ITALIAN SYSTEM OF KNOWLEDGE

OECD PILOT PROJECT

Bianca Potì, Elisabetta Cioffi

ISRDS/CNR

1. The key aspects of the analysis

The aim of this paper is to contribute to the discussion on methods of analysis and policy implications of the national systems of innovation. The analysis is focused on the scientific and technical knowledge system, which is articulated in three main components:

- scientific and technical competences available in the national system;

- the horizontal and vertical linkages among different competences and institutions;

- the role of policy regulation and S-T institutions towards the development of the relations among heterogeneous actors, which are considered as the key element of the innovations.

The background of this analysis is that learning is the main potential source of comparative adavantages among countries and that new knowledge at the microeconomic level comes through "external" mechanisms: fundamentally education and combination (acquisition or sharing) with other different competences and actors.

The sources of new knowledge are fundamentally of two types:

I embodied or based on an exchange of goods and services carriers. This is the most important mechanism, conditioned by the country's industrial structure, at least if we consider the innovative performances in a relatively short horizon. In the study we identify two processes:

investments or adoptions of new capital goods by firms;

user-producer exchanges of innovative goods and services. In particular M. Porter has led attention on the positive impact of a domestic market and of advanced domestic users on the innovative and competitive results of a country. We followed this direction and found coherence between the Italian technical and commercial specialization and the main innovative clusters. Indexes of diffusion and spillovers are used here to analyse the knowledege distribution;

II independent from a goods and services exchange carriers. Many different modes of transfer and exchange of knowledge are recognizable here: R/D collaborations or subcontracting, education and mobility of qualified personnel, patents acquisition, diffusion through publications, informal relationships, consultancies. What is more interesting to investigate in the case of independent from goods exchanges knowledge transfer, are the so-called triangular relations among universities, business firms and research institutes. The rationale for these hybrid associations among profoundly different institutions is not univocal in the literature: according to some points of view it could have been driven from policies promoting socio-economic programs, which link together public laboratories and industrial firms. According to other scholars, the process of coming together of scientific and industrial institutions could have been promoted by industry, both for its growing interest in using scientific knowledge and for its changing orientation towards more cooperative relations and more open circulation of knowledge. Finally it could have been spurred by independent resources providing strategies of scientific laboratories.

The other two components of the S-T knowldege system analysis are :

- S-T competences: here the completeness or the degree of specialization in scientific disciplines and technical fields and the quality or the impact of the scientific and technical output are considered. Useful specializations and a good quality of the competences are the basis for starting collaborations and knowledge exchanges, particularly if the promoter are the business firms. Moreover the absorptive and creative capacity of business firms through R/D and education and the transfer capacity of public research institutes, through outputs supplied in suitable forms, are considered. A critical aspect, for the effective use of the potential effects of relations between various agents, is represented by the so called (by Carlsson) economic competences of business firms. These are defined as the orientation to commercially exploit new knowledge and can be recognized in the industrial diversification processes. In this paper they are represented through the national technical specialization by patents in two different periods and the manufacturing structure evolution after a decade: in Italy the changes have been marginal.

The policy and institutions which support the distribution of knowledge: it is largely accepted that the knowledge transfer and exchange activities are often complex and costly processes, which are not only a private matter. For instance, regulations more or less favourable to the University-industry relations influence the dimension and the forms assumed by the transfer processes. An efficient system of knowledge distribution is those which increase the social value of the produced knowledge, by increasing the probabilitiy of new combinations and accumulation. Our analysis has also the aim of singling and pointing out to policy makers both the nodal points and virtuos circles of knowledge diffusion and the problematic areas.

2. The methodology

Fundamentally two methods of study were identified:

- partial study of the entire system, through analysis of knowledge distribution in some specific, operative clusters. In this case an in depth analysis is possible, where transfer mechanisms and knowledge carriers are identifiable. A national system approach, nevertheless, would need the finding out of the linkages among different clusters, something like networks or clusters of clusters;

- a complete model of distribution mechanisms and of knowledge stocks and flows, without carrying out a full scale quantitative study. This is the method we followed. In this case there are not partial operative clusters, but technological sectors or industries and different institutional agents. We described the way in which three categories of agents (education institutions, public research and transfer institutes, business firms) are organised:

- the capacity for innovation within each category (competences);

- the knowledge distribution links intra-firm, intra-industry, inter-sectors and inter institutions;

As to the aim of quantifying the mobile and distributable knowledge, where an incomplete appropriation is present, only partial results were reached, through the use of diffusion and spillovers indexes. Fundamentally the quantifiable areas of knowledge exchanges were those of the embodied carriers (capital goods and innovative goods and services) and that of the research activities. Other carriers have not been explored, because of the lack of information, such as the distribution of national patents by sector of use.

