CHARTING NATIONAL INNOVATION SYSTEMS — AN AUSTRALIAN APPROACH*

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Summary

This is an account of work in progress. It has three aspects.

Firstly, it discusses trends in Australian R&D — in its international context — and the broad policy emphases that have resulted from the analysis of international comparisons.

Secondly, it proposes a new way of presenting old data. Though indicators formed by a process of normalising expenditures as shares of GDP are very useful, we expand on some earlier work in which we suggested that useful supplementary information can be obtained by a process of normalising by aggregates based on OECD-wide data. By considering R&D in its business and non-business components we are able to compare shares of OECD-wide aggregate R&D expenditures (inputs) with similarly constructed indicators of major outputs — patents in the business case, and research papers in the other. In the latter case, it is also possible to look at citations — a measure of impact.

Finally, we discuss a way of mapping policy issues in innovation. In our view, this has the potential to systematise discussion and comparisons of national innovation systems — of the qualitative aspects particularly — in a manner useful for analysis.

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* Views expressed in this paper are those of the authors, and are not necessarily those of the Government of the Commonwealth of Australia, or of DIST.

Introduction

Fostering innovation is now a vital component of national policies in most OECD countries. It is now widely accepted that the role of governments is not merely to monitor progress and intervene to avoid market failure, but also one of making adjustments so that the overall innovation system will operate more effectively. However, a common problem many governments face in times of decreasing national budgets is what priority to give such activity in the face of many other competing demands. And if some priority is to be given to stimulating innovation, or diminishing impediments to it, what actions would be the most effective?

These problems are the motivation for seeking to gain a better understanding of national innovation systems — the collection of conditions, traditions, institutions, government policies and programs, and competitors, that constitutes the broad arena within which all markets operate and all firms must innovate and compete.

Australian R&D Trends and Policy Emphasis

Probably the best understood aspect of any nation's innovation system is the role of R&D. The evidence suggests that innovative firms are mostly those that perform R&D. The structure and role of R&D in Australia, both public and private, is a principal key to describing Australia's national innovation system.

The stimulus to describe the current Australian innovation system has its origins in the recent history of R&D spending, widely regarded as rapidly improving in Australia through policy initiatives that galvanised business investment.

The oil shock of the early 1970s in Australia, coupled with a sharp step downwards in the level of tariff protection to a highly protected manufacturing industry, had brought business R&D expenditure down to a low of 0.25 per cent of GDP in 1981-82, about 60 per cent of its prior peak level. This reflected a seriously depleted Australian innovation system.

To turn this picture around, policy during the 1980s focused on stimulating business R&D. This proved very successful, tripling to 0.74 per cent of GDP by 1994-95. Nevertheless, business R&D remains low by international standards — see Chart 1.

Chart 1 Business expenditure on R&D (BERD) as a proportion of GDP, change and growth rates in BERD — international comparisons

		Period 1981 to 1988		Period 1988 to 1994	
	%BERD/GDP (latest)	Change	Average annual real increase in BERD	Change	Average annual % real increase in BERD
Sweden (1993)	2.32	0.54	8.3	0.33	3.8
Japan (1994)	1.91	0.54	8.8	-0.03	1.6
Switzerland (1992)	1.88	0.44	7.9	-0.26	-3.6
United States (1994)	1.80	0.29	5.7	-0.20	0.6
South Korea (1993)	1.72	1.02	37.9	0.44	12.9
Germany (1994)	1.54	0.36	5.0	-0.53	-0.5
France (1994)	1.47	0.19	4.4	0.11	2.9
Finland (1994)	1.46	0.43	11.2	0.38	2.8
United Kingdom (1994)	1.43	-0.02	4.1	-0.04	-0.2
Belgium (1991)	1.11	0.16	3.9	-0.10	0.2
Denmark (1993)	1.05	0.28	9.1	0.22	6.5
Norway (1993)	1.04	0.45	11.7	-0.09	1.2
Chinese Taipei (1994)	1.03	0.08	14.1	0.44	15.6
Netherlands (1993)	0.99	0.35	7.5	-0.34	-4.0
Canada (1994)	0.91	0.17	8.0	0.14	4.3
Ireland (1993)	0.84	0.16	10.6	0.38	18.2
Austria (1989)	0.80	0.15	3.5	na	na
Singapore (1993)	0.75	0.36	28.1	0.24	17.6
AUSTRALIA (1994-95)	0.74	0.28	17.7	0.21	8.0
Italy (1994)	0.67	0.21	8.2	-0.03	0.5
Spain (1994)	0.47	0.21	13.9	0.06	3.3
New Zealand (1993)	0.31	0.06	-0.6	0.03	3.6
India (1992)	0.19	0.03	7.0	0.01	3.7
China (1994)	0.11	na	na	0.11	-1.6
Average (24 economies)	1.11	0.29	10.3	0.07	4.2
Average (OECD only)	1.20	0.29	8.4	0.01	2.7

Source: DIST based on OECD and national sources.

Chart 2 Expenditure on R&D in government agencies and universities as a proportion of GDP, change and growth rates, and basic R&D as a proportion of GDP— international comparisons

