The Innovation Process and Network Activities of Manufacturing Firms

Conceptual Considerations and Empirical Evidence from the Metropolitan Region of Vienna

Manfred M. Fischer

Director, Institute for Urban and Regional Research
Austrian Academy of Sciences
Professor, Department of Economic and Social Geography
Vienna University of Economics and Business Administration

Abstract

Innovation networks of manufacturers are currently receiving much attention as a competitive strategy. The contribution represents a response to the growing recognition that there are very important reasons why we need a better understanding of the relationship between innovation and networking. This response is conceptual in form, but enriched with some empirical evidence from the metropolitan region of Vienna. The paper demonstrates unambiguously the importance of external network activities during the innovation process that are organized around five types of networks: customer networks, manufacturing supplier networks, producer service supplier networks, producer networks and co-operation with research institutions and departments of universities. The data clearly indicate that networking is not only and primarily a metropolitan phenomenon. Spatial proximity is just one, but evidently not the decisive criterion for innovation-oriented relationships. The geography of networking largely extends to national and international levels.

38th European Congress of the Regional Science Association, Vienna, August 28 – September 2 1998

1. Introduction

Manufacturing firms in Europe have come under increasing pressure in recent years. This pressure arises from three major phenomena and processes that affect the entrepreneurial environment: *first*, the transition from internationalisation to globalisation accompanied by a process of global concentration in a number of industries, *second*, the establishment of the Single European Market and the prospects of the Economic and Monetary Union, and *third*, the opening of the Iron Curtain and the increasing competition from the newly developing market economies in Eastern Europe. Firms may react in different ways to meet these challenges. But there is a wide agreement that new technologies along with novel forms of work organisation and management play a crucial role to respond successfully to rapidly changing market conditions and to remain competitive in an increasingly European or even global economic environment.

This contribution has a focus on innovation and network activities and reflects the reasons why we need a better understanding of both the innovation process and the process of network formation. This response is largely conceptual, based on the body of evolutionary theory of economic change that comprises a rich environment of learning and interaction, the two central elements in the current understanding of the process of innovation (Nelson and Winter 1982, Dosi 1988, Lundvall 1988, 1992, Suarez-Villa 1989). Some empirical evidence will be provided from a survey carried out in the metropolitan region of Vienna.

The contribution is organized as follows. The next section provides a basic account of the key elements of the analysis: technology, codified and uncodified knowledge, and innovation. Then, section 3 continues to describe the nature of the innovation process on the basis of current thinking and understanding which emphasize three major elements: the role of design in the wider sense, learning that allows firms to create dynamic advantages, and interaction whether internal to firms or external with other firms and institutions.

Section 4 moves to the diffusion of disembodied knowledge. Special attention is laid on the notions of knowledge spillovers and the absorption capacity of a firm. Both play a central role for a deeper understanding of external network activities of firms which takes section 5 in focus. The line of reasoning starts with a characterization of the network mode of organisation that provides the necessary relations to use outside knowledge, continues then to discuss in which circumstances this mode is superior to market transactions and vertical integration, the two forms of organisation previously recognised by economic theory, and finally points to the diversity and localized nature of networks. Section 6 then presents some empirical evidence of innovation and network activities of manufacturing firms in the metropolitan region of Vienna. The concluding section summarizes some of the major findings of the discussion.

2. Technology, Knowledge and Innovation

Innovation – in the form of advancing technology – provides the principal source of change for firms, regions and nations. It is, however, a complex concept with many meanings. For the purpose of this contribution, it is important to provide at this juncture working definitions of technology, knowledge and innovation.

We will begin by defining *technology* in accordance with Mansfield et al. (1982) as consisting of a pool or set of knowledge. It is important to distinguish knowledge from information. Information may be interpreted as factual (Saviotti 1988), while knowledge establishes generalizations and correlations between variables (Andersson 1985). Particular pieces of information can be understood merely in the context of a given type of knowledge, for example a theory. New knowledge creates new information and this information can be understood and used only by those who possess the new knowledge. In this sense knowledge has a *retrieval/interpretative* and not only a *correlational* function (Saviotti 1998).