The main sources of data were:

- two national innovation surveys, carried out in different periods by the National statistical office, with the support of Isrds/Cnr. The first survey received 16000 answers by business units, having introduced new or improved product or processes between 1981 and 1985. Only 8220 indicated the main user sector and the innovative matrix (users-producers of innovation) referred to this universe. The second innovation survey received 7553 answers from business units having introduced technical innovations in the 1990-92 period, that is a third of the total answers: 22.787, equivalent to the 68,5% of the total surveyed universe (all the business firms with more than 20 employees);

- the annual survey on scientific research of the National statistical office. In 1991 (the most up to day available data) the public research institutes (not included Universities) were 416 and the business units 1150. Since 1991 the survey included new information about intramuros R/D (internal and in collaboration) and on extramuros R/D.

We referred also to an analysis on an input-ouput basis, two more surveys on innovation and research, and a database on patents:

- the Oecd analysis (G. Papaconstantinou and N.Sakurai, 1995) on total R/D intensity: the methodology was to estimate technology flows by using enterprise R/D expenditures data with input-output and investment flows data. The only input-ouput matrix available for Italy is still 1985. The analysis generated indicators of how industries (in different countries) use different types of inputs (intermediate and investment goods), where technology is expressed in terms of the R/D embodied in these inputs.

Moreover acquired technology is divided into a portion obtained from domestic and another from foreign suppliers. Technology is assumed to flow from an industry to another, when the industry where R/D originates sells products to other industries, which use them as inputs in their production processes;

- the Pace survey, conducted by Merit et al. (Bocconi for Italy) on innovation strategies of Europe's largest industrial firms. The response rate for Italy was 48,5%, that is 97 units (areas of responsibility of the answering R/D manager) on the total of 200 surveyed. This is a cross sectional analysis on one year and does not provide information on best practice, but information on what R/D managers believe are important factors to innovation;

- the 1991-93 Csc survey on scientific research in 160 Italian business firms;

- the Cespri-Bocconi database on patents and copatents (1978-91).

Bibliometric analyses (based on patents and publications), were not enough exploited for studying the relations among scientific and industrial agents, because it seemed a difficult task calculating the references made to scientific papers in patents field, by applications from the same country and studies on this subject were not found. The bibliometric data were used only to analyse the scientific and technical specialization of Italy (a study realized by D. Archibugi and M. Pianta, Isrds/cnr) and to investigate S-T collaborations in patenting.

3. The organization of the report

The organization of the report is as following: in the next paragraphs the analysis of Italian system of knowledge is developed. Each paragraph is articulated on the basis of some main available and selected indicators. At the end of each paragraph there is a synthetical comment and the supporting tables are indicated.

First (paragraph 4) the stock of scientific and technical competences is examined, in terms of quantity (dimension and intensity) and quality. Then (paragraph 5) the general intra and inter institutional relations are considered, in terms of financing, R/D links, sources of informations and transfer mechanisms for innovative activities. Paragraph 6 deals with the inter industrial flows. Inter industrial relations are the only area where it was possible quantifying the knowledge flows in terms of total R/D intensity (internal and embodied in capital flows), R/D expenditure spillovers and innovative activities spillovers. Two are the more evident limits of this exercise: the (till now) lack of a global measure of the knowledge available (the knowledge pool) by sector and the fact that (at the present stage of the study) the innovative activity spillovers are measured by the frequence of user-supplier links and not as a quota of the sales, therefore it is not possible to sum up them to other indexes.

In the paragraph 7 the relations among Universities, research and transfer institutes and business firms are explored. This is an area of analysis where it is not easy to find a synthetical measure of the rate of links, because the regulation of these relations and the formal mechanisms of interaction are not enough developed. Consequently, the triangular relations have to be referred to a set of quantitative indicators (such as financing, R-D collaboration and contracts, copatenting and programs) and to qualitative information about the exchanges (transfer carriers, scientific outputs). The other paragraphs were examined more in short and they deal respectively with: (8) the intrafirm organization of the coordination between research and other functions; (9) the performances, both at meso level, in terms of innovations as quota of the sales of the manufacturing sectors, and at the national level, in terms of export specialization profile; (10) the S-T policies, where a business firms evaluation of the efficacy of different incentives was considered. Moreover, in the same paragraph a short analysis of the gate keeper institutions and the infrastructure for cooperation is available. These four last paragraphs could be better treated in the future. A cluster analysis concluded the examination of the national system of knowledge (paragraph 11). Its aim was gathering industries on the basis of their more or less intensive intra and inter institutional linkages and their innovative performance.

In the conclusions a synthetical interpretation of the national knowledge system and some reflections on future developments of the analysis are given.

4. Scientific and technical competences

The first aspect to consider is the absorptive and creative capacity of business firms given by R/D activities and education. The R/D investment of manufacturing system is far below that of the other countries (7G), both in terms of size and intensity. The Berd intensity grew up during the eighties, but after a period, the 70s, of losses in the technical knowledge accumulation (slowing down of the Berd intensity). In H-T sectors the Berd grew up during the last ten years, but only in pharmaceutical, rubber and more recently in electromechanics the country have a revealed advantage; chemicals and electronics are areas of despecialization in research activities. The R/D expenditure is concentrated in large sized firms (84% in firms with more than 1000 employees) and in industrial groups (60%); the role of the foreign groups is not relevant (14%). The stock of R-D personnel is far below that of the other countries (G7) and the rate of growth of researchers has slowed down in '81-'92; this loss of resources happened mainly in industry and in public research institutions.