		Period 1981 to 1988		Period 1988 to 1994		
	R&D expend. in govt and universities as % GDP	Change	Average annual % real increase in R&D	Change	Average annual % real increase in R&D	Basic R&D as %GDP (most .recent year)
Sweden (1993)	0.94	0.16	5.3	-0.04	-2.8	0.53
Norway (1993)	0.90	0.07	3.7	0.23	4.4	0.28
Finland (1994)	0.89	0.18	7.9	0.17	3.7	na
France (1994)	0.88	0.11	3.7	-0.02	0.9	0.50
AUSTRALIA (1992-93)	**0.88**	**-0.02**	**3.3**	**0.14**	**5.0**	**0.45**
Netherlands (1993)	0.83	0.03	2.3	-0.01	2.7	na
Germany (1994)	0.79	0.07	3.5	0.02	5.6	0.49
Switzerland (1992)	0.77	0.10	0.7	0.22	4.3	na
Denmark (1993)	0.73	0.11	5.6	0.08	3.2	na
New Zealand (1993)	0.72	-0.18	-2.5	0.13	7.5	na
United Kingdom (1994)	0.69	-0.18	-0.4	0.06	2.3	na
United States (1994)	0.65	0.07	5.1	-0.07	0.1	0.42
Canada (1994)	0.64	-0.03	2.3	0.05	2.6	na
Japan (1994)	0.64	-0.02	3.6	0.03	4.1	na
Austria (1989)	0.55	0.06	4.9	na	na	na
India (1992)	0.54	0.23	12.4	-0.11	-1.2	na
Belgium (1991)	0.54	-0.03	0.6	0.16	14.2	na
Italy (1994)	0.52	0.13	7.3	0.01	1.7	0.24
Singapore (1992)	0.51	0.23	22.8	0.15	16.1	na
Chinese Taipei (1994)	0.48	0.16	10.6	0.06	10.8	0.29
Spain (1994)	0.45	0.07	6.4	0.15	9.9	0.15
Ireland (1993)	0.39	-0.03	2.2	0.04	7.4	0.07
China (1994)	0.34	na	na	-0.07	8.6	0.03
South Korea (1993)	0.28	0.11	17.3	0.03	8.6	na
Average (24 economies)	**0.65**	**0.06**	**5.8**	**0.06**	**5.0**	**0.31**
Average (OECD only)	**0.71**	**0.04**	**3.5**	**0.07**	**4.1**	**0.35**

Source: DIST based on OECD and national sources.

At the same time, the Government modestly expanded its investment in public R&D, from 0.75 per cent of GDP in 1981-82 to 0.88 per cent of GDP in 1992-93, and reshaped the delivery of public R&D to more effective use, especially by industry— see Chart 2.

Taking a static comparison between these recent Australian R&D expenditure levels and those of other OECD nations provides us with some key insights into the nature of Australia's innovation system. In business R&D expenditure rankings, Australia at 0.74 per cent lies well below the OECD average of 1.2 per cent. In public R&D expenditure, Australia at 0.88 per cent lies well above the OECD average of 0.71 per cent. (Of course, the situation had been much worse in 1981-82.)

These perceptions — that Australia's public sector science was strong, while business R&D was weak, led to three broad policy emphases that successive Governments have maintained since the early 1980s:

1. Maintain the strength of public sector science
2. Improve the innovativeness of the business sector
3. Capitalise on public sector strengths by improving linkages with business.

The static comparison from Charts 1 and 2 suggests that the balance in the Australian innovation system is tilted towards the public science base and away from business. However, the R&D growth rates in the charts suggest that Australia is trending towards a more balanced system.

Over the most recent eight year period, growth rates for Australian R&D show the second fastest business R&D growth rate in the OECD at 8 per cent, while public research growth is much less, at around 3 per cent.

This picture can also be confirmed by two clusters of indicators that use national levels as a proportion of total OECD levels. These clusters use R&D expenditure, scientific publication counts, and patent counts.

In Chart 3, we have derived OECD based comparisons for business in twelve nations[1]. Australia's share of OECD external patenting since the early 1980s tracks with great precision the ebbs and flows in the corresponding share of business R&D expenditure. Interestingly, the Australian data correlate in this way much more satisfactorily than is the case for other countries — though Spain and Ireland show some similarities between their growth and changes in BERD share and external patenting share. Only a few countries — notably the Netherlands — correlate in this way between BERD and domestic patenting.

There are good reasons for using OECD totals rather than world-wide totals, eg:

- Taking most OECD economies, data are available on the same basis for a wide range of indicators.
- In the majority of cases, OECD economies are a mature ones — so that most data and methodologies for obtaining data are reasonably stable over time.
- For some indicators, high growth across a number of rapidly developing economies is significantly affecting world totals — in some cases this is exacerbated because there have been coverage problems (eg, for China).

