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EU Policies for Innovation and Knowledge Diffusion[♥]

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Abstract

The aim of this paper is to analyse past and present EU policies towards innovation and knowledge diffusion and confront them with policies in other major industrialised countries. The confrontation we make primarily regards the innovative performance of the EU relative to the US and Japan, and points to a certain gap between Europe and the other two countries, especially in terms of the ability to transform innovation into commercial success.

We outline the fundamental trade-off of RTD policy, namely providing incentives to innovate, which requires the appropriation of the returns to innovation, and ensuring the diffusion of knowledge, which is larger, the less knowledge is appropriable. The review of policies over the last two decades points to a shift in emphasis of policy, from one side of the trade-off to the other, namely from the focus on incentives to innovate to a focus on diffusion. The main idea of policy is now to create an environment favourable to innovation and knowledge diffusion. For this purpose, networks should be developed within the economy: in particular the relationships between firms and universities or other knowledge institutions have to be intensified.

What we show in the report is that, while the shift in emphasis has helped point to some previously neglected problems in innovative activities, it has also led to a lack of precise policy recommendation. It seems that all actions that favour relationships have to be adopted; networks have to be developed but the adequate type, size and institutional context of networks does not appear to be much discussed. In addition, the motivation for agents to take part in networks seem to be neglected, while this is essential for such networks to be created in the first place. In other words, the incentives to take part in innovative activities, and in particular the possibility to appropriate some of the returns from the innovation arising in the network, have to be specified. We show that the consideration of intangible assets brings new insights into the debate.

[©]: *This paper constitutes the first report of a European research project on the measurement and policy implications of the intangible economy, RESCUE / PRISM and has benefited from financing from the European Commission, IST Programme.*

1. Introduction

The scope of this paper is an analysis of the EU policy set and reorientation required to accelerate the circulation and commercialisation of innovation and knowledge in the EU, taking account of leading-edge policy practice elsewhere in the global economies. The chosen focus is on policy towards knowledge creation and diffusion, namely RTD and knowledge diffusion policy. It includes a review of existing EU innovation and knowledge diffusion policies, of their effects (using evidence from the literature); a comparison with other major industrialised countries (the US in particular); policy implications in light of our preliminary reflection on the nature and effects of intangibles (the economics of intangibles).

We outline the fundamental trade-off of RTD policy, namely providing incentives to innovate, which requires the appropriation of the returns to innovation, and ensuring the diffusion of knowledge, which is larger, the less knowledge is appropriable. The policy traditionally recommended by economists assumed that knowledge could be reduced to information, that is, codified knowledge. Information can be transmitted at almost no cost and the use of information by some individuals does not precludes the use by other individuals: hence information has the characteristics of a public good. The result is that diffusion is not a problem and policy should focus on providing the incentives to innovate, via subsidies, a property right system, and so on. Recent developments in economics have stressed however that knowledge is not composed of information only; it also comprises tacit knowledge, that is, know-how, competence. The latter kind of knowledge is not easily transmissible, essentially because its acquisition requires to incur learning costs (trying out, observing, adapting the existing knowledge base, etc.). This is discussed in more details in the report. What is important here is that such literature has had a large influence on policy-making and has contributed to a shift in emphasis of policy, from one side of the trade-off to the other, namely from the focus on incentives to innovate to a focus on diffusion. The main idea of policy is now to create an environment favourable to innovation and knowledge diffusion. For this purpose, networks should be developed within the economy: in particular the relationships between firms and universities or other knowledge institutions have to be intensified.

What we show in the paper is that while the shift in emphasis has helped point to some previously neglected problems in innovative activities, it has also led to a lack of precise policy recommendation. It seems that all actions that favour relationships have to be adopted; networks have to be developed but the adequate type, size and institutional context of networks does not appear to be much discussed. In addition, the motivation for agents to take part in networks seem to be neglected, while they are essential for such networks to be created in the first place. In other words, the incentives to take part in innovative activities, and in particular the possibility to appropriate some of the returns from the innovation arising in the network, have to be specified.

We think that the consideration of intangible assets brings new insights into the debate. The third section of the paper discusses the nature and effects of intangibles, and show that they might be the key determinants of the nature of the networks most appropriate to innovation and knowledge diffusion. We point to the issues that will be analysed in more depth in the next stages of this research project and that will lead to some precise policy recommendations on such networks; in particular, on the role of innovative SME clusters relative to networks dominated by large firms; and on the distribution of property rights (between the various economic agents involved in innovative activities, and the public and the private sector in particular) that provide the right incentives to innovate while not precluding the diffusion of technological knowledge.

Such analysis and new findings on networks and the environment favourable to innovation and knowledge diffusion had wide policy implications, not only for RTD policy but also for competitiveness, growth and employment policies, for two reasons. First, R&D and innovative activities directly contribute to growth and employment. Second, our findings on creating proper environments also apply to environments favourable to competitiveness, to growth and employment. This will be made more explicit at later stages of our research, and will allow us to widen our policy implications of the intangible economy.

2. EU innovation and knowledge diffusion policies: from government to governance

2.1. The basic policy problem

The fundamental policy problem regarding innovation is related to the presence of research externalities, i.e. the fact that the innovative knowledge created by an individual or a company can be learnt by other individuals or companies without paying for it. In economic terms, this implies that the private returns to innovation are lower than social returns.

Firms have three main ways of mitigating this problem. First, they can try to make knowledge difficult to imitate, avoiding too much codification or communication with other individuals or firms; this solution may be difficult to implement however, for instance due to industrial spying. Second, they can try to internalise externalities, by making the new knowledge available in industrial associations, by signing collaborative R&D agreements, acquiring or merging with other firms that may use their knowledge. Such a solution allows the firm to take all the returns from the innovative knowledge, but it is quite costly, in particular due to the costs of internal coordination which rise as the group to coordinate gains in dimension. Third, the company can try to be a first mover in the likely applications of its new knowledge, and gain a first-mover advantage.

All such actions help protecting the innovation from appropriation, but the problem is that they hinder the diffusion of the new knowledge to the economy, although this might be favourable to economic development. Thus there is a fundamental trade-off between providing the incentives to innovate and ensuring diffusion.

In terms of public policies, the traditional solution to the research externalities problem have been:

1. setting-up market for knowledge, especially with the allowance of property rights over the new knowledge, in the form of intellectual property rights;
2. subsidies: given that knowledge can be easily appropriated and therefore that it easily becomes a public good, incentives to innovate can be maintained if R&D activities are subsidised; the problem with subsidies is that it is difficult for the policy maker to assert that R&D activities would not have been performed by the firms even in the absence of subsidies; there is information asymmetry and firms can easily hide some information in order to get maximum subsidies;
3. public production of new knowledge: innovative activities are performed in public research centres or other institutions and the new knowledge is then made available to firms; the problem with such a solution is that first, it may lead to a duplication of research efforts, as when different levels of government, regional, national or European, set the same research topics; second, the research priorities might be guided more by political votes or by lobbies than by welfare motives;

4. R&D collaboration: the government can favour R&D collaboration at the pre-competitive phases of research.

The fourth policy has been one of the main instruments used by the European Commission. The economic literature on R&D joint ventures is huge[1] and discusses the conditions for research ventures to increase society's welfare. One important short-coming is that research joint ventures are shown to be optimal for certain levels of spillovers (externalities) between firms. However, no study has yet managed to analyse such spillover parameter in depth, in the sense of showing precisely its determinants.

In the prevailing models of industrial organisation[2] spillovers refer to involuntary leakage and voluntary exchange of useful technological information, in the incremental kind of innovative activities. Two major types of innovation indeed exist. First, fundamental innovation, creating a major technological discontinuity, such as the invention of the steam machine or electricity. Discontinuities are relatively rare and may both destroy or enhance the competence of the existing firms in the industry (Tushman – Anderson, 1996). In that case new entrants often play an important role in the diffusion of the new technologies in the industries, because incumbents have to change skills, abilities and knowledge in order to adapt the new technology. Gambardella et al. (2000) show that the diffusion of the biotechnologies in the pharmaceutical industry has been eased by the arrival of new entrants specialised in biotech, while incumbents had to change their research methods and knowledge base and did it primarily through agreement with or acquisition of new entrants. Second, incremental innovation, meaning improvements in existing products or processes, is more frequent and generally extends the life cycle of existing technologies. Contrary to discontinuities, incremental innovation does not result in drastic changes in industry structure (concentration, relative position of the different players, number of firms in the industry).

Such analysis and policy recommendations rely on two major hypothesis. First, all knowledge can be reduced to information, i.e. can be codified and transmitted at no cost. Second, all interactions between agents take place on competitive markets.

Both assumptions can be criticised. The first assumption is restrictive in that a large part of knowledge cannot be codified because it is tacit. A typical example of tacit knowledge is knowing how to ride a bicycle: one knows how to ride it, but would find it difficult to explain all the mechanisms enabling equilibrium and movement on it. The relaxation of the first assumption leads to the possibility of increasing returns to knowledge. Several economists have provided evidence in favour of this: for instance, Machlup (1982) argues that the more one invents, the more likely one will be of inventing again; Scotchmer (1991) confirms this. In fact, returns to knowledge creation can be either decreasing or increasing: doubling the number of researchers does not necessarily lead to the doubling of innovation; however, combining human capital and organisational assets (both intangibles) in an appropriate way can increase the probability of discovery: for instance, doubling the number of researchers and organising researchers so that they work in different teams dealing with different activities has been shown to increase the probability of discovery (Nonaka - Takeuchi, 1995, who underline the importance of such variety for creativity in innovative activities).