The skill levels of the workforce is concentrated below the high schools, in other diplomas. The University did not supply a consistent number of human resources to industry, even if differences among generations of entrepreneurs and managers can be found.

As to the creative capacity within the education and public research institutes, the R/D expenditure of University increased 7% (average annual rate of change) in real terms during '81-'91 after a long period of crisis. The R-D expenditure of University, which is a relatively more important research performer in Italy than in other countries, at the beginning of eighties had reached a minimum. At the end of '80s the size of the Italian higher education R/D expenditure was still far from those of the other nations (G7).

The role of the public research institutes slowed down since the half of '80s, in part because of the reduction of some public programmes (nuclear energy; space). Some (mission oriented) research institute recently has attempted to change its specialization and to move towards more interactions with industrial firms (Enea).

The transfer capacity of the public research institutions, examined through outputs supplied in a suitable form, are concentrated on scientific publications. Patent applications by universities and research organizations are on a very small scale; particularly limited is the role of the public research institutions, in spite of the multidisciplinarity and more applied interest of their research activity.

The completeness and quality of the available scientific competences: the share of the scientific publications with respect to the world was 2,4 in 1990, lower than the share of other European countries. Italy has a high degree of scientific specialization, concentrating the efforts in selected subfields, even if this specialization has slightly fallen over time. The scientific specialization is higher even if the size of the national scientific base (the size of the national community) is considered. Revealed scientific advantages are in medicine, biology, chemistry, physics and mathematics. Engineering and information technology, the disciplines where the interest of business firms for scientific results is present, are less developed. Chemistry is a discipline where the declared industrial interest had an high variability. The quality of the scientific competences, or the importance of the best scientific publications, measured by citations, is narrow too.

The economic competence of the business units, defined as the capacity to perceive the economic interest to involve themselves in new technical fields, is considered a critical area in Italy. In fact the rates of technical revealed advantages, measured by patents, are still concentrated in consumer goods, some sectors of mechanics, electrical appliances and typewriters. The fact that over time there has been cumulativeness of the technical specialization pattern, can be explained through:

- the limited number of applications in new technologies. The number of external patent applications in H-T sectors and their shares on international market increased, but less than the total patent applications, thus confirming the Italian specialization profile;

- the patents' birth rate concentrated in a small number of large firms (lateral birth) and determined mainly by their diversification processes. The growth (even though modest) of innovative activity registered by patents, has been accompanied by high rates of (patents) natality and mortality, above all in mechanics, chemistry and electronics. Management failures (such as delay in the exploration of new opportunities) and instability of innovative effort in H-T of business units, due to effective obstacles (instability of the management, weak position on global markets and financial resources) were often the causes.

The lack of enough "economic competences" can in effect mask other problems and for instance it can bring back also to problems of creative competences (limited R/D efforts) or isolation from the (lead) users or insufficient internal process of communication among R/D and other functions.

The industrial structure, which supports the technical interrelations and reflects the innovative changes, was not significantly transformed among '81 and '91. Marginal changes are present only at high disaggregated level, while the domestic demand structure has changed more than production. The distance from other national industrial structures has been maintained or it increased in the same period.

In short, the creative capacity within public and private institutions in terms of R/D expenditure, is relatively low and resources loss has been registered in different periods (recently in industry and research institutes). The scientific and technical competences are concentrated on a limited number of fields (high specialization) and are scarsely interrelated: consumer goods and mechanics on the industrial side, life sciences, mathematics and physics on the scientific side. The transfer capacity of the scientific institutions is concentrated on publications, the patent applications are the exception. There is, nevertheless, a little known side of the commercial activities in universities, which specific analyses have revealed: the supply of services, expecially consultancies, tests and certification. The personnel mobility from University to industry, the links in terms of managers and employees with an Universitary degree, regard a very small number of people.

(See SECTION I from table 1 to table 39)

5. General intra and inter institutional flows.

The relations among different institutional agents are supported by various carriers, which influence, in function of their contents, dimension and direction, the way of producing and using knowledge. In the following only a list of the principal forms of interaction is presented, without examining the effects.

The financing given by Italian industry to University research is the lowest among all the industrialized countries, even if a slight increase has been recorded in the last ten years. In effect case studies on public research laboratories strategies (Gambardella, Potì) revealed the existence of a higher dependence (20% on average) of laboratories from private sources. The forms of the relation between industry and public R/D institutions, which are behind this financing, are of a commercial type more than research collaboration contracts.

The public support to industrial R/D activities is about 15% (in 1991) of its expenditure; it grew up during the eighties at an average rate of 7%, but it is now, at the beginning of '90s, falling down. This financing does not bring always important knowledge contents, but can influence the research paths of business enterprises. In Italy the predominant form of this financing was individual incentives, with a low capacity of orientation and coordination.