Knowledge has some further outstanding characteristics that are worthwhile to mention. Knowledge is *cumulative* (Teece 1981, Nelson and Winter 1982). This implies path-dependence and the creation of barriers, as established participants – in given technologies – accumulate a differential advantage with respect to potential entrants. Knowledge in firms has also a *collective character*. This means that knowledge is not simply the sum of the pieces embodied in the individual workers of the firm (Saviotti 1998). In this sense, the knowledge base of a firm may be defined as the collective knowledge that a firm uses to produce its output.

The knowledge base contains knowledge in all its forms, from simple and routine procedures of everyday life to the methods of organization and management, from the machinery (i.e. embodied knowledge) to the scientific concepts, methods and theories that enable newer inventions. In the most cases, a piece of knowledge can be located somewhere in a range between the completely tacit and completely codified extremes. Knowledge is always at least partly tacit in the minds of those who create it. The process of codification is necessary because knowledge production is a collective undertaking that requires communication. The transmitter and the receiver have to know the code if they are able to communicate. The codification process for a given subject amounts to the gradual convergence of the scientific community and of other users on common standardized definitions and concepts, on common contents and theories. The degree of codification differs for different types of knowledge at a given time. Knowledge closer to the frontier, and therefore more recent, is likely to be more tacit than already established knowledge (Saviotti 1998).

Codified knowledge is that form of knowledge that is tangible in some way, usually in print form such as scientific papers and patent applications. Much knowledge is codified and publicly accessible. But much of the essential knowledge – especially the newer parts that we consider the frontier – resides within tacit form in the minds of experienced individual researchers or engineers. This person-embodied knowledge is generally difficult to transfer, and is often only shared by colleagues if they know the code through common practice. On the one side a given type of knowledge may become more codified as it matures, on the other side the act of embodying it into specific goods and services may reintroduce some tacitness again.

Traditionally, knowledge was viewed as a public good because it is possible for the producer of knowledge to prevent its use by economic agents who do not pay anything in exchange for it. But even a completely codified piece of knowledge can not be utilized at zero cost by everyone. Only agents who know the code can use the piece of knowledge at zero imitation cost. Others – if they realise the economic value of a given piece of knowledge – have to learn the code first before being able to retrieve and imitate. Tacit knowledge is an important element of the knowledge that firms require for innovation. Such knowledge is generated in different ways, which are generally described as mechanisms or modes of learning. Such mechanisms or modes vary in dependence on the type of knowledge and on the institutional setting in which learning takes place.

Commercial products and production processes represent various combinations of pieces of knowledge, codified and tacit knowledge, in a specific technology set. *Innovation* is generally defined as the activities of developing and commercializing new products and processes (see, e.g., Hall 1986). These innovation activities are of two major types: fundamental which involves the creation and utilization of a piece of new scientific, technological or organisational knowledge; and incremental which concerns product or process improvements based on existing knowledge (Freeman 1986). The partly tacit character of knowledge is likely to be responsible for the importance that localized networks of personal contacts play for innovation activities of firms in some metropolitan regions. The intra- and interfirm and industry diffusion of innovations over time and space represents technological change.

3. The Interactive Character of the Innovation Process

Over a long time period thinking about technological change and innovation was dominated by linear models, in the 1950s and 1960s by the technology-push and then by the need-pull model. In the first model, development, production and marketing of new technology followed a well defined time sequence that originated in basic and applied research activities, involved a product development stage, then led to production and possible commercialisation. In the second model, this linear process emphasized demand and markets as the source of ideas for R&D activities. Despite the appealing logic of such conceptualizations the models came under increasing attack, particularly because of the apparent disorderliness of the innovation process in a post Fordist era.

Current thinking about the innovation process emphasizes the tacit and non-codifiable nature of technology, the importance of learning-by-doing and learning-by-using in the innovation process and the cumulative nature of learning. Learning is now widely accepted as central element in the process of innovation. Learning allows firms to create dynamic advantages so that the force of imitation is outrun by the pace of innovation. Since innovation reflects learning as much as it does novelty, and since personal contacts are crucial for transferring pieces of tacit knowledge, the partly tacit character of scientific and technological knowledge is responsible for the central importance of interactions in the innovation process.