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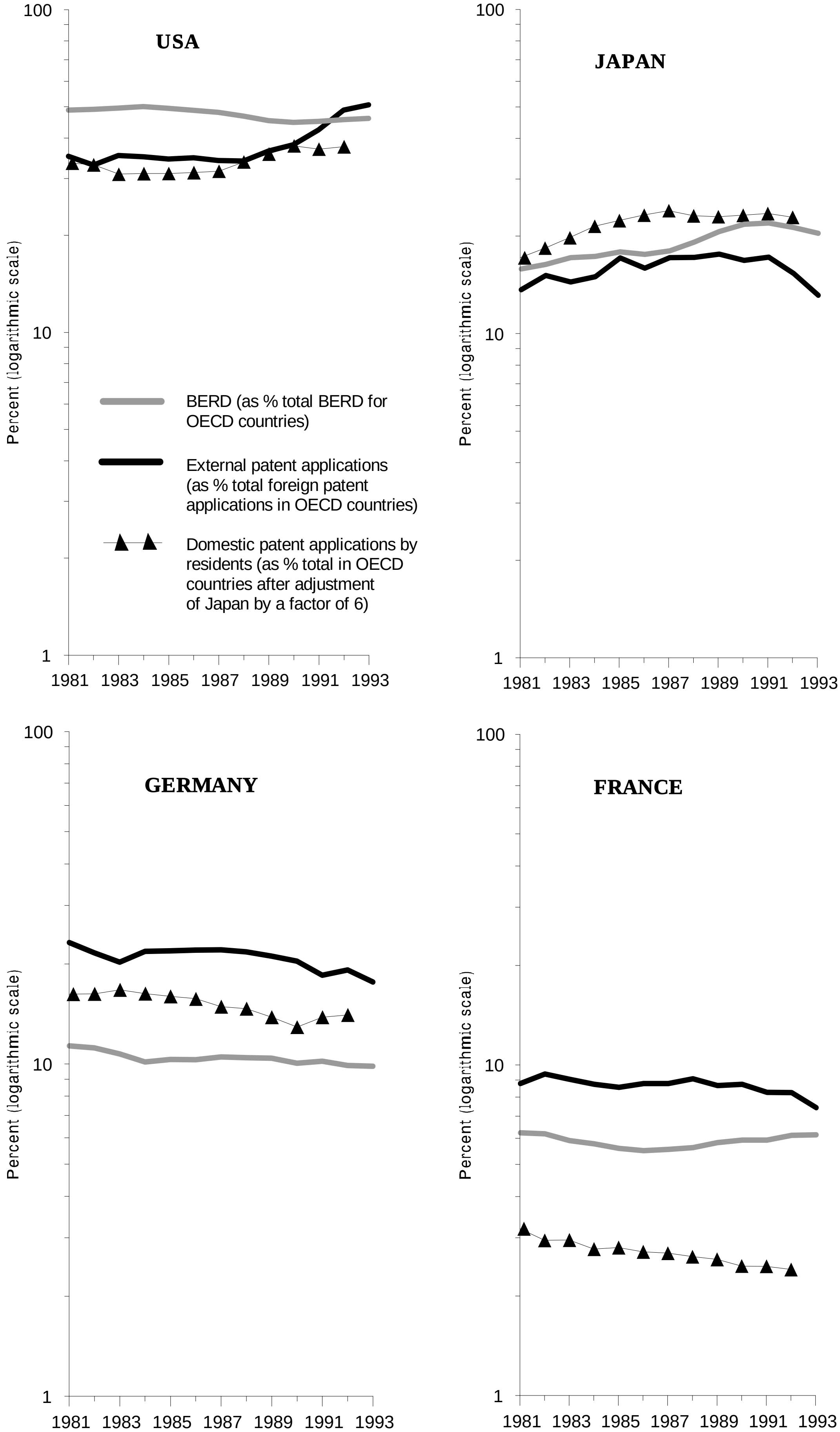
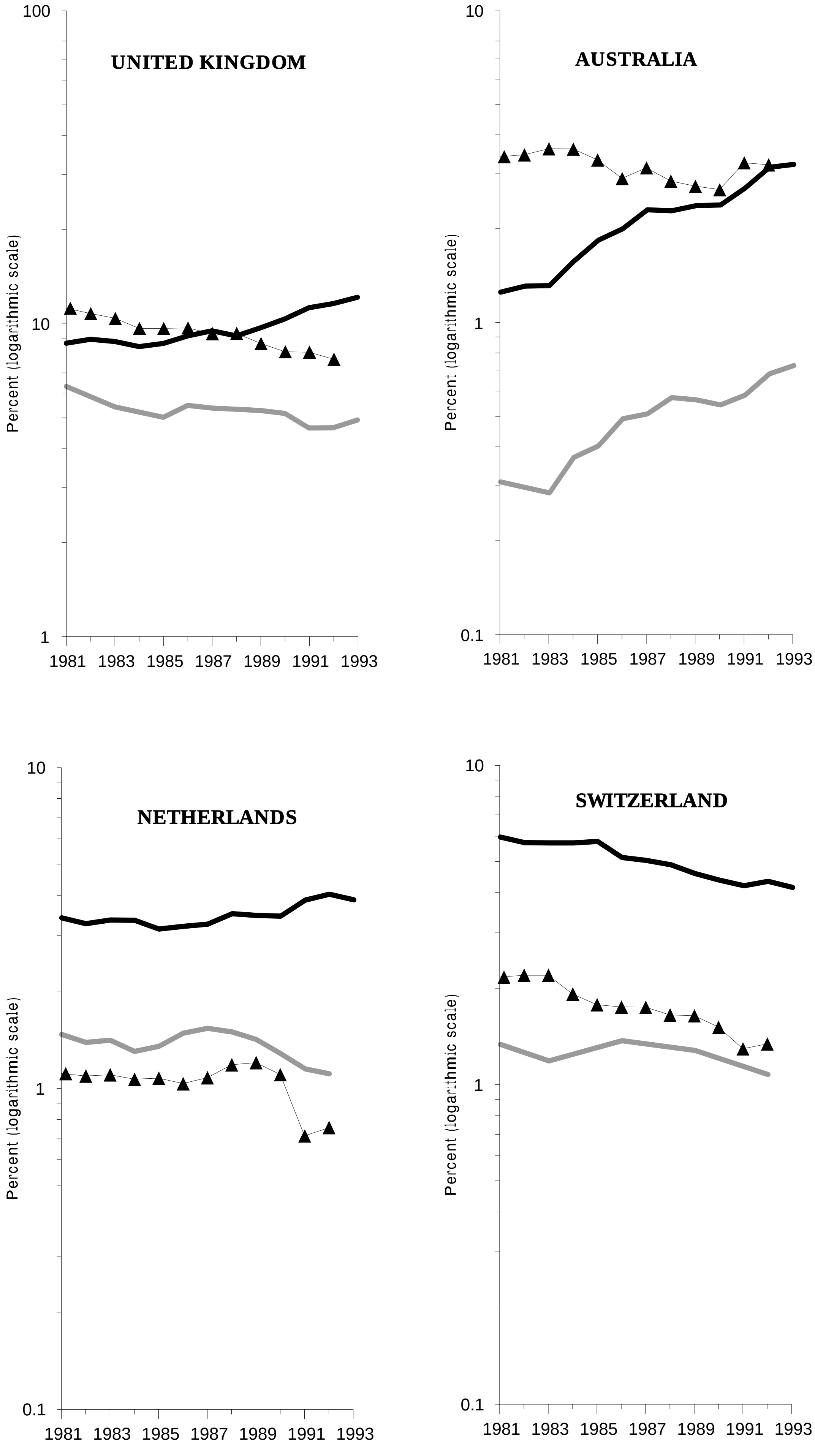
[1] See Bryant K and Lombardo L (1996) *Comparisons based on national shares of OECD-wide aggregates for BERD, patent data, non-BERD, and bibliometric data: a means of comparing national systems of science and innovation*, Room Document, OECD Conference on New S&T Indicators for the Knowledge-based Economy, 19-21 June, OECD, Paris.