The industrial R/D subcontracting, or extramuros expenditure, represents on average 14% on the total industrial R/D expenditure. The rates of R/D externalization are higher (respectively 22% and 15%) in the two extremes dimensional classes: the smallest (20-49 employee) and the large (>500) firms. In the R/D subcontracting there is an unilateral transfer of knowledge, from outside, but the control or the capacity to use these partial contributions rests on the buyer. The industries which use more R/D subcontracting are pharmaceutics, non metall minerals (ceramics and glass), some specialised machinery and ships. This is not a diffused phenomenon: there are industries without any extramuros research and more often the expenditure is low.

The R/D collaborations are measurable only in terms of frequencies and not as quotas of intramuros expenditure. In research collaborations the direction of knowledge flow is bilateral. This is an important form of diffusing and creating new knowledge, but generally it is a complex relation, where problems of appropriation and committment exist. In Italy 36% of the business units with a stable research activity (which represent a small quota of the total manufacturing industry) have realized almost one R/D collaboration. The partners are mostly Italian enterprises (25%) or Italian universities (20%).

The enterprises, which realized innovations (processes and products) during 1990-92, largely used information and knowldege from various sources. The main important carriers were, in order, the internal functions, the equipment and materials suppliers, the commercial expositions and the users. Only 20% of business entreprises had relations with public institutions (university, research and transfer) finalised to innovate. The acquisition of patents interested one third of the innovating firms.

These patterns changed in function of the size: the small business units (20-49 employees) used more frequently information acquired from the suppliers than the internal one and in general used each kind of source less than the average, except information from clients and competitors. Internal functions were the first information carriers for large firms (>500 employees), where a larger possibility (and necessity) of exchange, pooling, assimilation and transformation of different types of internal knowledge exist. In general, each source was more frequently used by large firms than on the average, especially the relations with public research institutions and patents, used by more than the half of large firms.

At sectoral level (Pavitt classification), the suppliers were the most important source of information for the traditional industries, and all the other relations (including clients and competitors) was less diffused than on the average. In the specialised supply industries and in R/D intensive industries, relations with clients, competitors and public research institues are more frequent than on the average. These two groups of industries promote a more diversified and wide network of links.

Almost all the innovating firms (83%) acquired and/or transferred technical knowledge through different mechanims. The small sized firms and the traditional and scale intensive sectors was mainly technology users; large sized firms, specialized supply and research intensive industries were mainly suppliers of technical knowledge.

The knowledge exchanges are localised above all inside the country: the acquisition from foreign sources concerns the embodied technology (1/3 of firms) and the inter-firms collaborations (1/3). The technological international exchanges from/to Italian innovating firms are localized mainly in Europe.

The main mechanisms through which knowledge is exchanged are: the adoption of capital and intermediate goods or embodied knowledge (61%of innovating firms), the acquisition of qualified personnel (32%)) and the consultant services (29%). The collaborations with other firms interested only 23% of innovating firms. All the other mechanisms (patents, R/D subcontracting; project subcontracting and merger activities) were less important.

The small sized firms (less than 100 employees) followed this pattern, but interfirms collaborations were more important than on the average: more than half of collaborations were in small firms. According to some author (Torrisi, 1994) a division of labour among large and small firms is envisageable: in the last group a more specialized and specific knowledge, more easily transferable, is concentrated. Such a kind of competences of the small firms need to find complementary knowledge and a larger field of applications.

In short, it is not possible to quantify in value how much of knowledge for innovation is transferred and exchanged through various carriers and mechanisms, but it is possible to have an idea of the density of these exchanges. Frequencies (on total of innovating firms) are concentrated in hierarchical and network coordination mechanisms; in embodied (tools and equipment) and innovative exchange (users). The nodal sectors promoting links are specialised supply and R/D intensive industries; excluding traditional sectors, which have more simplified networks of relations (suppliers is the main important source of knowledge), small firms have relations with clients and competitors and in general promote inter-firms collaboration based on division of labour and specialised knowledge.

(See SECTION II from table 1 to table 14)

6. The inter-industrial distribution of knowledge

This is the only area of the national knowledge system where building flows matrices was possible. Three matrices was built:

- the R/D flows matrix;

- the capital goods matrix: through which Oecd calculated the total R/D intensity by sector;

- the matrix of innovative goods and services.

In the R/D matrix the distribution of R/D expenditures by sector and groups of products is represented for 1991. It was built as a 15x15 square matrix, where columns (the groups of products) were regrouped in such a way to be comparable with the raws.

The R/D matrix represents only the distribution of R/D expenditures by industries (raws) and themes (columns) and the cells represent the opportunities or the potential supply of new knowledge, which can be effectively acquired only if inter firm relations (collaboration or whatever) are established.