Another important point is that the acquisition of knowledge is costly: acquiring and mastering new knowledge requires investments in learning, trying out, understanding, etc. The cost of acquisition of new knowledge increases with the distance between the new knowledge and the existing knowledge

[1] Starting from the late 1980s: d'Aspremont-Jacquemin (1988, 1990); Katz-Ordover (1990), Martin (1991), Shapiro-Willig (1990).
[2] See De Bondt (1996) for a review.

base. For instance, a company established in the pharmaceutical industry for a long time has to incur important cost to acquire the new biotechnology knowledge, since its previous knowledge base was focused on a different research technique (Gambardella et al., 2000). The nature of technology has been widely studied, and a number of features can be outlined. First, technology is complex and is the result of cumulative learning. Thus home R&D is not a perfect substitute to buying foreign technologies, because own research activities allow firms to develop the capabilities to assimilate outside technologies (knowledge base, literature on tacit versus codified knowledge, etc.). An important result of the literature is that firms spend more time developing (design, build and test prototypes) than researching (developing scientific laws and models). The consequence is that technological knowledge is not easily transferable: one of the conditions for technological knowledge to diffuse is that firms build the capabilities to assimilate such knowledge.

The evidence from empirical research on spillovers confirms the hypothesis of the existence of cost in knowledge acquisition. Thus intra-industry spillovers are found larger in industries with high technological opportunities and with similar products and manufacturing processes (Eliasson, 1994, Jaffe, 1986). Inter-industry spillovers tend to be smaller than intra-industry spillovers (Bernstein, 1988). However, such observations have to be qualified by the fact that the measures of spillovers are imperfect and probably underestimate their true values (Patel - Pavitt, 1995).

As a result, knowledge is an impure public good,[3] the diffusion of which requires learning and transaction costs and can be hindered by barriers to knowledge access. The private returns are not always less than the social returns. When the first hypothesis is relaxed, policy recommendations change. The role of policy is to focus on the organisation of the knowledge distribution system and increase the “distributive power” of the innovation system (Foray, 1994). In addition, innovation and diffusion are not totally distinct, and policies for innovation and the diffusion of knowledge cannot be independently defined (Cohen – Levinthal, 1989).

The second hypothesis is also restrictive, since it is quite obvious that not all relationships between individuals take place on competitive markets. Some agents may negotiate bilateral contracts, without referring to the market; some externalities may arise from conversations between individuals during various social events. Some concepts developed by regional economists in their analyses of clusters of small and medium sized firms are useful in this respect. In particular, they stress the importance of the Marshallian capital (or relational capital) in favouring knowledge exchange and the coordination of activities in such clusters. The Marshallian capital comprises the set of market, power and cooperative relationships that are developed between actors (individuals, firms, institutions) which have a similar culture. Regional economists refer to the territorial dimension of activities, where the territory and the space are not only physical but also include the space of relationships between actors (called “milieu innovateur” by some authors: Aydalot, 1986; Carmagni, 1991; Maillat et al, 1993; or “industrial atmosphere” defined by Marshall, 1890). The cultural proximity, in terms of a sense of belonging, a capacity of interactions between individuals, the sharing of common norms, determines the Marshallian capital, which translates into collective learning through different channels, including a high mobility on the local labour market, stable and profitable relationships between local actors, and spin-offs.

The application of such analysis to research externalities allows to shed new light on their determinants. The Marshallian capital determines the extent of the diffusion of knowledge and collective learning. The set of relationships that constitute the relational capital might then be the key

[3] A pure public good is both non-rival (the consumption by one individual of the public good does not reduce the amount of the good left to other individuals) and non-excludable (it is impossible to prevent some individuals from accessing the good). Knowledge is an impure public good in that learning costs imply that it can be excludable.

to understand spillovers…the economic literature so far lacks a discussion of the identification of spillovers and in particular of the channels through which they are realised. The major determinants of innovation which are focused upon are firm size and R&D expenditure. But the Marshallian capital built in a given economy (a region, or country, or set of countries) or built by a firm (both internal and external) might be the fundamental determinant of both innovation (collective learning that results in knowledge creation hence innovation) and knowledge diffusion. Many economists have stressed the importance of proximity to favour the diffusion of knowledge, but the focus has been on geographical proximity (Acs – Audretsch, 1990; Audretsch – Feldman, 1996; Anselin et al., 1997, 2000).

Under the hypotheses of both knowledge as broader than information and interactions between individuals that can take place out of markets, the policy recommendations change and are of two major kinds: policy should aim at

1. favouring the emergence of collective interactions in the production and diffusion of knowledge (rather than create markets):
2. managing the ex ante and ex post coordination problems: ex ante, the problem is to elaborate collective goods (ex ante division of research labour); ex post, the problem is to make sure that the new knowledge is complementary to other projects in the society, so that the probability of exploiting positive externalities is high.

In economics, the school which relaxes the two restrictive assumptions above is the evolutionary theory; it stresses the importance of networks between individuals and institutions to favour knowledge creation and exchange. Such literature has developed the concept of national innovation system (NIS), which can be claimed to have contributed to the shift of emphasis of EU policies from about the 1990s. We discuss the advantages and limitations of the concept in more details in sections 2.4. to 2.5., when we come to the evaluation of policies.

2.2. Shift in emphasis in the 1990s

Bianchi (1995) shows the change in emphasis of European industrial policies at the beginning of the 1990s. Instead of directly affecting the decisions of agents (the firm, the industry) regarding enterpreneurship or innovation, policies affect agents' incentives to make the appropriate decisions, by providing the conditions favouring such decisions. Thus for instance in terms of R&D collaboration two lines of actions are implemented. First, action on the costs of relationships (information and coordination costs) by providing for instance forums where firms can meet. Second, actions on the collective intangible assets (framework programme that builds a common knowledge base, etc.).

Thus the EU has developed policies to exploit the research infrastructure:

- relationships between the university and industry (e.g. ESPRIT);
- publicly funded research labs;
- support to industrial technological development. Public subsidies to private R&D can affect innovation through three channels: complementing private spending (increase in R&D spending); catalysing inter-firm collaboration or targeting specific technologies.
- favour competition. Economists argue that competition provides incentives to innovate, since monopolies tend to exploit their advantages without much dynamism. In the EU, the main problem in this respect is the tendency of national governments to continue favouring national firms or prevent the real unification of the European market (e.g. mutual recognition principle which does not work in practice in many sectors, including the pharmaceutical one).

The Framework Programmes (FPs) now represent the bulk of EU innovation policies. Such programmes are elaborated for 4 years and define the priorities in terms of research and development of the community. Globally such priorities have been the technologies of the future (material, information and communications) and the technologies related to natural resources (environment; life sciences, including biotechnologies; energy).[4] Pelkmans (1997) argues that the institutional provisions for these programmes are highly inefficient, since it may take up to three years to decide one, due to Member States unwillingness to transfer competencies in an effective way. In any case, the objective of FPs is to favour cross border collaboration to exploit spillovers and to contribute to the Internal Market.

Two main reasons for defining a technology policy at the EU level can be identified. First, the subsidiarity principle implies that the presence of cross-border externalities and scale economies beyond the national frontier is the condition for a policy at European level to be justified, together with the demonstration that the coordination of Member States policies is not feasible or imperfect. Regarding innovation, such conditions are fulfilled, especially the cross-border externalities. Second, the EU technology policy should contribute to the establishment of the Internal Market and to the main EC objectives, such as cohesion, sustainable development, competitiveness of European industry and citizens' welfare.

A recent project designed by the European Commission is the European Research Area[5], aiming at correcting the structural weaknesses of European research and proposing measures in its support, especially in the 6th research Framework Programme (2002-2006). The main weakness appears to be the fragmentation of research efforts in the EU, so that the ERA project aims at favouring the coordination of RTD policies at the different levels, namely regional, national and European, and favour the mobility of individuals across the EU. The 6th Framework Programme is the main tool to support the creation of the ERA. Its main objectives are:

1. the integration of research, to maximise the impact of the efforts made in the priority research areas defined by the FP;
2. the structuring of the ERA, to promote and strengthen cooperation and synergies between and within the national and regional programmes on human resources and mobility;
3. the strengthening of the foundations of the ERA, to stimulate and support coordination programmes and common actions among Member States and European organisations; and to develop a common knowledge base for a coherent implementation of policies.

The instruments proposed to meet these objectives are the realisation of integrated projects, the building of networks of excellence and the realisation of joint projects between the European Commission and Member States.

In fact, the ERA project appears to just rename previous objectives and proposed actions; the European Commission has been stressing for a long time the importance of joining national R&D efforts to avoid duplication and make a whole more than the sum of the parts.

[4] We do not review here all the programmes adopted by the European Commission since its beginning, because we think this is not the scope of this paper; we focus instead on main recent policies and their evaluation.

[5] COM (2000) 612 Final – "Making a Reality of the European Research Area: Guidelines for EU Research Activities (2002-2006)".

Table 1. Main aspects of ERA

Integrating European Research	
Priority thematic areas	**Anticipating needs**
Genomic and biotechnology for health	Policy support
Information society technologies	Frontier research, unexpected developments
Nanotechnologies, intelligent materials, new production processes	Specific SME activities
Aeronautics and space	Specific international cooperation activities
Food safety and health risks	
Sustainable development and climate change	
Citizens and governance in the knowledge society	
Structuring the ERA	**Strengthening the foundations of ERA**
Research and innovation	Coordination of research activities
Human resources and mobility	Development of research and innovation policies
Research infrastructure	
Science and society	

Source: COM (2000) 612 final.