Chart 3 Trends in BERD and Patent Applications




UNITED KINGDOM
Percent (logarithmic scale)
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NETHERLANDS
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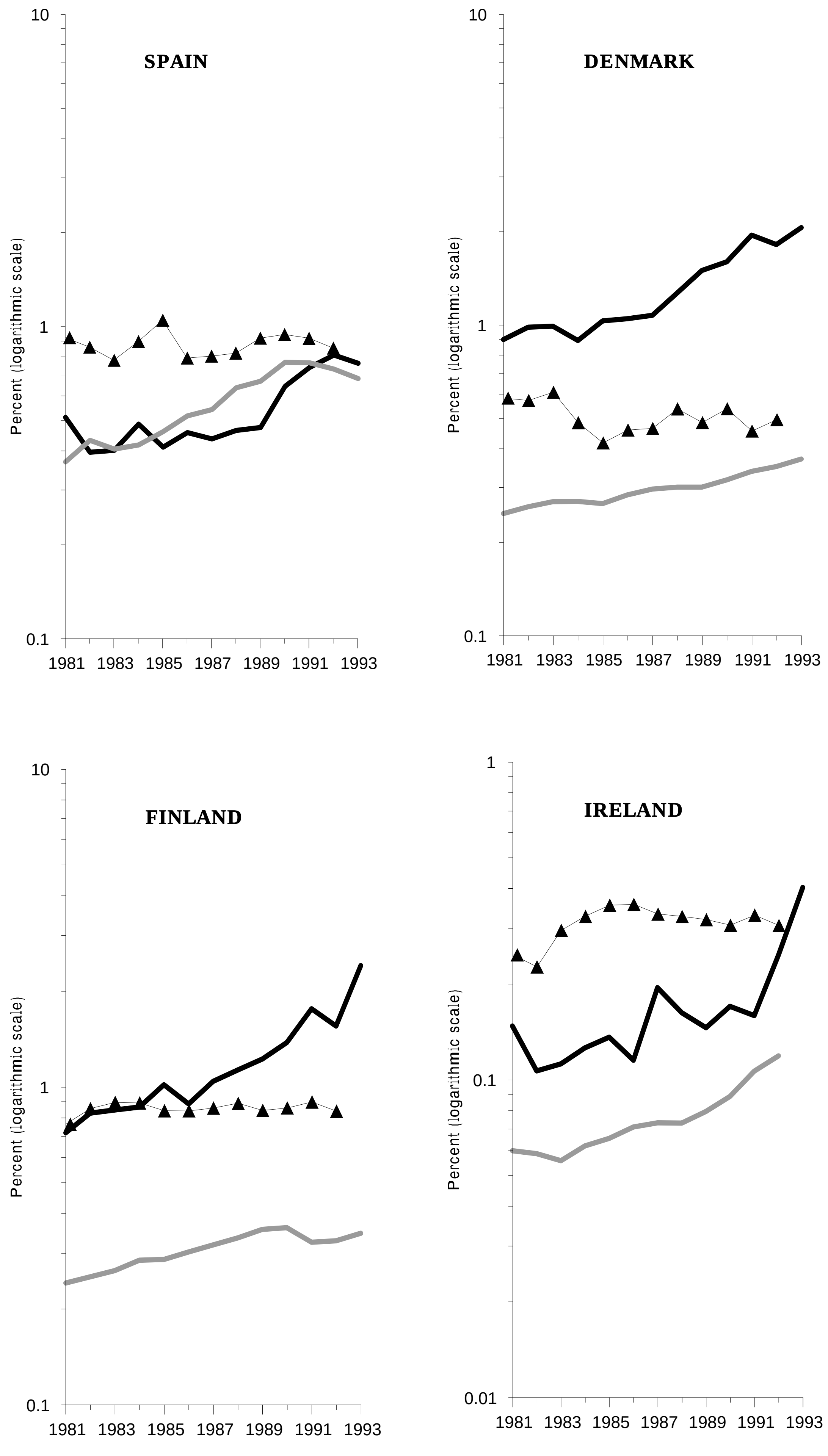