Two main R/D circuits are recognizable, with different patterns of knowledge distribution. Four industries are in the first circuit, which represents 62% of the total industrial R/D expenditure: motorvehicles and other transports, pharmaceutics, telecommunications, aerospace. These industries invest research resources mainly in their core technology, the diversification (number of other technologies) is very low, with the exception of transports. In this circuit the diffusion index is near zero for each industry: the expenditure of each industry is equal to the R/D investments of other sectors in their technology. The spillover indexes are very low, except for transports: the industries which spend more in research, are autoconsumers. The main research circuit is not a promoter of new knowledge in other technical fields.

The second research circuit gathers four industries: electrical/electronical machinery, chemistry, machinery, informatics. It represents one third of the total industrial R/D expenditure. These industries (except informatics) diversify in a large number of other technologies. The group is not homogeneous: the diffusion index is low, but positive, in electrical/electronical machinery. This macro-sector can find an amount of research expenditures executed by other industries in its core field equivalent to its internal expenditure. In machinery and informatics the diffusion index is low and negative: these two industries are potential net users of others' research activitiy. Chemistry is a sector which invest more in research than it can find externally. One third of the research actvities of the industries of the second circuit are spillovers for other sectors.

The effective use of the knowledge produced in others' R/D activities can be found in the frequencies of R/D inter firms collaboration. More collaborations with other firms are established in two types of industries:

- motorvehicles, other transports and informatics; both have important R/D internal activities and are also net users of other industries' research;

- consumer or traditional industries (textiles, footwear and wood), which have not important internal research activities.

Two sector spend more than others in R-D extramuros subcontracting to other firms : pharmaceutics and machinery.

Two innovative matrices have been built on the first and on the second Italian innovation survey. The first is simply a reelaboration of De Bresson, Sirilli et al. (1993) matrix, on links between producers/users of innovations introduced in 1980-'85. The secod matrix was built on the last survey and it is a representation of the links among supplier and users of innovative goods introduced in 1990-92. The cells represent the frequencies of links.

Two main groups of users can be found, each of one representing 30% of the total linkages. Three main users are in the first group and five in the other.

The first group of users of the innovations introduced in 1990-92 is represented by final consumers, trade and construction. Here are the highest total frequencies and the highest numbers of links with different sectors (see table). The main innovative suppliers of this circuit are consumer goods manufacturing industries (textile, footwear, foodstaff), machinery and metall products.

The second group of users of innovations is formed by textile/clothing, machinery, foodstaff, metall products and motorvehicles; it is characterized by lower frequencies of links and lower number of different supplying sectors than the first one. It substantially identifys two types of domestic markets, one is formed by traditional manufacturing industries (the two most important suppliers of the first group of users) and the other is the machinery group (motorvehicle, metall products and machinery). The traditional industries are fed on innovations by themselves and by the machinery. Inside the machinery group the innovation supply is fundamentally an intra-supply; a link with the electronic/electrical industry, that have had so an important role in other country (the development of the Japanese internal market of machinery in the '70s).is only marginal. The electronic/electrical industry supplys only 6% of the total innovations acquired by the machinery industry.

In short, final consumers still drive the innovation carried by goods exchange in Italy; their suppliers (traditional industries and machinery) feed on innovations largely by themselves or by intra-industry linkages, if a macro sector "machinery" is considered.

If the most important suppliers are considered, a confirmation of the previous analysis is found. The most important suppliers of innovations are machinery, metall products, textile-clothes and non metall minerals. Foodstaff, electrical/electronic machinery, chemistry and rubber are at a certain distance in terms of link frequencies. Each of these industries mobilize a high number of inter industrial linkages (except foodstaff). The most important links (the lead users) for the machinery industry are with final consumers, traditional manufacturing industry and the macrosector of machinery; for textile and foodstaff they are with final consumers. Different are the "markets" of the innovation for chemistry and rubber: health, agriculture and foodstaff.

The diffusion index of the major suppliers' innovations is positive, both if the total matrix 22x40 is considered and if the only interindustrial matrix 22x22 is taken into account: they all are net suppliers (except textile). The spillover index has a high value, near to 1 for a large part of the considered major suppliers.

In comparison with the 1981-85 innovative matrix, the above analysed supply of innovative goods is less orientated towards final consumers and more towards inter-industrial linkages, even if the structure of the main users and suppliers remain the same (see table).

The diffusion and spillover indexes, actually calculated as link frequencies, cannot be added to R/D spillovers, calculated as expenditure values. This is why it is not possible, at this stage of the analysis, to have a total estimation of the knowledge pooled by each sector through different transfer mechanisms.

The density of the total innovative exchanges is calculated for 1981-'85 in De Bresson, Sirilli et al. The innovative activities resulted clustered within a restricted set of economic linkages: 11% on the total number of possible cells, if a similarly sized input-output matrix is considered with the innovative one.

Indicators at sectoral level combining performed R/D and externally acquired technology have been calculated (Oecd, Papaconstantinou et al.). They offer a better insights of the role of capital inputs in technology diffusion. The idea in the background is that the buyer industries can capture part of the results of others' R/D efforts, increasing its productivy in such a way. The industries of small and technology-follower country like Italy are assumed to benefit largely of capital diffusion and it is necessary to sum up internal and embodied R/D to have a more precise idea of their knowledge availability.