In line with this view, linear models of the innovation process have been supplanted by interactive models of innovation. These models stress the feedback effects between upstream (technology-related) and downstream (market-related) phases of the innovation process, the many interactions of innovation related activities both within firms and in network agreements among them, and the central role of industrial design [in a wider sense] in the innovation process. Broadly speaking design includes several dimensions (Kline and Rosenberg 1986): ‘initiating design’ which reflects invention, ‘analytical design’, the study of new combinations of existing products and components, rearrangement of processes.

Figure 1: An Interactive Model of the Innovation Process: Feedbacks and Interactions
[adapted with minor changes from Kline and Rosenberg (1986), Myers and Rosenbloom (1996), Malecki (1997)]

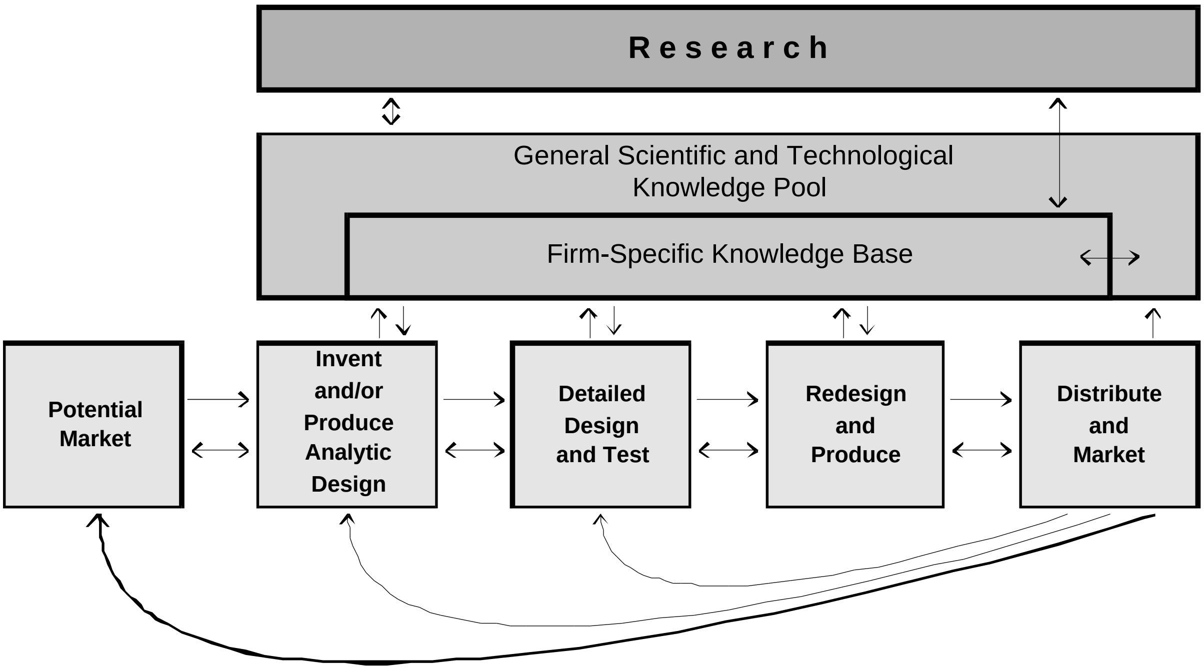

Figure 1 represents an interactive model of the innovation process which is now commonly referred to as the chain-linked model (Kline and Rosenberg 1986, OECD 1992, Malecki 1997). The innovation process is portrayed as a set of activities that are linked to one another through complex feedback loops. The process is visualized as a chain starting with the perception of a new market opportunity and/or a new invention based on novel pieces of scientific and/or technological knowledge [i.e. initiating and/or analytical design]; followed by detailed design and testing, redesign and production, and distribution and marketing. Initiating and analytical design is crucial for the knowledge production in order to create inventions and innovations, while redesign is important for their ultimate success. Problems arising during the processes of designing and testing new products and production processes often link to science and especially to engineering disciplines in academia.

The model recognizes interaction as a central element in the process of technological innovation. Two types of interactions can occur. The first concerns interaction processes within a corporation [i.e. intrafirm networking] such as loops that link R&D and engineering and production, and loops that link different groups within R&D. These links may be complemented by interfirm networking, the second type of interaction, with other firms and institutions of the wider science and technology environment in which the firm operates.