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DENMARK
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Percent (logarithmic scale)
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FINLAND
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Percent (logarithmic scale)
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IRELAND
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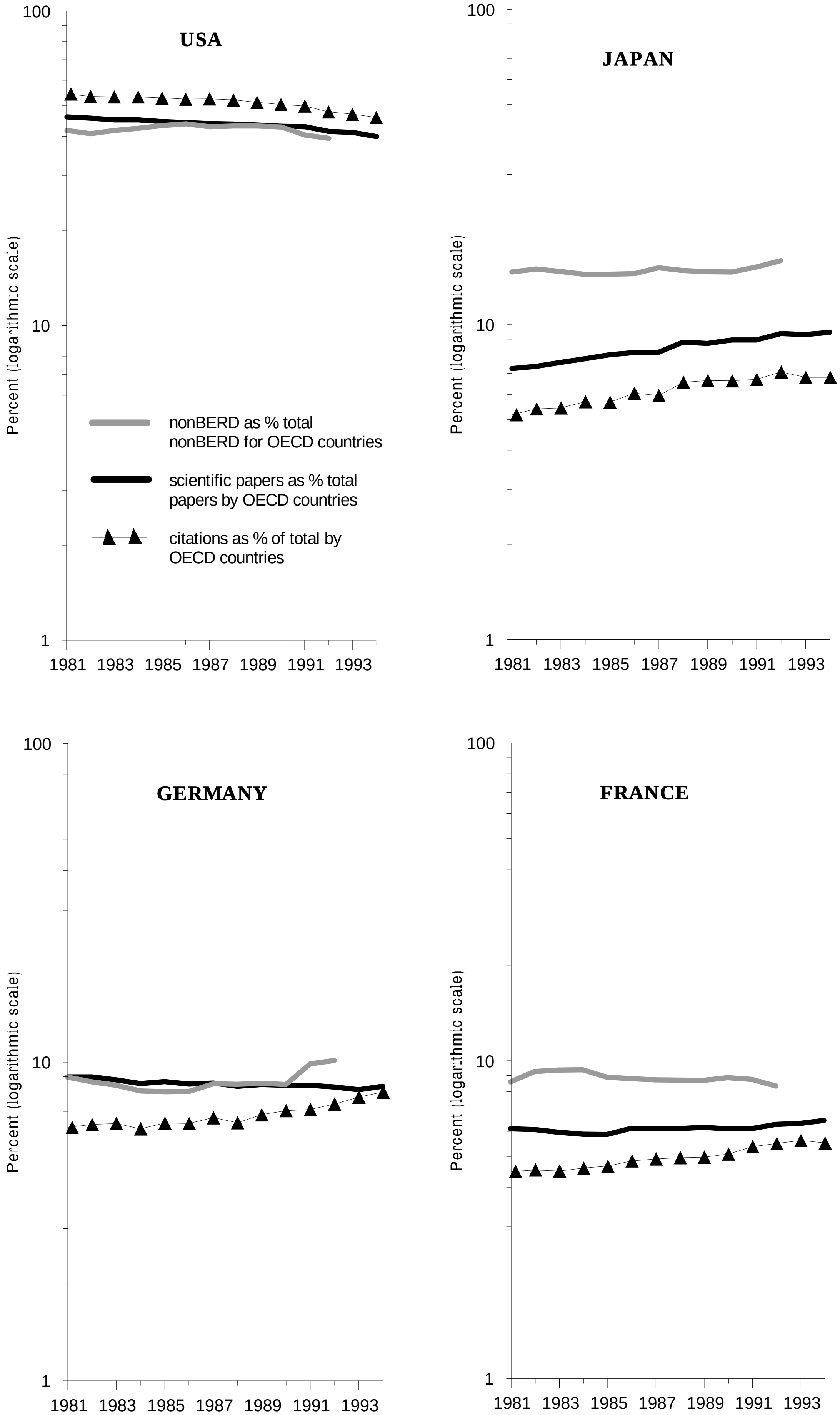
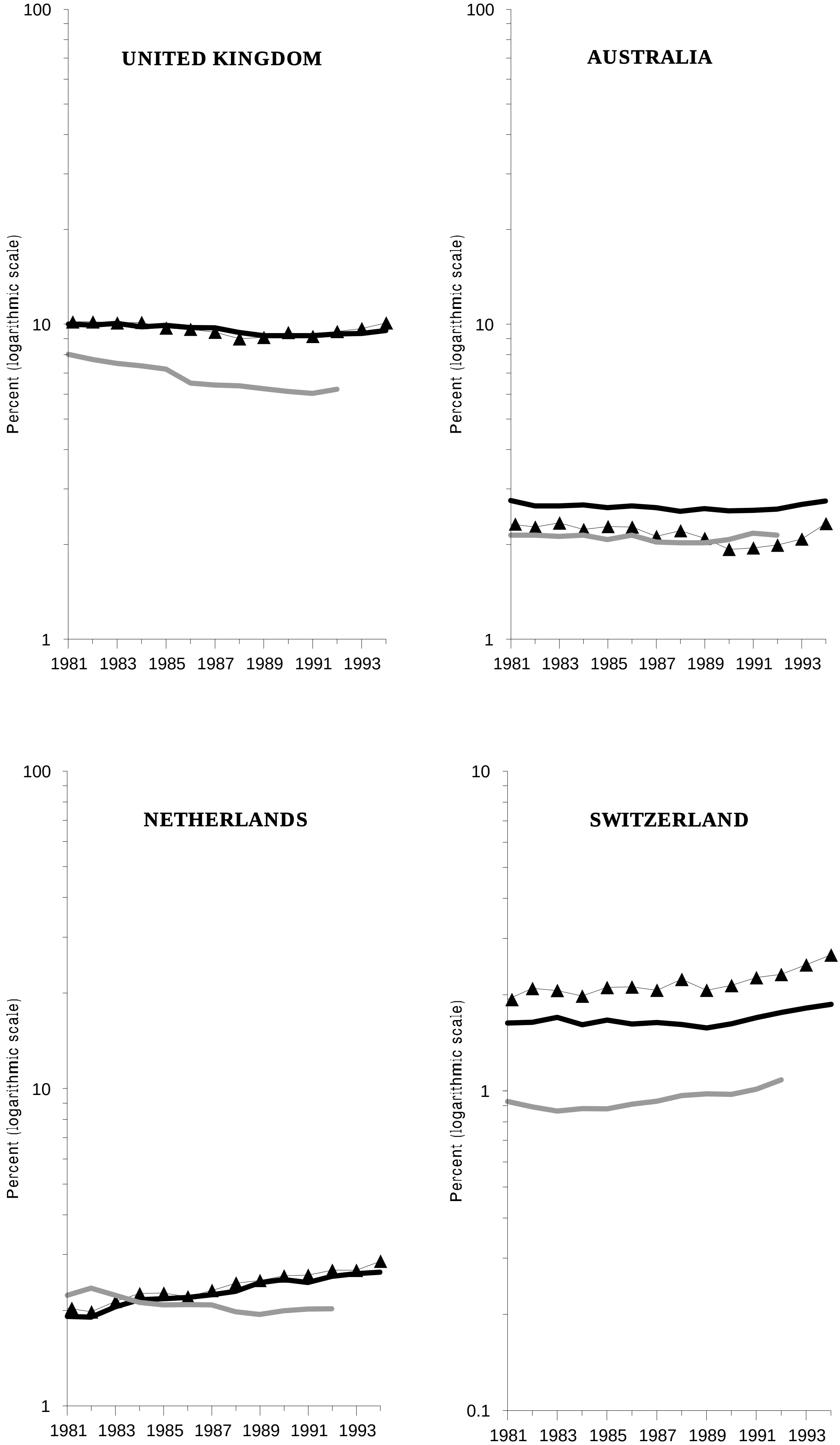
Chart 4 Trends in nonBERD and Scientific Papers