The direct R/D intensity is lower than that of all the other more industrialized country in all types of sector, high, medium and low technology industries (except for the medium technology in Canada). The total R-D intensity (internal+embodied) is again the lowest in all sectors in comparison with the other countries.

In spite of the importance of the embodied knowledge and specifically of the capital diffusion as source of innovation in Italy, the country benefits only from complementarities between much lower technology industries. Intersectoral complementarities, that are a key factor to support efficient diffusion patterns, concern mainly traditional sector and their equipment suppliers and the intra-flows of the machinery group. Complementarities between high R/D performing producer sector (like electronic and computers) and downstream industries are absent in the country, as see also above.

The internal intersectoral complementarities influence also the demand of imported technoloy: if the effect of imports and domestic sources, as means of acquiring technologies, on technological intensity (on the base of 1985 input-output table for Italy) is compared, an equivalent importance between the two sources is found for Italy (differently from other small countries).

In short, there is a strong complementarities among the three levels of analyses presented above: the R/D spillovers and the potential flows of disembodied knowledge diffusion; the intersectoral links among innovation suppliers and users; the capital goods diffusion. The technology is developed firstly through research activities and the level of knowledge pool available (through spillovers) to each sector influences linkages and networks. In Italy the high technology industries (identified as the higher R/D performers) are not promoter of new knowledge in other applicative fields. They are islands of H-T, cut off from the rest of the industrial base. The "second R/D performers" spillover one third of their R/D to other sectors, except informatics. Chemistry and electrical/electronical machinery are in different measure potential suppliers of disembodied knowledge, but their global level of R/D expenditure is relatively limited. Here a place for S-T policy action is envisageable, to support technological knowledge creation in such a way to extend the applicative fields and potential links in R/D activities in this fields.

The innovative users-suppliers linkages let identify the main intersectoral complementarities which can push upstream R/D activities and support diffusion patterns of innovative goods. In Italy the cluster of the main innovation suppliers is not in R/D intensive manufacturing industries, but in machinery and consumer goods producer sectors. Also here is envisageable space for a S-T policy action in promoting more linkages between the macrosector machinery and the electric/electronic machinery. Collaborations or subcontracting activities among these two macrosectors are limited, for hystorical reason: the machinery industry has deep roots in the Italian industrial development and it is grew up separately from, and without incorporating, electric/electronic competences. Machinery industry is a low user of flexible automation equipments and a low seller of electronics and computers applications.

Also the aspect of absorbing capacities and of available competences come into this: the possibility of effective use of innovations developed elsewhere depend from an increase of S-T knowledge base of the potential users. Education and research have an important role not only in the H-T sectors but also in the medium and low technology industries. In Italy medium tecnology industries can have an important key role.

(See SECTION III from table 1 to table 16)

7. The triangular knowledge distribution

The central question treated here is a qualitative one: are the links among industry and the public research institutions strong or weak? It was not possible to find a synthetical measure of the rate of links through bibliometric indexes and the paragraph is developed as a case study. Anyway bibliometric analyses have a limited scope in situation (like the Italian one) where formal linkages among the three institutions are not well developed.

The centrality of the question depends on the fact that University (in particular) have a relatively important role in R/D performing in comparison with industry (even if the State financing is below that of the other countries -G7-) and that an opinion of weak linkages and failure in knowledge transferring is largely diffused. The problem is complicated by the fact that the experience of mission oriented agencies and programmes was limited in Italy and consequently that information on the links between large firms and public research organisations is dispersed.

What matter is to understand where are (what the carriers, who the promoters) linkages, how eventually the relations among the three institutions influenced their research activities and finally what could be the S/T policy role.

If we consider industrial strategies, the financing given by Italian industry to University research is the lowest among all the industrialized countrie even if a slight increase has been recorded in the last ten years. The use of scientific knowledge as a source of innovations is still very low, even if we consider only large sized firms. Moreover, Italian industry acquires knowledge from foreign institutions at an higher level than industry in other countries (Pace, Merit, 1995) or, to say it differently, the rate of national integration between public research and industry is lower than the small national dimension could justify.

On the policy side, government financial support of public research institutions has always been substantial and recently the financing of Universities has increased. Since the mid '60s there was a shift towards more applicatory contents of public research, reinforced since the '80s by a policy of technology transfer. Such a policy has been essentially based on the possibility for public institutions to exploit the inventions deriving from their research: the liberty of patenting and assigning the patent to a third party, earning the related royalties. Finally, since the end of the'80, an important institutional reform has been undertaken, according to which the universities can become independent at different levels: statute, organization and financing. This change should represent an incentive to open the academic community to market mechanisms.