Establishing in Europe an environment favourable to innovation means "encouraging technology transfer, ensuring venture capital is available, helping to protect property rights and developing human resources." (Buigues et al., 2000, p 325). These seem good ideas, but it is difficult to find in the literature some explanation on what protection of property rights is compatible with knowledge transfer, what are the trade-offs, whether other financial capital than venture capital is available in Europe, to what extent human resources are underdeveloped in the EU.

The policies in the USA and Japan have been different from the European ones. In Japan, government-sponsored research joint ventures have continued to be developed, but with the recent aim of creating a technological superstructure for a large group of high technology sectors. The US has established specific programmes to promote cooperative R&D only recently. We next compare the relative performance of the EU, the US and Japan.

2.3. Innovative performance of the EU

One recent instrument put in place at European and national level to assess progress in innovation (and competitiveness in general) has been the "benchmarking" exercises and the innovation scoreboards. Table 1 below summarises the main results of the 2001 Innovation Scoreboard performed by the European Commission. Before analysing the data, a note on the quality of the indicators might be useful.

Due to its complex nature, the measurement of technological activity and innovation is imperfect. The two main measures are R&D expenditure and patenting activities. The main criticism of the former indicator are the following:

- underestimation of technological activities related to production (R&D is classified according to the main activities of the firm, not all activities; innovation occurs not only in R&D department, but also in the production department, where learning by doing can take place);
- capture imperfectly the technological activities of small firms, which do not have formal R&D lab and accounting;

- underestimation of technologies related to information processing (software);
- common criticism: measures the input and not the output of innovative activities.

As to patents, the main criticism of such a measure of R&D output are:

- time lag: if patenting occurs early in the R&D process, then patents are a poor measure of the output of R&D (Pakes - Griliches, 1984);
- persistent variations across sectors and countries in R&D productivity, as measured by patents granted per unit of R&D spent. The main reasons are first, the imperfections of the measurement of R&D; second, the intersectoral differences in the use of patents to protect innovations; for instance patents are much more important in the pharmaceutical industry than in the car industry, where other means are used to protect innovation (first mover advantage; focus on process innovation, etc.); third, procedures and criteria for granting patents vary widely across countries.

Sectors differ largely in the sources, rates and division of technological activities. Much work has been done on the technological differences and interdependencies across sectors (Scherer, 1982; Pavitt, 1984; Robson, 1988; Geroski, 1991).The main results are the following:

- more than 75% of the development of new technologies is concentrated in the same core sectors: machinery and instruments, electrical and electronic, chemicals, transport (and pharmaceutical);
- in all core sectors the focus is on product innovations that are adopted in a number of user sectors;
- the main user sectors are textile, food, paper and printing;
- intersectoral differences in productivity growth are best explained by the use of technology rather than its production.

Such studies remain at the aggregate level and do not explain how sectoral linkage appear and develop, neither how they evolve over time. Firm-level studies have shown that smaller firms also produce technologies but larger firms include multiple technologies (the diversity of technologies in the firm increases with firm size). However, a country with a lower score in a particular aspect than another country does not necessarily means that the country with lower score has to put policy priority to catch up in that particular aspect. For instance, a country might have less graduates in S&T but this might be compensated by higher on-the-job training; Europe might lag behind in terms of patent application but this might mean that what is needed in Europe is more stress towards the commercial applications of innovations, rather than more R&D activities.

Table 1 shows the results of The *EU Innovation Scoreboard* for the year 2001. The scoreboard is divided into five broad categories, which reflect the main subjects considered as intangibles, more specifically: *human resources, knowledge creation, diffusion of knowledge, finance and Information & Communication Technology*. The structure of the following analysis is oriented to a comparison, when possible, between the three main economies in the US, EU and Japan.

Human resources

In all major industrialised countries there is a link between the input of research and development and productivity growth; competitiveness, sustainable economic growth and job security rely on the conversion of knowledge into innovation. More recently, in these countries, it is the services sector that has seen higher growth, with both new employment fields and value added chains arising. This is especially true in those knowledge-intensive fields in which high-grade technologies expand existing, or even create new markets. Industry and services are growing closer and closer together via their reciprocal market ties; and service providers mainly act as customers and suppliers to industry. Moreover, the spatial clustering of skills in research-intensive industries and high-grade services encourages technological innovation and thus, ultimately, the technological performance of the overall economy.

In this context, the share of highly skilled employees should present a relatively accurate picture of the innovativeness in services. The human capital tied up in the labour force is a sector for successful innovative activities, and is also indispensable for the application of technical knowledge from manufacturing industry.

In the EU, more than 31.5 million employees were working in manufacturing industry in 1999[6], i.e. only about a fifth of total employment, whilst almost two third were working in the service sector. Knowledge intensive services have made a significant contribution to the expansion of this sector. In that same year, roughly 50 million people were in knowledge intensive services in the broader sense, with one in ten (5 million) in Information and communication oriented services (ICS). In fact, employment in KIS (knowledge-intensive services) rose in the course of 1995 to 1999. Europe-wide, about 5.3 million jobs (gains of 2.9% on average per year) were created in this sector, and more than 700.000 of these in Information and Communication sectors.

Moreover, the high-tech sector in Europe has expanded appreciably. A total of nearly 122 million people in the EU were employed in research-intensive industries in 1999, with more than 50% of these in mechanical/automotive engineering, nearly 30% in electro technology/Information and communication and almost 20% in chemicals[7].

Looking at the present situation in the EU Innovation Scoreboard, the share of S&T graduates in all post-secondary graduates in Europe is 37%, while the percentage of employment in medium and high tech manufacturing sector is 7.7 and only 3% for high-tech services. The only comparison available between EU and the US is on the percentage of workforce in tertiary education, where the result in the US is double the one in Europe (respectively 26% against 13%).

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[6] Sources: Eurostat – CLFS, NIW calculation
[7] European Commission (2001): "*Statistic on Science and Technology in Europe*", France

Table 2. 2001 EU Innovation Scoreboard

	USA	JAP	EU	D	F	UK	I	E	NL	B	S	A	DK	FIN	EL	P	IRL	L
human resources																		
Share of S&T graduates in all post-secondary graduates	na	Na	37	48	31	37	32	32	30	26	47	33	32	58	38	28	39	na
Percent workforce in tertiary education	26	Na	13	13	10	13	8	13	23	11	13	6	15	12	12	7	11	11
Percent employment in medium and high tech manufacturing	na	Na	7.7	11	7	7.8	7.5	5.5	4.8	7.2	8.6	6.5	6.8	7.2	2.4	3.5	7.4	1.6
Percent in high tech services in total empl.	na	na	3	2.6	3.6	3.7	2.6	1.9	3.3	3.5	4.4	2.5	4.2	4.6	1.5	1.4	2.4	2.5
Knowledge creation																		
Government R&D funding as % of GDP	0.78	0.59	0.7	0.82	0.9	0.58	0.53	0.36	0.83	0.42	0.97	0.72	0.72	0.9	0.22	0.44	0.32	na
Business expenditure on R&D as % GDP	2.04	2.18	1.2	1.53	1.38	1.21	0.55	0.49	1.11	1.31	2.77	0.83	1.26	2.06	0.13	0.14	1.03	na
number of patent applications in high tech per million population	19.7	9.4	14.9	23.9	16.3	15	4.2	1.7	26.8	12.5	41.7	9.1	19.3	69.6	0.3	0	0.9	1.9
Diffusion knowledge																		
Percent of manuf. SMEs that innovate in-house	na	na	44	58.7	36	35.8	44.4	na	51	29.4	44.8	59.1	59	27.4	na	21.8	62.2	24.5
Percent manuf. SMEs in innovation cooperation	na	na	11.2	14.7	12	15.7	4.7	4.6	14.6	8.9	27.5	12.9	37.4	19.9	na	4.5	23.2	9.6
Finance																		
Capitalisation of new markets as % of GDP	57.3	na	3.4	3.7	4.7	1.5	1.1	na	0.3	0.1	31.2	0.5	na	2.3	17.5	0.2	0.4	na
Sales share of products new to the market in the manufacturing sector	na	na	6.5	3.8	7.9	6.7	13.5	9.5	6.6	2.6	6.9	5.6	5.1	7.3	na	7.2	8.4	na
ICT																		
Internet users / 100 inhab.	39.8	14.5	14.9	19.4	9.7	21	8.7	7.2	19	13.7	41.4	10.5	28.2	32.3	7.1	7	11.8	17.4
Change in share of total OECD production in high tech sectors over 1992-6	1	-7	na	-19	-15	-9	-12	4	-7	na	86	na	9	150	-36	na	na	na

R&D and knowledge creation.

