operations or established a new quality of co-operations.

One potential problem for the future lies in the lack of co-ordination between the different instruments of technology and innovation policy. This problem is one of co-ordination and complementarity: *i)* between the programmes (especially between **K**plus and K_{ind}/K_{net}); *ii)* between these programmes and other cluster-/network-oriented policies (*e.g.* at the regional level); and *iii)* between cluster-/network-oriented policies and other types of technology policy. Austrian technology policy has yet to solve this puzzle.

Table 4. **Type and focus of the programmes**

Type of programme	Targeting science-industry linkages		Addressing export-oriented networks of enterprises
Focus of programme	**K**plus	K_{ind}/K_{net}	Export cluster
Awareness of the possibilities of networks	X		X
Search for partners			X
Building trust and a shared knowledge base	X	X	X
Organising the network			
Ensuring provision of complementary resources	(X)		(X)
Active co-operation		(X)	

(X) = partly/indirectly addressed.

Table 5. **Programme funding**

	1998		1999		2000[2]	
	ATS million	EUR million	ATS million	EUR million	ATS million	EUR million
Grants from **K**plus[1]			60	4.35	120	8.7
Total volume of **K**plus projects			300	21.8	400	29
Grants from K_{ind}/K_{net}[1]			149	10.8	14	1.0
Total volume of K_{ind}/K_{net} projects			276	20.1	35	2.6
Grants from export cluster initiative[1]	2.8	0.2	13.6	1.0	17.6	1.3
Total			***798.6***	***58.0***	***586.6***	***42.6***

1. As expenditures other than R&D are also funded, the total sum of the grant is not equivalent to R&D expenditure.
2. Preliminary figures.
Source: BMWA, WKÖ, TIG.

NOTES

1. The notions of “clusters” and “networks” are used interchangeably in the context of the description of these programmes. For example, the K_{ind}/K_{net} programme aims at “creating networks and centres of competence to form the basis of industrial clusters”. On the other hand, the “export cluster” initiative – despite its name – is in fact comprised of networks.

2. http://www.bmwf.gv.at/4fte/materialien/techber99/index.htm.

3. A more detailed description of the programme can be found at: http://www.kplus.at.

4. A general description of the programme can be found at: http://www.bmwa.gv.at/organisation/sekiv/aktiv/kindnet1.htm.

5. Built on the lines of the very successful railway cluster Austria Rail Engineering (ARE), established in 1987.

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