As far as scientific institutions are concerned, the number of their patent applications, which show an interest in the scientific community towards the commercial exploitation of the research results, is well below that of the other European countries Such a diversity is particularly strong if research institutions (other than Universities), which have the function of promoting multidisciplinary and applied research, are considered. Until now the small dependence on private contracts has allowed both the possibility of autonomous paths for scientific research and the strong predominance of scientific community incentives (reputation and prestige rather than profit).

But this is not all the story. Official statistics do not register what can be found through case studies: in the following we refer to some specific studies on research laboratories in some specific disciplinary field, on some universities and on the association of public and private agents (Reale; Orsenigo; Perulli; Vivarelli-Audretsch; Gambardella-Potì).

The scientific laboratories depends on private financing more than it is known and this is a recent trend. This is not a generalised phenomenon and research contracts are not always the most important carrier of knowledge transfer; the supply of goods and services (supply of reagents, of equipment or test activity) is more diffused. Market relations with industry represent a limited experience of contact, because of the unilaterality of the information flow and the low committment of the research laboratories. Anyway it is a potential network, that could be transformed, like informal contacts, in contracts and collaboration if the opportunity is given, like in the case of finalised research projects.

The form of research collaborations with industry, where the laboratories are directly involved by the industrial partner in a logic of industrial type, is a minor one: here case studies confirm official statistics. Pharmaceutics is the industry which developed more R/D collaboration with public research institutes.

Cooperative and finalised research programms are the other form through which triangular links are established. From the scientific laboratories' point of view these were often success experiences, where industry come into a more familiar logic (precompetitve research). Anyway the transfer to industry and the use of the research results was a critical point.

In particular, the experience of finalised research is an important one in Italy. At the beginning (the mid seventies) the introduction of these projects was interpreted as the constituent phase of a new statute of the national research institution (Cnr), with a higher integration of its culture and functions to the need of the social system. Its aim was to modify the portfolio of the scientific research activities, through the introduction of research with socio-economic applications.

The experience has been useful to diffuse in the scientific community the interest for a research with socio-economic spillovers, to promote the availability of researchers to take part in processes of transfer, to modify the cognitive approach, now more interdisciplinary and open to interactions with other agents. But the critical point remains the low number of interactions with industry and the short transformation of informal in formal relations with it, that is a fact greatly influencing the effective use of the scientific results. If relations with industry are lacking, it is not possible to find a solution to two important bottlenecks for the transfer activities: the scarse knowledge of the possible applications, with the risk of giving a useless orientation and the lack of enough competences in the scientific laboratories to manage the application of results.

Succesfull experiences of transferring activity indicated the location as the key factor. The more the interest of industry for research or the industrial R/D expenditures in a region, the more the number of enterprises which demand scientific knowledge in the same area, the more the research units were inclined to and realized transfer initiatives. The reason for this finding can be found in the characters of the national innovation system, where central infrastructures, bridging scientific and technical research do not work efficiently (long lasting relations promoted by cooperative national programs, efficient transfer institutions are lacking) and the enterprises with collaboration or contract relations with public research institutions are a small number.

Here an important place for S/T policy can be identify: the potentiality for more linkages among scientific institutions and industry exists both in finalised research experience and in market and informal relations among the three institutions. What is necessary is getting over the idea of technology transfer (which is still present in the technological services) helping scientific laboratories getting more information on industrial demand and improve what is effectively weak, central function (for instance in the major public research institutes-Cnr-) for the relations with industry.

8.Intrafirm linkages

Internal knowledge is the most important innovation source for business firms (except small firms). The knowledge exchange, assimilation and transformation among different internal functions has a fundamental role in innovation success. This is an important area of investigation to look at more in depth. The lack of coordination among functions, the lack of knowledge exchange and of adaptation in key function like commercial functione can be a cause of innovation failure (as specific industrial case studies have shown- see Torrisi).

The Csc survey on R/D industrial strategies analysed these intra organizational aspects. Links among research and other functions are managed substantially by the leader of the R/D project, a central coordination is lacking, nor there is enough personnel mobility among different areas. The separation among functions prevails. Difficulties in developing strategies of internal technological change management and integration among technology and market are stressed. Lacking economic competences (definition is above) can arise in this way. Here is also a source of delay in the arriving on the markets and of competitive losses.

9. **Technological and economic performances**

Only two indicators are considered here:

- the quota of new products/processes on sales of firms innovating during 1990-92 and the degree of incremental content of innovations (technological perfomance);

- the export specialization (economic performace).

46% of the sales of innovating firms were independent from any innovation; 26% were process innovations, 15% new products and 12% incremental product. The absolutely new products (new for the market) were only 14%; in small and medium sized firms (20-4999) new products for the firm prevailed; only in large firms (>1000) new products for Italy representd 51%.

Incremental innovation and innovations based on imitation of competitors products carachterize innovative strategies.

Italy has reinforced its specialization in low technology, labour intensive exports since 1980; its despecialization in H-T is diffused to all sectors and it got worse during the 80's. Differently from the other large Oecd countries, Italy export traditional goods, electrical machinery and non metallic minerals and import chemicals, communications equipment and computers. The getting worse of the import-export ratios during the eighties can be attributable to some process of international integration (vertical and horizontal) of production.