In 1998, gross domestic expenditure on R&D (GERD) in the United States was € 202 thousand million[8], or one and a half times domestic R&D expenditure in the EU-15 (€ 141.2 thousand million) and twice that of Japan (€ 102.5 thousand million). In that year, R&D expenditure increased in the EU-15 and the United States in terms of volume by 4.6% and 8% respectively. They thus continued the global trend which had emerged over the previous five years. In contrast Japan showed a decrease of 4.2%. The order is different if R&D expenditure is measured in relation to GDP. The United States (2.58% of GDP in 1998 and 2.82% of GDP in 2001) were in the lead and continue the upward trend which had been apparent since 1994. Japan exceeded the previously highest level it had achieved at the beginning of the 1990s reaching 3.03% in 1998, but it showed a decrease in 2001 with 2.77%. Expenditure in EU-15 has been increased from 1.86% of GDP in 1998 to 1.90% in 2001 and it changed the relative downward trend begun at the end of the 1980s[9].

An analysis of the distribution of domestic R&D expenditure among the three main institutional sectors (the business enterprise sector, the government sector and the higher education sector) reveals a virtually identical structure in Japan and the United States, where the business enterprise sector accounted for three-quarters of the total expenditure. On the other hand, in the EU-15 the proportion of R&D expenditure committed by the public sector (higher education and government) was below the expenditure in the USA (0.70% in the EU-15 and 0.78% in the USA). In contrast, the proportion committed by the business enterprise sector was only 1.20% of the GDP in the EU compared with 2.04% in the USA and 2.18% in Japan.

Patents

An analysis of the evolution in applications for European patents[10] in the EU between 1989 and 1998 reveals an annual average increase of 3.2%[11]. In 1998, 82.969 EPO patent applications were filed by Europeans, Japanese and Americans. The EU predominates with 48% of applications. Japan and the United States account for 18 and 34% respectively. Relative to 1990, when 64.838 patents were applied for, the shares of the EU and Japan have fallen by 2 and 3 points respectively to the benefit of the United States. This is explained by vigorous growth in the number of applications filed by the United States, which averaged 4.8% between 1990 and 1998 as against 2.7 and 1.3% respectively for Europe and Japan. In 2001, the number of patent applications in high tech sectors per million population has seen the USA with the highest share (19.7) , followed by the EU and Japan, respectively with 14.9 and 9.4.

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[8] Source: OECD, 2001.

[9] R&D expenditure as a proportion of GDP is calculated according to the European System of Accounting (ESA ’95). This methodological change allows a better coverage of economic activities than ESA ’79.

[10] A patent is a public title of industrial property conferring on its owner the exclusive right to use his invention for a limited number of years. The use of patents can be seen as an indicator of technological activity, and these indicators are alternatives to direct measurement of the output of scientific and technological research activity.

[11] Source: European Patent Office (EPO) and Eurostat.

Innovation and knowledge diffusion

The ***1997 Oslo Manual***[12] describes innovation as being "*at the heart of knowledge-based economy*", where knowledge in all its forms is seen to play a crucial role in economic processes. Furthermore, the ***Community Innovation Survey (CIS)*** defined technological innovation as: "*the introduction onto the market of a technologically new or significantly improved product or the implementation of a technologically new or significantly improved process*" and innovation is said to occur as a result of an interaction between market opportunities and the enterprise's knowledge base and capabilities[13]. The Community Innovation Survey, organised by the European Commission and conducted in 1992, was replaced by the Community Innovation Survey 2 (CSI2) conducted during 1997/1998 in 17 EEA countries and based on the 1997 Oslo Manual. The focus of CIS2 is mainly on firm, with emphasis on the innovation in the manufacturing industry. However, it also extends to cover the service sector, which is now considered as the main user of innovation generated from the manufacturing industries[14].

As result of CIS2, on average 51% and 40% of enterprises in the manufacturing and service sectors respectively were innovative in the period 1994-1996. The proportion of innovating enterprises increases with the size class in both the manufacturing and service sectors. In the service sector, 73% of large enterprises were innovative compared to only 48% and 36% in the medium size and small size classes[15]. In the EU countries, 62% of innovating enterprises are both product and process innovators; 24% are product innovators and only 14% are process innovators only. Among all the enterprises in the manufacturing sector, 44% developed new products and 39% developed new processes. Of the enterprises, 21% were novel innovators, that is, their products were not only new to the firm but also new to the market. On average a quarter of the innovators in the EU countries has established a cooperation with another partner in developing new products and processes. The actual proportion stands at 28% in the manufacturing sector with a marginally lower proportion of 26% in the service sector[16]. Among innovators with cooperation, the highest proportion in both sectors (58% for manufacturing and 67% for service) has established a joint partnership with enterprises within a group. Vertical cooperation in the manufacturing sector is most common with clients and customers (47%) and suppliers of equipment (46%). On the other hand, in the service sector the highest proportion of vertical cooperation occurs with competitors (41%) and suppliers (39%). In both sectors, one third of innovating enterprises have innovation cooperation with either government or private non-profit institutions or universities.

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12 Eurostat and OECD: "*Proposed Guidelines for collecting and interpreting Technological and Innovation Data – Oslo manual*", revised version, 1997, Paris.

13 Archibugi, D. - Cohendet, P. - Kristense, A. - Shaffer, K.A. "*Evaluation of the Community Innovation Survey – Phase 1 DGXIII*" European Commission, 1994, Luxembourg.

14 Oslo Manual, pg. 44, section 4.2.3

15 The results are based on answers from 39500 enterprises. The following size bands, based on number of employees, have been used to characterise enterprises:

- *Manufacturing*

Small: 20 to 49 employees,
Medium: 50 to 249
Large: 250 or more

- *Services*

Small: 10 to 49
Medium: 50 to 249,
Large: 250 or more

16 European Commission (2001): "*Statistic on Science and Technology in Europe*", France.

An important point is that, on average, in the manufacturing sector, half (51%) of the innovators with innovation cooperation have commercialised an innovation that was new to the market. The corresponding proportion for the innovators without a cooperation agreement is only about a third (36%). Moreover, the proportion of novel innovators with innovation cooperation is higher than the proportion of those without cooperation. Nevertheless, the proportion of novel innovators with innovative cooperation increases with the size of the enterprises. Moreover, *one important indicator on the impact of innovation activities is the relative share of turnover due to new or improved products*[17]. CSI2 revealed that 32% of turnover in the enterprises of the manufacturing sector was due to new or improved products. However, only 6% of this turnover was due to products which were also new to the market. Moreover, it can be seen that the turnover due to products new to firms increases with size, from 15% for the small enterprise, to 21% for the medium enterprises and 38% for the large enterprises. The 1997 Oslo Manual recommends that a firm's reasons for engaging in innovative activity should be identified via its economic objectives in terms of products and markets, and how it rates a number of goals that process of innovation can bring within reach. In both the manufacturing and service sectors, improving the product/service quality was considered as the most important objective (by 60% of manufacturing enterprises and 68% for service enterprises). The other objectives which were considered as important by manufacturing firms, were opening up new markets or increasing market share (54%) and extending product/service range (46%). In the service sector, almost 50% of enterprises considered these same objectives as very important. In both sectors, a minor importance was attached to objectives such as replacing products/services being phased out, fulfilling regulation and standards, lowering production costs by reducing material and energy consumption, and reducing environmental damage.

On average, 21% of the manufacturing innovators have been involved in government programmes to encourage innovation activities, compared to only 10% in the service sectors. Nonetheless, the pattern for the manufacturing sector is: *the larger the firm, the higher the percentage of innovators receiving government support*.

ICT

Economic growth can be achieved through increased and improved use of labour and capital or through a rise in multi-factor productivity (MFP). However, a new factor that has been driving growth in some countries is information and communication technology (ICT). ICT is often embodied in other non-ICT goods, and it plays a role as an intermediate input to capital goods production. Three types of ICT assets are distinguished: *hardware, communication equipment* and *software*[18] but for the purposes of theoretical exposition, they are lumped together here as the flow of ICT capital services as distinct from the flow of non-ICT capital services.

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[17] European Commission: "*Statistic on Science and Technology in Europe*" 2001, France.

[18] The System of National Accounts 1993 stipulates that software purchases by firms should be considered investment expenditures, incurred to build up and intangible asset, the stock of software available in the production process. With the implementation of the SNA93 in most OECD countries, the first set of estimates of software expenditure has become available in countries national accounts. However, unlike hardware, whose current price investment can be assessed with reasonable confidence, the measurement of software expenditure at current prices is subject to many uncertainties and estimation methods differ across countries. For example, Lequiller (2000) found significant cross-country differences in the allocation of software expenditure between fixed capital formation and intermediate expenditure. This may be as indicative of differences in methodologies as it may reflect truly different investment patterns across OECD countries. Consequently, comparisons of software investment across countries have to be treated with considerable care.

The economic expansion in the United States in the 1990s was led by large and sustained growth in business investment. Remarkably, the rate of capital accumulation in the US business sector almost doubled in the second part of the decade, mainly because of strong investment in ICT capital[19]. The rate of growth in IT (information technology) equipment in the United States in the 1990s doubled with respect to the 1980s and accelerated in the 1995-1999 period to reach 34% per year on average. Hence, the growth of investment in the 1990s has been largely driven by growth in ICT investment. This is particularly evident in the case of the United States where ICT investment accounted for over 50% of non-residential investment growth in the most recent year[20]. Volume growth in IT equipment investment has been so significant because of a steady decline in its relative price, giving rise to substitution between different types of capital and between ICT capital and labour. The rapid price decline for computers and office equipment accelerated further in the late 1990s with respect to earlier years. Software has nonetheless been a major driver of ICT investment growth in the late 1990s, contributing 25-40% of overall investment growth. This result is however different for the three economies in the US, EU an Japan. In fact, it is observable from table 1 that the ratio Internet users per a hundred inhabitants is respectively 39.8, 14.5 and 14.9. Overall, the percentage in the US is more than twice the percentage in Europe.