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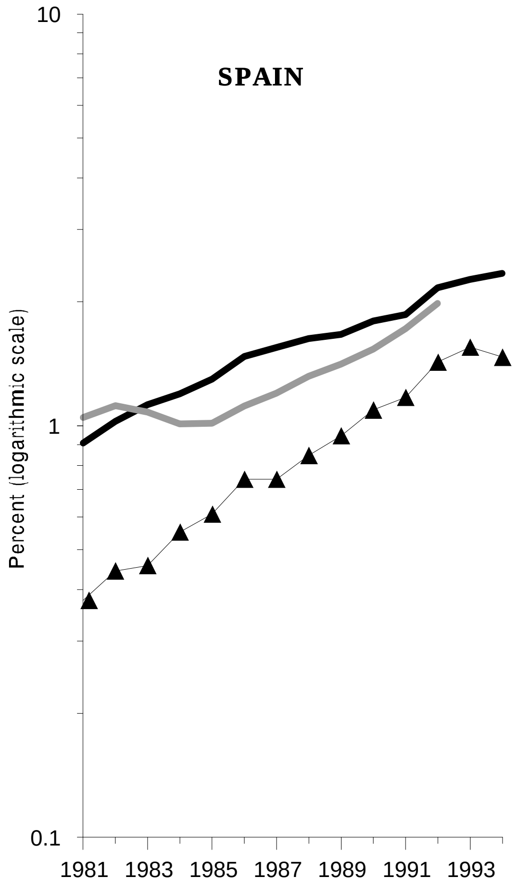
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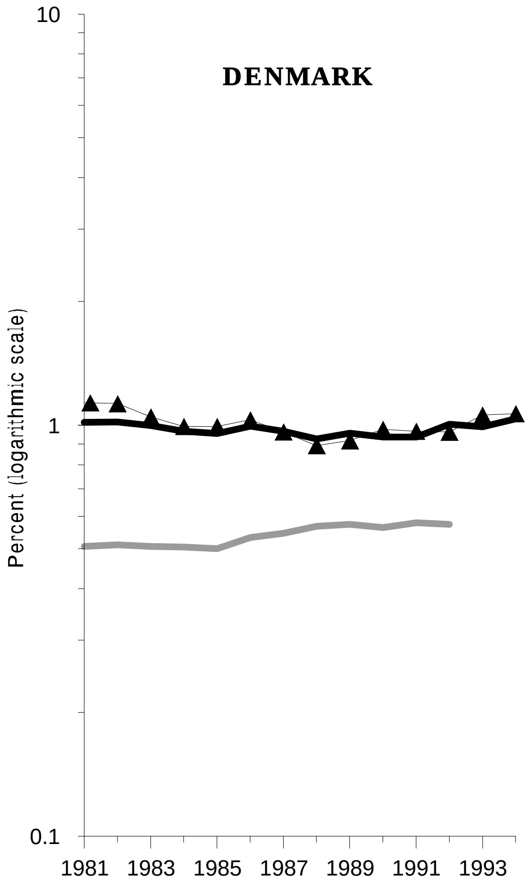
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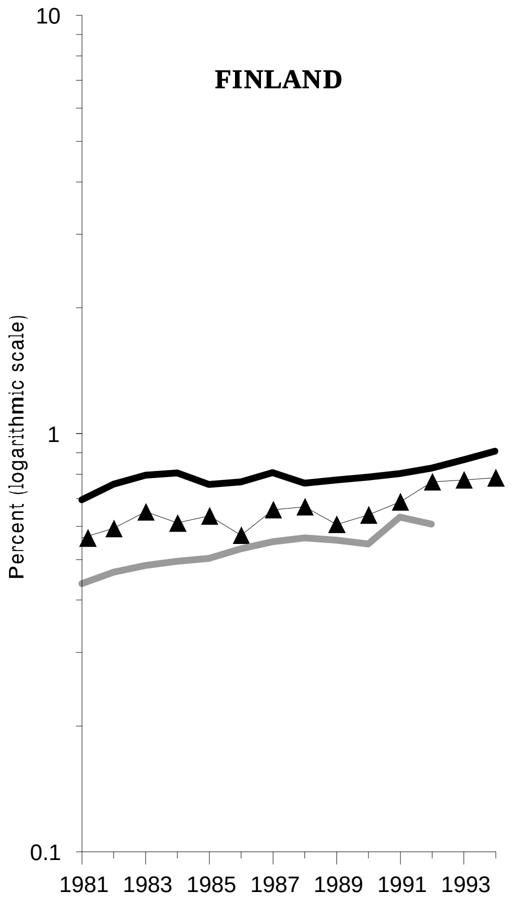
FINLAND
Percent (logarithmic scale)
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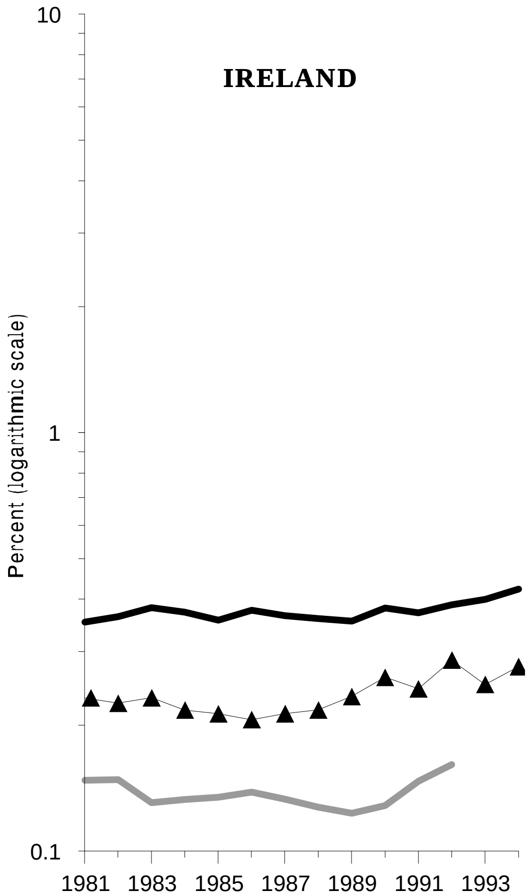