4. Technology Diffusion, Absorption Capacity and Knowledge Spillovers

The recognition of the interactive nature of the innovation process has resulted in the breaking down of the earlier distinction between innovation and diffusion. The creation of knowledge and its assimilation are part of a single process. Firms need to absorb, create and exchange knowledge interdependently. In other words, innovation and diffusion usually emerge as a result of an interactive and collective process within a web of personal and institutional connections which evolve over time.

Knowledge transfer may occur through disembodied or equipment-embodied diffusion. The latter is the process where innovations spread in the economy through the purchase of technology-intensive machinery such as computer assisted equipment, components and other equipment. Disembodied technology diffusion refers to the process where technology and knowledge spread through channels other than embodied in machinery (OECD 1992). This type of knowledge transfer may occur via the descriptions of new products or production processes to be found in catalogues, publications or patent applications, but also via seminars and conferences, and R&D personnel turnover. It can be also the by-product of mergers and acquisitions, joint ventures or other forms of interfirm co-operation.

Two notions are central to an understanding of disembodied technology diffusion: the first is that of absorption capacity and the second that of knowledge spillovers. The *absorption capacity* of firms and research institutions refers to the ability to learn, assimilate and use knowledge developed elsewhere through a process that involves substantial investments, especially of an intangible nature (Cohen and Levinthal 1989). This capacity crucially depends on the learning experience which in turn may be enhanced by in-house R&D activities. The concept of absorption capacity tells that in order to be able to access a piece of knowledge developed elsewhere it is necessary to have done R&D on something similar (Saviotti 1998). Thus, R&D may be viewed to serve a dual, but strongly interrelated role: first, to developing new products and production processes, and second, to enhancing the capacity to learn.

The degree to which R&D is important for the development of a firm's absorption capacity largely depends on the pace of advance and the characteristics of outside knowledge (such as the degree of codification and the degree of appropriability) in a specific technology field. The faster the pace of advance of the field is, the lower is the degree of codification, the higher is the degree of appropriability and the greater is the effort needed to keep up with the developments. The more tacit a specific piece of knowledge, the more time and effort are usually required to learn the code of that piece and to transform it into commercially and firm specific relevant knowledge.

Firms, especially smaller firms, that lack appropriate in-house R&D capacities have to develop and enhance their absorption capacity by means of other sources, such as by learning from customers and from suppliers, by interacting with other firms and by taking advantage of knowledge spillovers from other firms and industries (Lundvall 1988). These sources provide the know-why, know-how, know-who, know-when and know-what important for entrepreneurial success (Johannisson 1991, Malecki 1997). Network arrangements of different kind provide a firm that assistance necessary to take advantage of outside knowledge.

Disembodied knowledge diffusion originates in the externalities that characterize the innovation process and knowledge spillovers that occur when the firm developing a piece of new knowledge cannot fully appropriate the results of knowledge creation. The degree of appropriability differs for different types of knowledge at a given time. Appropriability is expected to fall systematically during the maturation of a technology as the degree of codification and the number of economic agents knowing the code increase.

Knowledge spillovers arise because knowledge and innovation is a partially excludable and non-rivalrous good (Romer 1990). Lack of excludability implies that knowledge producers have difficulties in fully appropriating the returns or benefits and preventing other firms from utilizing the knowledge without compensation (Teece 1986). Patents and other devices such as lead times and secrecy are means for knowledge producers to capture partly the benefits related with knowledge creation. It is important to recognize that even a completely codified piece of knowledge can not be utilized at zero cost by everyone. Only those economic agents who know the code are able to do so (Saviotti 1998).

Non-rivalry essentially means that a new piece of knowledge can be utilized many times and in many different circumstances, for example by combining with knowledge coming from another domain. The interest of the users of knowledge is, thus, served best if innovations once produced are widely available and diffused at the lowest possible cost. This implies an environment rich in knowledge spillovers (OECD 1992).