However, in the period 1990-2000, the existence of a large ICT producing industry is neither a necessary nor a sufficient condition for countries to benefit from growth effects of ICT. This is demonstrated by the example of Japan: it has the largest IT hardware producing sector of the seven countries analysed, and did not exhibit above-average growth contributions[21] from ICT equipment. The OECD (2001a) finds that firms in the United States have enjoyed considerably lower costs of ICT investment goods in the 1990s than firms in the European countries and in Japan. Barriers to trade, in particular non-tariff barriers related to standards, import licensing and government procurement, may partly explain cost differentials. Higher price levels in other OECD countries may also be associated with a lack of competition within countries. In fact, countries with a high relative price level of ICT investment tend to have a lower degree of competition, as measured by indicators of economic regulation.

As a conclusion to this section, we can say that the European Innovation Scoreboard could reflect in a metaphorical way the stream of a waterfall. In fact it sees at the very top the human resources. More specifically, human resources are treated in terms of education, training, skills, thus capabilities that enable the creation of knowledge. Hence knowledge creation appears to be considered as dependent upon the coordination of human resources in programmes of research and development. However, the creation of knowledge is not enough, because knowledge has to be exploited in order to provide economic benefits. It must be diffused through a continuous innovation process and a further diffusion of the innovation. In the end of this metaphorical waterfall, ICT represents a result of the previous features and a new means as well. ICT could represent an asset and a new generator of assets at the same time.

It might be argued that the intangibles analysed above could not be separated. In fact, it could be unlikely to observe innovation without the contribution of human resources concentrated in activities of research and development. Yet, knowledge *per se* might not have the same effect as

[19] Colecchia, A. - Schreyer, P. "*ICT investment and Economic Growth in the 1990s: is the United States a unique case? – A comparative study of Nine OECD countries*". OECD Science, technology and Industry Directorate and Statistic Directorate. 2001.
[20] Colecchia, A. - Schreyer, P. "*ICT investment and Economic Growth in the 1990s: is the United States a unique case? – A comparative study of Nine OECD countries*". OECD Science, technology and Industry Directorate and Statistic Directorate. 2001.
[21] Two sources: ICT can be considered an input in themselves or in their use.

knowledge developed in a context of entrepreneurial culture and of stimulus to develop and exploit this knowledge. It could be like to pretend to find water in the lake below the waterfall without seeing the waterfall too.

2.4. The case of university – business relationships

Analyses of the situation of the European technological performance in the 1990s have often used the expression "European paradox" (European Commission, 1995): Europe has a considerable amount of R&D (although it appears to consistently rank third behind the USA and Japan, if we consider the R&D expenditure in relation to GDP, while it is second, behind the USA, considering the gross domestic expenditure in R&D: see table 2) and has no serious technology gaps, but European firms appear to suffer from an inadequate ability to turn their inventions into commercial success, especially in high-technology sectors, like electronics and information technology.

Not only did scholars come to such a conclusion, but the European Commission itself has been aware of this problem. Therefore, numerous policy measures were examined with a view to increasing the technological competitiveness of European firms. Most of the new measures were inscribed into the conceptual framework of both the National Innovation System (NIS) (Nelson, 1985; Lundvall, 1992) and the knowledge economy (Smith, 2000; MERIT, 2000). The concept of NIS emphasises the need for interactions between the agents of innovation, particularly government, university and firms. This interaction is particularly stressed by the "triple helix" approach, that may be considered as an evolution of the NIS approach (Etzkowitz - Leydesdorff, 2000). While in the NIS firms have a leading role in innovation, in the triple helix approach such role is played by the historical existence of different kinds of interactions between the three institutions. In the past, the government dominated in the interactions between the three institutions, but it has been shown that the actual tendency is an equal term interaction between the three. The knowledge economy framework comes to the same conclusion, even though it moves on a more abstract level: it focuses on the circulation of knowledge, whose speed and effectiveness is the key for success in the contemporary economy, which is increasingly based on intangibles goods: knowledge is the "intangible asset" *par excellence.* Therefore, a key policy concern should be the circulation of knowledge among economic actors, in particular between the institutions that "produce" knowledge, like the universities, and those that "use" it, such as firms (obviously with the awareness that firms themselves do produce knowledge, especially of a tacit type). More generally, the role of networks in research processes is emphasised; the increasing role of networks is particularly important in the so-called "new economics of science" (David et al., 1999). Another sophisticated conceptual framework, deeply related both to the modern concept of NIS and to the knowledge economy, is the framework of the "learning economy" (Lundvall, 1992), which points to the need for intensive interactions between university and industry: according to this approach, knowledge is the main resource and learning is the process that allows the accumulation of knowledge, through the interaction between different agents. University is a main source of knowledge and therefore it is of fundamental importance that firms have access to it. A bridging problem may arise, so that government might have to intervene to establish links between knowledge producers and knowledge users. This conceptual framework leads to the conclusion that the new fundamental "intangible asset" for a firm, and for the whole economy, is the ability to create and absorb technologies through interactions. Technology transfer becomes the main function to be implemented.

As a consequence of this awareness on a theoretical and political ground, several European documents published in the nineties (European Commission, 1995; Jones-Evans, 1998) have stressed the need to reinforce the linkages between university and industry and, coherently with this purpose, many European technology policies were elaborated to meet this aim. Of course, although the focus is on universities, other institutions "produce" knowledge and research. For example, some large public research institutions and some agencies created in order to facilitate knowledge transfer play an important role too.

Two main linkages exist between university and industry. First, university is the main source of human capital, although further training is often necessary for the new graduates. The formal education provided by universities is the basis for the absorptive capacities of technological development by firms. Second, the research conducted by university departments is usually a source of technological improvement, whose commercial exploitation is realised by firms. However, a number of authors[22] examine the relationship between science and technology in more depth and stress that there is a fundamental difference between universities and business, in terms of objectives: business research is usually oriented towards shorter term goals. This does not mean that basic research performed by universities should be put aside, but that the complementarity of university and business research is not straightforward.

These two kinds of relationship, however, cannot be considered as proper "linkages": they do not imply a direct contact between the university and the industry: educated people may be hired after they have left the university and the results of scientific research are published in books and reviews, although firms may incur learning costs. Such linkages are in fact market relationships. The problem is that such linkages exclude certain types of knowledge flows. As stressed in the first section of this paper, certain kinds of knowledge are not marketable: in this case direct linkages are the only effective way to acquire knowledge.

Making a list of the possible direct linkages between the two institutions is not an easy exercise, due to the numerous informal relationships involved; measuring them is even more difficult. For this reason, the main linkages which have been identified and focused upon have been those related to explicit R&D collaboration and personal contacts, via for example consultants or entrepreneurs who come from university and remain in contact with their departments (and have set up a spin-off). The Framework Programmes of the European Commission have aimed at reinforcing such linkages, especially through R&D cooperative projects. Geuna (1999) studied the determinants of the participation of the Higher Education Institutions (almost exclusively universities) to the projects of the Framework: he concluded that a higher scientific productivity of the university positively influences both the probability to join an EU-funded project and the number of times it participates. Other empirical studies, especially referred to the Austrian (Schibany - Schartinger, 2001) and Italian (Alessandrini - Sterlacchini, 1995) situations conclude that industries with high internal R&D, and therefore especially large firms, are more inclined to collaborate with universities and more satisfied of it. Therefore, the collaboration between university and industry appears, in the European situation or at least in many European countries, like a sort of elitist phenomenon.

This represents an important, and probably fundamental, difference between the EU and the United States. The American system of collaboration between universities and firms is characterized by the presence of some leading universities, like the MIT which was born with this specific purpose. Nevertheless, such a system has contributed to the diffusion of industry-sponsored research and to the transfer of technology to commercial applications (Geiger, 2001). In Japan, that could be considered to rank second in the "world technology competition", some tight and frequent personal relationships exist that tie university researchers with individual firms, even though such linkages encounter some bureaucratic obstacles. In the EU, there appears to be a sort of reciprocal scepticism

[22] Rosenberg, 1982 is a classical contribution on this point.

towards collaboration, especially in the Mediterranean area. Probably influenced by a more humanistic background, universities define themselves and are perceived by firms as “pure research” institutions, whose nature is inadequate to or would be improperly transformed by a focus on applied research. This results in a difference in mentalities which is not easy to overcome. Universities appear more reluctant to collaborate, since the above mentioned analyses of Italian and Austrian situations show that firms propose collaboration much more frequently than universities do. Also when public incentives induce firms and universities to collaborate, the lack of an adequate mentality produce negative effects: an empirical study on the dynamics of network formation within the BRITE-EURAM program, for the Second and Third FP (respectively 1990-94 and 1994-98) reveals the prevalence of a competitive behaviour, that is less socially efficient than a cooperative one, and the existence of trade-offs between short-run productivity of research and long-run cohesion of technological capabilities (Garcia-Fontes - Geuna, 1999).