IRELAND
Percent (logarithmic scale)
10
1
0.1
1981
1983
1985
1987
1989
1991
1993

Chart 4 illustrates broad trends in shares of OECD ‘‘nonBERD’’ — university and government agency R&D plus the small amount of research carried out in the private non-profit sector. These OECD based comparisons for the non-business sectors are for the same twelve nations as in Chart 3. Trends in shares of R&D expenditure are compared with trends in the output of research papers and trends in the citations to nationally produced research papers. Australia’s performance is much flatter than in Chart 3, with a small increase in scientific papers and their impact from about 1990.

NonBERD R&D expenditure reached its lowest point in Australia over 1988 and 1989. At this stage, the then Government allocated additional funds and a number of new initiatives were announced in a White Paper in mid-1989.

The outcome of these initiatives can be seen in a recovery in Australia’s share of OECD research papers a year or so later, and a recovery in the share of OECD citations a year or so after that.

Among other countries, the performance of Spain is remarkable. In fact, taking Charts 1 to 4 together, the performances by Spain, Finland, Denmark and Ireland over recent years are all in various ways impressive. These four countries might well be regarded as European pacesetters in innovation, just as (more dramatically) the four “Asian leaders” — Korea, Chinese Taipei, Singapore and Hong Kong — have been in another part of the world.

Mapping National Systems of Innovation

Because of the importance and increased understanding of innovation, we have begun to explore and map the many other factors, besides R&D, that are part of Australia’s national innovation system. A detailed account was published earlier this year.[2]

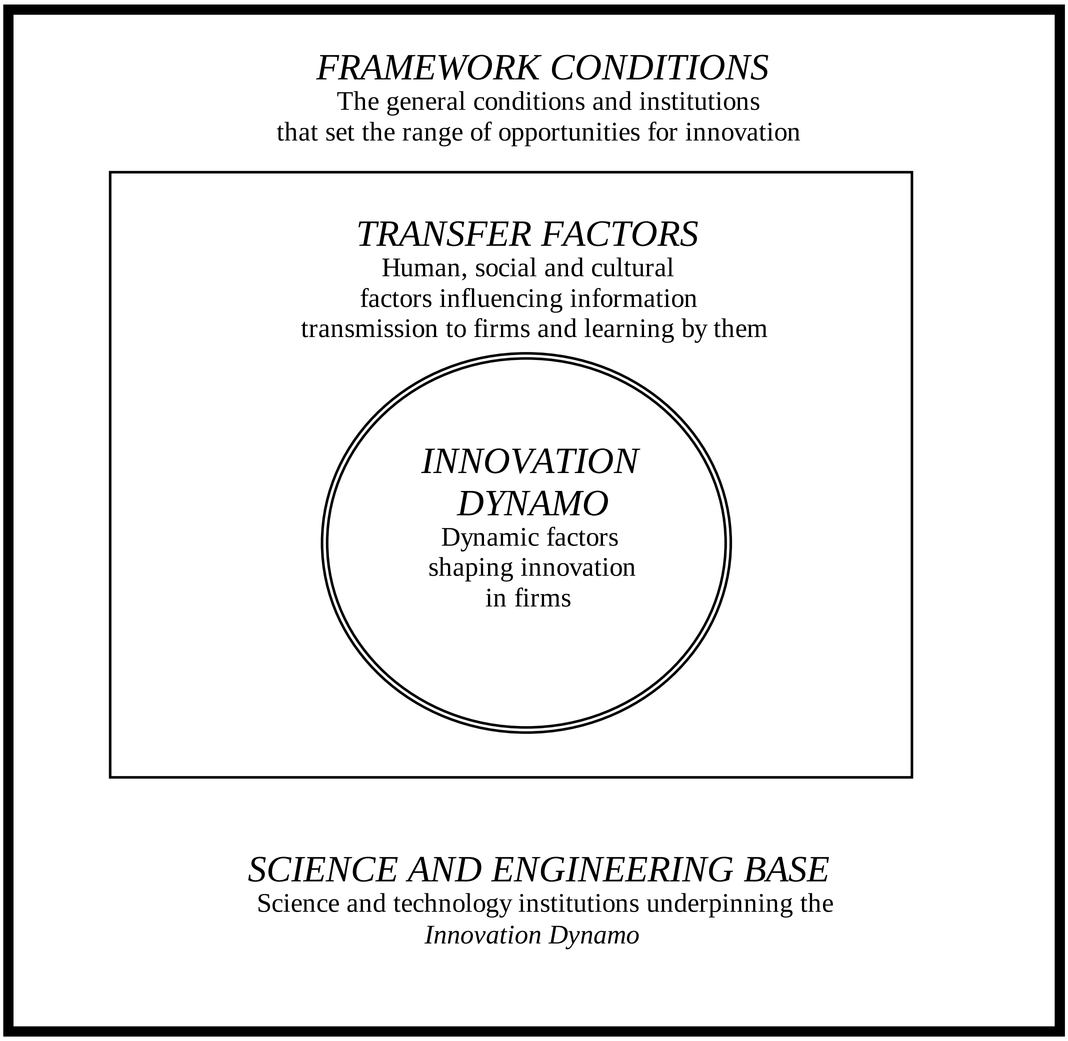
This is based on the concept of an “innovation policy terrain”, or map of innovation policy issues. This idea has now been carried further in the new edition of the *Oslo Manual* that provides guidance on standard practices to be followed in the measurement of innovation and the establishment of national innovation indicators.