The positive economic results come from consumer goods and machinery (electrical), that is from the most important innovative cluster (see above).

10. Scientific and technological policy

Direct financial incentives and, at a certain distance, indirect financial incentives, are estimated the most useful policy instruments from innovating firms. Research and technological services have a certain rilevance only for large firms (>1000 employees).

Italy is carachterized by the direct financial incentives prevailing, in comparison with other European countries, where public institutions ' research (PACE, Merit, 1995) and cooperative programmes are estimated more important by large firms.

A critical aspect is represented by the S-T infrastructure, fundamental agent of linkages creation and exploitation. A short examination of the main infrastructure, is given in the following:

<u>Infrastructure for cooperation</u>

<u>Cooperative programmes</u>

Three types of programmes are recognizable: programmes managed by industrial firms and consortia (National research programmes), with the participation of Universities, mainly in H-Ts;

finalised research projects managed by the National Research Council; agreements on programme, among industrial firms, Universities and research institutes. The R-D expenditure of all these types of programmes is still a small percentage of public expenditure.

<u>The techno-legal activities to support innovative activities</u>

These activities have been largely underdeloped in the past.

<u>Standards infrastructures</u>

Italian public expenditure for S-T standard infrastructures is much below the minimum level.

<u>Technical qualification</u>

The national system of certification is very fragmented and low financed by the State.

The Patent office

The evolution of the office will be that of an information diffusion service on the national patent applications and support to licensing and transfer the patents.

Interface infrastructures

Bridging institutions

The main bridging institutions in Italy are local spontaneous interfaces. These service centers are differently specialised and have been particularly active in some geographic and economic aggregation (industrial districts). The mapping of these institutions permitted the identification of 75 centers in 1985 and 150 in 1992. These infrastructure are classified in four typologies, connected to their main function: information diffusion; relations among enterprises; internal functions of business units; external economies. This local interfaces have contributed to the fact that the small and medium sized firms have been quite effective in absorbing and adapting technology developed externally to the same business unit.

Scientific and technological parks

A national policy for the development of S-T parks has been recently designed and it is oriented to promote these intiatives first in the south of Italy, with the aim of diffusing and transfer technologies to small and medium sized firms

University-industry research consortia

The activities of these infrastructures have slowed down, in consequence of the present decreasing of the business units research effort.

In short, the necessity of improving the S-T infrastructure and the knowledge diffusion policy, in comparison with the more exploited support to R/D and knowledge creation, is manifest. Cooperative programmes and a different organization of finalised research can be balanced instrument, of creation and diffusion.

11. The cluster analysis

The aim of the cluster analysis was to find out how industries can be grouped, if different type of indexes of inter and intra institutional relations (separated in different paragraphs above) and performance (two indexes) are considered. This exercise has to be more refined.

First results are that consumer goods and machinery cluster together in a group with good innovative performance, medium value of inter-firm links and lack of relations with university.

12. Conclusion

Italian knowledge system has an underdeveloped S-T basis (high S-T specialization) and it is not internally convergent, if the number and the multidirectionality of links are considered. In particular:

- the density of innovative linkages is low (the economic space where innovative links are localised is a small one);

- the multidirectionality of exchange is low, since the final consumers are the first users of innovation;

- the spillovers from the first R/D performers, the H-T industries, are very low: these industries are not promoter of knowledge, they are insulated in the industrial structure.

Is Italy, then, a country where R/D and manufacturing activities are and will be separated and where giving money to research is an unefficient choice? The system approach promoted by the Oecd pilot project, which want to throw light into the source of connections (all forms of knowledge exchange), help to find a solution to the mystery of the separation between economic and technological performances in this country.

The knowledge system approach let us look into the origin of this phenomenon and not only at its consequences. Above all we want to underline here the fact that this kind of analysis, very flexible, let know where are the positive key nodes. It can help policy makers, suggesting some direction to follow: investing where possibilities of extending networks and diffusing knowledge exist means having increasing returns.

If some very brief policy suggestion can be advanced here, on the base of the analysis, for the Italian case it could be:

- cooperative research in electronic and chemical applications;

- promotion of more connection among machinery and electronics industries;

- more favourable regulation, formalization and centralized promotion of bilateral exchange between industry and university.

Finally, the aim of this project is very ambitious, since the scope is to measure all the flows of a system on the commun basis of knowledge and to give a coherent description of this complex and differentiated system. At the present stage of the study the quantification is still partial, but the results are the same interesting: an integrated interpretation of traditionally separated phenomena.

As to future direction of investigation, we wish to suggest:

- the necessity of creating more connection among different kind of relations, here examined separately;

- the necessity of more homogeneity among methods: qualitative (case studies), descriptive (based on surveys) and quantitative;

- to explore the possibility of extending the quantification;

- eventually to concentrate on quantitative analysis of inter industrial links or looking for better exploiting studies on industry-university relations.