In a certain sense, the American economy is more dynamic and more capitalistic. Universities are managed in a more entrepreneurial manner than in Europe. Historically, the common interests induced both the universities and the industry to cooperate, thus overcoming some initial difficulties and perplexity, expressed for instance in the student protests during the seventies. American universities appear to propose collaboration, contrary to the European case. However, such a situation is not without problems. In particular, universities face a trade-off between independence and business funding, and run the risk of favouring scientific faculties to the expense of other faculties. Business is concerned about the long-term orientation of university research. Some problems also arise regarding the diffusion of the research results: universities aim at a large diffusion of the results, through publications, while business is more prone to patent research and obtain exclusive property rights, hence a restriction of the diffusion of the new knowledge. This problem is being tackled in the US, while the EU is still at too early a stage of university-business collaboration to be confronted with it (Alessandrini – Sterlacchini, 1995).

Nevertheless, US universities do not seem to have lost their autonomy: in 1991, only 4.9% of university research was funded by firms (compared to 7.7% in Germany, 7.8% in the United Kingdom and only 2.4% in Italy, Alessandrini – Sterlacchini, 1995). This shows that the essential factor for economic success is not the “privatisation” of the university system and the provision of high amounts of business funds to universities, but rather both high public and private R&D expenditure together with a well-functioning education system, and diffused and well-regulated linkages between university and industry, not exclusively based on economic considerations.

The advantages of university-business relationships are numerous. The above mentioned empirical study in Austria (Schibany - Schartinger, 2001) shows both the range of incentives for business to collaborate with universities and the benefits actually obtained. Schibany and Schartinger provide evidence that the main role in knowledge transfer is played by the human factor and therefore by tacit knowledge. In fact, the first motive quoted by business for collaboration is the problem-solving capacity of universities. This means that the intellectual competence (human capital) and methodology (knowledge) learnt at university is perceived as even more important than the specialist education. This has a clear policy indication: university should keep their education goal of providing a general “way of reasoning”, which should be combined however with developing a practical capacity to solve specific problems. The European Commission is conscious of the risks of too specialist an education (MERIT, 2000). The specific role of university research is also recognised in the empirical survey, since 68.3% of the respondent firms considered the chance to access state-of-the-art science as a very important benefit of the linkage, while 51.3% recognised access to the high quality of university research as a clear benefit. 51.3% of firms claimed to be certain that the collaboration may increase their research capacities. Firms expect to receive ideas for new products and processes, as well as a direct support in the development process, new instruments and techniques. An empirical study conducted in Germany in 1993 on about 2900 firms in the manufacturing sector (Becker - Peters, 2000) shows firms' benefits, in the R&D function, from the collaboration with universities. The main finding is that in general, knowledge generated in the academic sphere has significant effects on the innovative activities of firms: technological capacities are expanded with positive effects on the development of new and improved products. Others (see, for example, Schuetze, 2000) underline that the collaboration with university in R&D projects reduces the risk sustained by the firm. Universities may also benefit from the cooperation: they may have greater funding for research, may have access to new ideas and techniques and may develop specific research projects and fields.

From a social point of view, the public interest towards cooperation is justified if the overall effect of the cooperation is the enhancement of the level of research. As stressed in section 2.1., such condition should be met because R&D collaboration may be considered as a proxy for knowledge spillovers: there is an internalisation of externalities, that should imply a higher level of research.

Other difficulties arising in the relationship between firms and universities are related to the different nature of the two institutions, implying different goals, a different culture and also a different organisation (universities are much more bureaucratic). However, these difficulties may turn into advantages if the actors are able to define a clear and favourable framework of rules. After all, even though the two institutions have to fulfil different functions in the innovation system, an intermingling of the two cultures is highly desirable, for the reciprocal and social advantages.

Countries with few relationships between firms and universities may lack proper incentives to set up relationships. For instance, too restrictive regulations on the mobility of university personnel and the lack of information on the content of the activity of the other institution: regarding this last point, a poor communication about what universities do and what may be relevant for industry emerged in the study by Schibany and Schartinger on Austria. These two issues may have important policy implication. An efficient policy that stimulates the cooperation between university and industry should take all the different possible types of interactions into account and try to facilitate them. Schibany and Schartinger highlight different types of interaction:

- the personal mobility in terms of sabbaticals of university researchers in the enterprise sector or permanent change of university researchers to the enterprise sector;
- a spin-off formation of new enterprises;
- lectures by business people at universities;
- the training of business people by university researchers;
- the joint supervision of PhDs and Masters' theses;
- the joint publications between the university and the enterprise sector;
- the joint research projects between the university and the enterprise sector; and
- the financing of research assistants by the enterprise sector.

The spin-off process has emerged as a particular and important source of innovation, leading most EU countries to pursue active policies to promote the establishment and growth of university SMEs. Several initiatives have been taken for this purpose, such as the institution of science and technology parks, of incubators or university enterprise centres, the mobility of researchers and the financing of technology transfer. However, the European Commission itself recognises that these schemes do not appear as close to SMEs as they are in the USA. In fact, the lack of entrepreneurial mentality in universities appears to be the main difference between the EU and the USA even in the spinoff process.

Another point to examine in more depth regards the characteristics of both institutions, namely firms and universities: firms differ in size, sector, and so on. Differences among faculties should also be considered. As already mentioned, larger firms have a higher tendency to collaborate with universities. However, substantial differences also exist between countries. Thus Nordic European universities have a higher propensity to develop linkages with high-tech SMEs, while universities in the Mediterranean countries develop less linkages, partly because of the prevalence of low-tech enterprises in the industrial structure of the country. However, being low tech does not necessarily mean absence of potential spillovers. One policy option to examine is, where possible, that of trying to enhance the technological level of small firms, so that they could benefit from direct linkages with research institutions, especially trough personnel mobility rather than through R&D collaboration. The sector analysis shows that both the frequency and the type of linkages widely vary across sectors.

Regarding university-industry relationships, policy should be defined at both European and national level. At national level, specific policies are needed to develop the linkages between university and business, because of the diversity in both firm characteristics and university systems across the EU and because of the different level of existing collaborations. Thus for instance in Northern European countries, such as Sweden (Jones-Evans, 1998), the level of interaction between university and industry is comparable to the US one; the situation is completely different in the Mediterranean countries: a major weakness of Italy is the poor linkages between the two institutions (Malerba, 2000). The results of the Framework Programs (Geuna, 1999) show very different propensity to collaborate across countries. It follows that instruments such as benchmarking and adoption of best practices should by applied with caution, taking into consideration the different situations, cultures and also resources of each country. These should not be considered, obviously, as they were not modifiable, but they are the natural starting point, also considering that the qualitative differences may be a source of richness, particularly in a rapidly changing economic environment. The European Commission (Jones-Evans, 1998) has recognised the necessity to take local differences into consideration.

It is clear that policy should create an environment favourable to relationships rather than directly set up or impose the relationships. One of the aims of the European Commission is, rightly, to be a facilitator of this relationship. The Framework Programmes, instruments like public agencies, the Industry Liaison Office (see Jones-Evans, 1998 for an evaluation) are directed towards this goal. But these important policy measures run the risk of being insufficient or even superabundant: cultural proximity should not be neglected, as relationships develop between individuals who share, at least partly, a common culture, norms and values. In other words, the social capital may be an important determinant of the frequency and the nature of linkages. The strength of the European policy should be directed to stimulate a debate in order to overcome the mentality barriers to collaboration. Creating a favourable environment also means to overcome the other difficulties pointed out in this section: the lack of reciprocal information, the unsatisfactory definition of property rights, legal barriers and low incentives to cooperate. Both tangible and intangible factors interact to create innovation and to favour its diffusion, and the explicit consideration of intangible assets helps derive policies that take all such interactions (or complementarities) into account.

2.5. Evaluation: from "government" to "governance"

The shift in emphasis of EU RTD policy can be called a shift from "government" to "governance", i.e. from a clear definition of each level and area of competence of policy, together with public intervention targeted at specific players, to a blurred definition, where levels and areas interact, and where the scope of the policy is to provide the right environment rather than act directly on agents. In terms of RTD policy, "government" was the policy of subsidy and support to specific industries, and "governance" is now the idea of providing the environment favourable to innovation and its commercialisation.

Few empirical studies have evaluated the EU RTD programmes; the support for both generic technologies (Sematech in the US, ESPRIT, BRITE, RACE, etc.) and for research collaborations (to reduce costs and spread risks, to avoid duplications of research efforts and to exploit economies of scale in R&D) has been popular, but few detailed studies has assessed their effects, apart from the impact studies carried out at national level. Caloghirou - Vonortas (2000) assess the EU research joint ventures, pointing to the differences between countries but not estimating the precise impact on the economy. They find large differences between the policies of individual EU Member States. Policy approaches have ranged from indifference to the issue until recently (Ireland) to rapidly decreasing attention (UK), to lukewarm policies (Greece, Italy), and to firmly established programmes to assist cooperative industrial RTD (France, Spain). The level, type and technological focus of the various programmes have varied widely. The European Commission's policies appear to have played the role of catalyst and coordinator and Member States see them as complementary to their own policies.

Research collaboration has focused on pre-competitive phases, especially in Europe, but the evidence presented in section 2.3. is that Europe is still lagging behind in terms of ability to transform innovation into commercial success. In Japan, the particular focus on collaboration to increase the diffusion of some technologies appear to have been successful, and three conditions appear to have contributed to this success: the complementarity of the technologies of the participants; the transfer of personnel between participants; and the collaboration at earlier stages of research with strong competition at the commercial level.

The reasons for the low returns in bringing successful products on the market has long been recognised. Thus in 1993 the European Commission published a White Paper which argued that the main problems were the inadequate links between universities and business, the lack of risk capital, insufficient stress of R&D as a corporate strategy, the difficulties of researchers in starting a new business and the weak market research.