Examining the broad range of innovation policy initiatives that have been taken across the world suggests that there are three main classes of innovation issues being addressed. These concern business enterprises (‘‘firms’’), science and technology institutions, and issues relating to the tranfer and absorption of technology, knowledge and skills. In addition, the range of opportunities for innovation is also influenced by a fourth set of factors — the surrounding environment of institutions, legal arrangements, macro-economic settings, and other conditions that exist regardless of any considerations of innovation.

We find it helpful to visualise these four classes of issues in the way illustrated in Chart 5.

[2] See Chapter 1 of Bryant, K, Lombardo,L, Healy, M, Bopage, L, and Hartshorn, S, [Department of Industry, Science and Technology] 1996, *Australian Business Innovation: A Strategic Analysis*, AGPS, Canberra

Chart 5   The Innovation Policy Terrain - A Map of Issues



Essentially, the Map has four domains:

- *FRAMEWORK CONDITIONS:* include matters such as corporate and patent law, macro-economic policy, competition policy, capital availability — particularly venture capital, access to markets — particularly foreign markets, and infrastructure and other structural features such as the balance between industry sectors, the relation between sectors, and the balance between national and foreign firms.

- The *SCIENCE AND ENGINEERING BASE:* covers specialised training, the repositories of the accumulated pure and applied knowledge base, universities, basic research, community interest R&D (eg, health, environment, defence), strategic R&D into generic technologies, and R&D (agricultural, for example) that is not readily appropriated by individual businesses (small farms).

- *TRANSFER FACTORS:* cover a range of diffuse and often informal factors that to a greater or lesser extent will encourage or impede innovation activity within firms, particularly firms' receptivity or absorptivity in relation to new ideas or developments — specific factors include value systems, linkages and networks (informal as well as formal), ease of "spinning-off" new commercial enterprises that can pursue particular developments in a single-minded fashion, the ease of accessibility to public sector S&T institutions, and the readiness with with skilled personnel can move between positions and organisations.

- Activities within the confines of the innovative firm *(INNOVATION DYNAMO)* fall into three sub-categories:

  ⇒ In *strategic sub-categories*, management focus is very important. This covers strategic direction in relation to markets and technology. "Style" is intended as a shorthand for a number of things — not merely the form of the organisation and its work practices, but more management and employee attitudes throughout the firm towards "best practice" and quality, and therefore influencing the extent to which continuous improvement and incremental innovation will occur.

  ⇒ *R&D* activities are particularly important for the development of the firm's capabilities quite aside from the benefits that also result from the development of any new technology or the solving of pressing technical problems.

  ⇒ *Non-R&D* activities such as technology adoption, design, and commercialisation are vital.

The INNOVATION DYNAMO is the domain most central to innovation, covering factors very directly impinging on a firm's innovativeness. It groups policies and programs that are stimulating R&D and its commercialisation, technology acquisition, design, and enterprise organisation. In more detail:

In relation to enterprise focus, there are great differences among firms in Australia in adopting best practice management and a strategic outlook; the policy response in Australia is the *AusIndustry Enterprise Improvement Program*.

As discussed above, stimulating business R&D has been very successful in Australia. The policy response to earlier low levels was the *industrial R&D tax concession*, a *competitive grant scheme* for industrial R&D, and recently the *R&D Start program* for larger industrial research ventures.

Stimulating research commercialisation through specific policies and programs showed mixed success in Australia illustrated by the program known as *Management Investment Companies*, disbanded after a few years operation. The present commercialisation programs are the establishment in 1991 of the *Australian Technology Group Limited* (ATG), and the *Concessional Loans for Commercialisation of Technological Innovation*.

Technology adoption often depends on the knowledge generated from in-house R&D or the networks that researchers establish outside the firm; the policy response in Australia is the *Enterprise Networking Program*.

TRANSFER FACTORS strongly influence the effectiveness of the linkages, flows of information and skills which are essential to innovation. The culture of the Australian population is important in this. Bringing science and business together involves a blending of cultures. In essence, these factors are based mostly around the prevailing culture. Factors such as learning and life long education may be highly valued, while the ease of communication in a country and tapping into the world's information sources may suffer impediments. In Australia we have a particular impediment to movement of people and their skills, arising from lack of superannuation portability.

The outer domains are the FRAMEWORK CONDITIONS and the SCIENCE AND ENGINEERING BASE. The latter consists of that part of the institutional arena that provides the broad scientific knowledge for activities within the innovation dynamo. It provides the skilled people for firms to carry out innovation, as well as advice, collaborative ventures, and new technology. This domain is where policy is very influential in Australia as we rank well in the OECD in terms of expenditure and the Commonwealth Government is the major source of funding.

The FRAMEWORK CONDITIONS that lie outside the science and engineering base comprise institutions which have mostly been established for reasons unconnected to innovation. Broadly, these institutions largely creat the economic and social environment in which innovation operates. They affect the range of opportunities presented to the innovating firm - what is feasible in one country may not be in another. A particular impediment to innovation in Australia concerns the financial institutions, which determine the ease of access to venture capital, as this appears to be more difficult in Australia compared to some other countries.

This idea of a national innovation system implies that innovation policy needs to adopt a holistic approach and take many factors into account. In fact, recent policy evolution in Australia has consistently been in this direction. For example the formation of *AusIndustry* has brought many Government innovation programs under one administrative umbrella and its "one-stop shop" mode of operation has promoted a more integrated approach. Similarly, science and business seem to be working together more effectively than in the past — universities and science agencies are earning much more from industry than previously.

In the map of our system, this suggests that the "innovation dynamo" may be becoming better linked to the "science and engineering base" through the "transfer factors". The latter are bridging the two different cultures involved. A useful way to proceed to gain insights for international comparisons of qualitative aspects of innovation systems would be to provide brief descriptions or assessments of each country's situation in relation to each component of the four broad domains of policy issues along the lines defined in Chart 6. We can readily do this for Australia, and would like to explore the possibilities for doing so for additional countries.

Chart 6 Qualitative Information in the Innovation Policy Terrain