Despite this lack of innovation output, the framework programmes have been shown to have positive effects on knowledge creation and networking, in the various impact studies carried out in the Member States (for instance, Georghiou et al., 1993; Larédo, 1995; Reger - Kuhlmann, 1995; Ohler et al., 1995; Luukkonen - Hälikkä, 2000, respectively in the UK, France, Germany, Austria and Finland). Luukkonen (2002) analyses the types of networks which are set up within the FP in Finland. He has two main results. First, regarding business-business relationships, firms are found to collaborate mainly with suppliers or clients, so that vertical collaboration is more frequent than horizontal one. Second, 64% of the projects with Finnish participants involved the collaboration of firms with either universities or public research centres. 70% of the companies involved in a FP project collaborated with a university, and 75% with a public research centre. Spillovers are found to be predominantly intra-sectoral and non inter-sectoral, and there are indications that the FPs may have reinforced the oligopolistic tendency of the European IT market.

This points to a number of problems with networking:

- collaboration is positive for spillovers but it also facilitates collusion; if firms' collaboration is favoured then they might secretly expand coordination to the market phase; Luukkonen (2002) points to such a possibility;
- this is less true when collaborating firms are small and more numerous (less easy to collude on market), but then it is more difficult to coordinate the participants.

Another controversial point is additionality. Additionality of the FP means that the collaborative project would have in any case (i.e. even without EC funding) been carried out. This is difficult to assess and evidence is mixed (Luukkonen, 2002).

Overall, the results of the FP and therefore EU RTD policy are mixed. Broadly, one can identify two negative effects (or lack of effects) and two positive effects. From the negative point of view, European competitiveness is still lagging behind relative to the US and Japan, although the EU situation is uneven, some Member States having a good innovative performance (Finland, Sweden) and others not (Portugal, Greece); the second negative point is the lack of transformation of innovation into commercial products, as already mentioned. On the positive side, despite the overall lack of competitiveness the EU is still up in the technology race; and the EU programmes have helped the creation of cross-border networks, between firms and between firm and university or other public research centres. Vavakova (1995) and Lucchini (1998) argue that the FP have provided a stable financial support to networking, reduced the competition among researchers and between researchers in the public and private sectors, and allowed access to complementary skills.

However, the above discussion points to a number of issues, which solutions might lead to substantial improvements in EU RTD policy. First, although networking undoubtedly has positive effects, there are also conditions for such positive effects to materialise, and these conditions do not appear to have been much discussed. The economic theory behind “networking” policy is composed of two branches: one is the strategic collaboration literature (see Katsoulacos – Ulph, 1995, for a review) and the other one is the evolutionary theory and the concept of national systems of innovation (NIS). The latter argues that since innovation and technological change results from knowledge flows and collective learning in interactions between individuals and organisations, which are conditioned by the institutional framework, and important policy to favour innovation is favouring networking. Such literature can be claimed to be also at the origin of the new emphasis of policy of creating environments that favour certain objectives rather than direct actions. Both approaches to networking do not analyse the adequacy of various types of networks according to the particular situation.

In addition, NIS is a concept and not a theory, implying that the different types of networks and the conditions in which they function is not well understood. Systems might not be national or supranational but rather dependent on other variables, such as the sector and the type of knowledge base (technology): for instance, the IT industry is international and talking about national or even European system of innovation is difficult, when firms are multinationals and may exploit spillovers all over the world. Innovation in a sector like fashion may be more related to regional characteristics, since the local culture and know how determines the type and quality of the product, so that the innovation system in this case might be more regional.

Another point is that besides determining the type of network (characteristics of the firms to be put into relationships, whether public research centres should be included, and how, etc.) one should also determine the size of the network. Too small a network might lead to the ignorance of some spillovers and to firms' collusion at other stages than pre-competitive research; too large a network may lead to a loss of knowledge in the numerous communication flows that have to be established.

Property rights and their distribution among actors in the innovation process might be essential in the determination of networking: if universities cannot obtain any patent, they will not have incentives to move to more applied research and to collaborate with businesses (this appears to be the case in the European pharmaceutical industry; see Bianchi - Labory, 2002); if smaller firms cannot collaborate with universities in more applied projects, the will not carry out any R&D and the result will be that R&D is carried mainly in large firms because only large firms have enough resources for it.

The main conclusion is that in Europe there is much fragmentation and lack of exploitation of complementarities, between countries, regions and actors at various levels and in various sectors. What the evaluation of EU RTD policy shows is that yes, networking would be necessary, but the types, size and focus of networks should be analysed in more depth.

The benchmarking exercise carried out by the European Commission might be useful in this respect, not to identify best practice in terms of networking in a country and recommend it for adoption in all other countries, but to identify the general characteristics of each country, in terms of innovation, culture, university systems, industrial sectors where firms are competitive, and so on. This would allow to assess the potential for innovation in some sectors and identify the priorities of supporting policies (for instance, put more resources where the country already has a comparative advantage), as well as to identify the potential for cross-fertilisation in Europe. For instance, Finland is very innovative in the knowledge-based sectors, while Italy is very innovative in design, fashion, at the product development stage: the combination of the two might lead to durable competitive advantages thanks to innovative products and new market creation.

Consequently, EU innovation policies, with their focus on creating an environment favourable to business and to innovation, end up being a list of recommendations without showing why those actions must be implemented together, how do they combine to produce innovations. The key question seems to be how do networks function. The reflection on the nature and effects of intangibles appears to be useful in clarifying this.

3. Conclusions: Toward a New Policy Framework

3.1. The need to relate innovation to other intangible assets

The discussion in the first part of this paper has stressed that innovation is a complex process, that results from the exchange, the accumulation and the collective generation of knowledge. In order to get more insights on the reasons for the lack of innovative competitiveness of the EU, a first step in the analysis is to relate innovation to other intangible assets.

More precisely, until now the literature on intangibles has tended to make wide categorisations of such assets: everything which is not physical or financially embodied is intangible. Consequently, innovation, organisational practices or human resources can be considered as intangible assets. However, these assets are also generators of intangible assets: human capital creates ideas and therefore generates innovations; a flexible organisation may allow more autonomy to its members who have scope to collect information, interact more with each other and generate more ideas, hence higher innovation. In fact, intangible assets appear to result from a combination of generators: for example, a patent, i.e. an innovation, results from R&D activity, human resources (engineers' creativity and competence) and organisational assets (the structure of the team of the engineers, their motivation, possibilities for communication influence the performance of the research activities).

In a context of globalisation and information technologies it is likely that the challenge for firms may not be to be the first to produce new knowledge, but rather recognise, obtain, employ and complement the relevant innovative knowledge. Recognising the resources that are necessary for the appropriate organisation of innovative knowledge activities: entrepreneurial talent, appropriate industrial and firm organisations and appropriate organisations of transfer and diffusion of technology, and of education and science activities.

The consideration of intangible assets imply the consideration of all channels through which knowledge may flow, as well as the possible obstacles to such flows. One example is the consideration of human capital, and the ability of the entrepreneur. The traditional literature of R&D spillovers in economics, mentioned in section 2.1., does not consider the role of entrepreneurs in transferring technological information. Baumol (1993) however stressed that an entrepreneur may have a fundamental role in finding the geographic locations where inventions of others can be introduced profitably and in taking the risk of adapting the exported techniques to the geographic and market conditions in the new location. Other channels include licensing technology, patent disclosure, publications or technical meetings, conversations with employees of innovating firms, possibly in the context of informal networks, hiring of employees of the innovator, reverse engineering (Mansfield, 1985). Undertaking R&D activities involves in itself spillovers, since one aspect of such activities is the collection of information and knowledge from outside the firm.

Besides this additional channel, an obstacle to the adoption of new knowledge which has been quite neglected is the organisational rigidity. The useful employment of a spillover knowledge is in itself a challenge for the management of innovation. In the pharmaceutical industry for instance, Henderson (1994) shows that the research productivity of firms is higher when firms are able to take advantage of the knowledge generated in all areas of the organisation. As stressed by De Bondt (1996 p 4), the development of "*a sustainable advantage may require the use of adequate knowledge management structures (e.g. pooling knowledge in semi-permanent project teams, more space in offices so that learning by walking around is stimulated, generalist training, rotation, incentive structures), or more generally, a 'learning organisation', that is "an organisation skilled at creating, acquiring and transferring knowledge, and at modifying its behaviour to reflect new knowledge and insights" (Garvin, 1983).*" The management of knowledge in firms is considered by Mouritsen in this RESCUE / PRISM research project.

Additional channels appear when one considers all the forms of R&D cooperation: it can range from strategic cooperation or alliances without cross-participations across joint ventures towards full cooperation and mergers. The latter form of R&D cooperation, mergers, does not appear to have been extensively considered in Economics. Such cooperation can also encompass different functional activities, such as R&D, marketing, production of components or information systems.

Economics has considered intangible assets, such as innovation, knowledge, human capital and organisation, but all rather separately. In reality, one might argue that all intangible assets (innovation, organisation and human capital) combine to create a firm's value: innovation (a new knowledge) does not have value unless it is transformed into a product that is sold on the market. In other words, innovation, the organisation of production, the organisation of commercial activities and employees (with their human capital) all contribute to the value created by this innovation. The organisation of the firm does not have value unless combined with human capital and tangible capital (such as machines and equipment). Hence it might be argued that the growing emphasis put by firms on their intangible assets (in audit, reporting, etc.) is due to a strategy of development of complementarities between intangibles and tangible resources, in order to increase value. Whereas in the past such complementarities were fixed (in particular product definition, technology, the organisational structure, job definition and skills of personnel, etc.) they tend to constitute now a strategic variable.

Intangible assets raise two major problems. First, they mean that there are other factors of production and of innovation that must be taken into account in the analysis: not only labour (in quantitative terms) and capital (mainly physical), but also intangible factors such as knowledge, human capital, organisational structure which influences the way individuals interact and therefore whether they can collectively create knowledge or contribute to the diffusion of some knowledge or competence within the organisation. Second, intangibles are both factors and assets, meaning both input and output and their combination is much more than the sum of the parts.

The fact that intangible assets are simultaneously assets and generators of assets can be explained by examining their nature in more depth. All intangibles are related to knowledge: the human capital of an individual depends on the set of knowledge the individual has accumulated during his life; innovation is knowledge creation; the organisation of a firm or of activities means primarily distributing knowledge to different units (the firm is divided into the marketing, the R&D, the manufacturing divisions, each specialising in one type of knowledge relevant to the productive activities of the firm) and organising knowledge exchange between such units. However, intangible assets cannot be reduced to knowledge only. Intangible assets are also capabilities, i.e. ability, competence to set up problems, solve problems, communicate with others, and so on. Knowledge without capabilities does not produce value, because, at the level of the firm, it does not produce the right product for the consumer hence success for the firm on the market.

Going back a classical economist, Adam Smith (1776), at the level of the firm such capabilities are the *work to be done*. Smith explained such a relationship using the example of a public mourning which suddenly raises the demand for black cloth; the result is that “the market is under-stocked with commodities, not with labour; with work done, not with work to be done” (Smith, 1776, p 52). In fact, when demand changes what is important is the work to be done, not the work done (i.e. the commodities), because the work to be done represents the capability to adjust production to demand fluctuations, a capability to undertake a productive function to produce a good. The work done represents what has been achieved, the accumulated knowledge, which is totally or partially embodied in the firm’s products; the innovation achieved in the past, the organisational and the tangible capital. The work to be done represents what the firm will be able to do given these existing assets, how much it will be able to adapt to changes. In the past, in the mass production system with standardised goods and stable market conditions, the work done was equivalent to the work to be done; with globalisation and the diffusion of ICT and services, the work to be done is much more important than the work done, and intangible assets are fundamental to the former.

The intangible capital or intellectual capital, which we could call, with reference to Smith, work to be done, of the firm has been defined by three elements:

- the human capital, i.e. the knowledge, skills, experience and abilities that employees have and that the firm does not own (and looses of the employee leaves the firm); examples are innovative capacity, creativity, know-how, professional experience, employee flexibility, motivation, satisfaction, learning capacity, loyalty;

- the structural capital is the pool of knowledge that stays in the firm when employees leave (organisational routines and procedures, systems, culture, etc.); examples are innovation capacity, organisation flexibility;
- the relational capital (or social capital?) consists in the resources related to the external relationships of the firm, such as those with customers, suppliers and R&D partners; examples include image, alliances, customer loyalty, customer satisfaction, market power, environmental activities.

At the level of a country, such work to be done or capability to adapt to change and to develop may be defined as comprising the same elements:

- the human capital, i.e. the knowledge, skills, experience and abilities that citizens have; examples are innovative capacity, creativity, know-how, professional experience, motivation, satisfaction, learning capacity, and entrepreneurship;
- the structural capital is the pool of knowledge that stays in the country independently of the flow in and out of citizens: culture, institutions, norms and values, rules, and so on; examples are knowledge diffused at school, laws and regulations, property right system, and so on;
- the relational capital (or social capital?) consists in the resources related to the networking in the country; infrastructures, language, political power,...

Therefore, a fundamental rationale for networking appears: the need to combine tangible and intangible capital to create the proper “work to be done”. In addition, the difficulties of networking become apparent: the compatibility of the three types of capital is essential for networking to function.

3.2. Some preliminary policy implications: linkages and intangibles

Most innovation policies recognise that innovation is not a linear process linking new knowledge to new products or process but a complex process whereby innovation results from complex interactions and networking among various people and organisations, both private and public. Policies are therefore aimed at building environments favourable to the creation of such networks. However, what networks are best conducive to innovation, how and why, is not properly understood.

The rise in intangibles and the reflection on their nature and effects has two major implications. First, it is necessary to include intangible assets in the economic theoretical framework, and for this purpose a return to classical economics is useful (as alluded to above, and discussed in more details in Bianchi - Labory, 2001). Second, the fundamental consequence of including intangibles in the theoretical framework is to point to numerous complementarities which types and effects have to be further examined. Complementarities include cross-fertilisations among activities, among institutions and among policies. The major policy implication is that what ‘creating an environment favourable to’ innovation or competitiveness, growth and employment, means is providing the conditions for such complementarities to be exploited.

For instance, one important European weakness appears to be the lack of ability to transform ideas into commercial success. Europe would be more oriented towards basic research, while the US would be more orientated towards the commercial applications of research. One would need a measure of this: ideally, the number of new products (or patents) over the total number of new ideas;

this is difficult to measure. However, one can say something on the likely causes of such a weakness. It could result from the lack of motivation of scientists to transform ideas into commercialised products; this could in turn result from the lack of linkages between scientists and innovators and business; the fear of scientists not to get enough share of the cake; a culture not focused on making money, a lack of social prestige for scientist to make money out of innovations; etc. There are many channels through which business and entrepreneurs interact with universities and researchers; not all channels have the same positive effects: it might be that some channels could lead to constraints and reduce the diversity of research activities.

The key elements to focus on in order to design policies to favour innovation and its diffusion are knowledge and networks. Knowledge is not a black box. Innovation occurs in complex systems and there are big risks of coordination failure. The proper policy may not be the one that identifies the technologies of the future, but the one that designs proper institutions and organisations (public goods) that solve the problems of coordination in the process of knowledge creation. One important public good is the shared body of knowledge (knowledge accumulated in the past) that allows collective learning, i.e. exchange and creation of knowledge.

The first part of this paper has shown that the idea that networks are key has already been discussed in the economic literature (mainly, the NIS literature) and the European Commission has recognised it. However, the problem is that the recommended policies end up being lists of actions to take without clearly identifying the kind of network that is aimed at, nor how precisely do the various actions combine to produce positive network effects. In particular, it seems that the fundamental dilemma of innovation policy, namely the incentive to innovate (thanks to appropriation of the returns) and the diffusion of knowledge (which contradicts the appropriation of returns), results in being neglected.

However, networks widely differ in their nature, as shown for the case of university-business relationships in section 2.4. The links can vary from the hiring of new graduates from university by firm to explicit agreements between the two actors to jointly perform some R&D activity. The cultural context also matters: in other words, the social capital. For instance, without a climate of trust between universities and business, no linkages will be built. The power of influence held by the different actors in the network also determine the success of the network in terms of knowledge exchange and knowledge creation: if an actor, say a large firm, is dominant in a network comprising also SMEs, then the kind of knowledge exchanged and the diffusion is likely to be biased towards the interest of the dominant player, that is, knowledge that is useful for it and knowledge flows tending to be unidirectional, in the direction of the large firm.

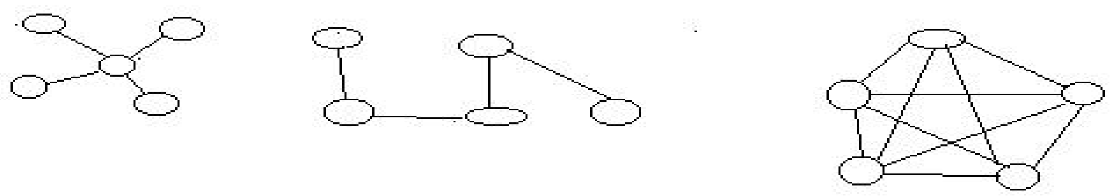
Hence there are economies to networking but there also are barriers to effective networking. One issue is how large should the network be? Should it cover the whole economy or one industry? Or should it be confined to a local area, such as a high tech cluster? Are we sure the knowledge generated by the cluster will generate benefits for the whole economy, and not only to the local area? The conditions for a network to be successful depends on:

- its size: if it is too big, it will be difficult for actors to set up links with all other actors, so knowledge might not diffuse so well; if it is too small, the diffusion will take place but knowledge creation might be limited, due to the lack of variety of the actors;
- the motivation of actors: if actors can benefit from the network, they will take part in it. One important aspect here is intellectual property rights: if these rights are defined in such a manner that actors tend to keep most knowledge for themselves and only a small part of knowledge is diffused, the network will not be useful;

- the distribution of power among actors: as stressed above, the domination by one actor may bias knowledge exchange and creation; however, it might also be necessary, if dominant actors are needed to properly exploit innovative results commercially;
- the social capital: if actors share the same social capital or have different but compatible social capital (i.e. culture, language, norms and values), relationships and linkages will be eased.

Other factors and conditions will be identified in the next steps of this research. The above-listed factors already point to different types of network, some of which are represented in the figure below.

Figure 1. Different types of networks



Therefore, the major policy implication of the analysis of the nature and effects of intangibles is that yes, networks are important to favour knowledge diffusion, but not all kinds of networking are good for innovation and knowledge diffusion. The condition for such network to function is that tangible and intangible assets be combined in a proper way.

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