The appropriability characteristics of particular technologies suggest that knowledge generation by a particular firm not only depends upon in-house R&D activities, but also on outside efforts – and more generally formulated – on the scientific and technological knowledge pool on which it can draw. With the interactive model of the innovation process displayed in figure 1 in mind, innovation and diffusion, thus, appear to be closely interlinked. Technology innovation leads to diffusion of knowledge that in turn affects the level of innovative activities at the firm level.

5. Networks and Network Formation

In recent years, new forms of interfirm agreements bearing on technology have developed alongside the traditional means of technology transfer – licensing and trade in patents – and they often have become the most important way for firms, regions and countries to gain access to new knowledge and key technologies. The network form of governance can overcome market imperfections on the one side and the rigidities of the vertically integrated hierarchy on the other. The limitations of these two modes of transactions in the context of knowledge and innovation diffusion have pushed interfirm agreements to the forefront of corporate strategy in the last decades (Chesnais 1988).

There are many definitions of *innovation networks* (see DeBresson and Amesse 1991, Freeman 1991), the one offered by Tijssen (1998) captures the most important points of the network mode. He suggests to define a 'network as an evolving mutual dependency system based on resource relationships in which their systemic character is the outcome of interactions, processes, procedures and institutionalization. Activities within such a network involve the creation, combination, exchange, transformation, absorption and exploitation of resources within a wide range of formal and informal relationships.' In a network mode of resource allocation, transactions neither occur through discrete exchanges nor by administrative fiat, but through networks of individuals or institutions, engaged in reciprocal, preferential and supportive actions (Powell 1990).

Networks show a considerable range and variety in content. The content differs according to specific circumstances. Its nature will be shaped by the objectives for which network linkages are formed. For example, they may focus on a single point of the R&D-to-commercialisation process or may cover the whole innovation process. The content and shape of a network will also differ according to the nature of relationships and linkages between the various actors involved (see Chesnais 1988). At the one end of the spectrum lie highly formalised relationships. The formal structure may consist of regulations, contracts and rules that link actors and activities with varying degrees of constraint. At the other end are network relations of a mainly informal nature, linking actors through open chains. Such relations are very hard to measure (Freeman 1991). Whenever interfirm transactions tend to be small in scale, variable and unpredictable in nature and ask for face-to-face contacts, then network formation will focus on closer proximity of the partners involved (Storper 1997).

Networks are for firms a response to quite specific circumstances. Where complementarity is a prerequisite for successful innovation, network agreements may be formed in response to firm specific proprietary tacit knowledge. The exchange of such complementary assets can take place only through very close contacts and personalized and generally localised relationships (OECD 1992). When technology is moving rapidly, flexibility and reversibility along with risk sharing represent another reason for preferring a network mode. Interfirm agreements are easier to dissolve than internal developments or mergers. The network mode provides much higher degrees of flexibility (OECD 1992). Porter and Fuller (1986) stress speed among the advantages that networks have over acquisition or internal development through arm's length relationships. The timing advantage of networks is becoming increasingly important as product life cycles have shortened and competition has intensified. High R&D cost may be another distinct reason for networking and force management, especially in the case of smaller firms, to pool resources with other firms, in some cases even with competitors (OECD 1992).

6. Innovation and Network Activities in the Metropolitan Region of Vienna

Any empirical study of innovation and network activities requires primary data collection, postal or interview based surveys, taking the individual manufacturing firm as unit of analysis. We have chosen a postal survey of manufacturing firms as the appropriate methodological tool for eliciting basic quantitative data. The postal questionnaire has undergone several rounds of development and revision within the framework of an international project on the Regional Innovation Potential and Innovative Networks in Metropolitan Regions, and was finally conducted from September 4 to December 15 1997 in the metropolitan region of Vienna (i.e. the city of Vienna and related communities). The key questions included the organizational structure, product and process mix, as well as the nature and extent of innovation and network activities. Data were collected from the population of 908 manufacturing firms with at least 20 employees, as identified by the Firm and Product Database Register (1995) organized and managed by the Department for Systems Research at the Austrian Research Centre Seibersdorf. 204 firms returned the completed questionnaire, resulting in a response rate of approximately 22.5 percent. This response rate is relatively low, but statistically still acceptable. Anecdotal evidence does indicate that industrialists are receiving postal surveys in ever increasing numbers and this has to have an effect on response rates.

Table 1: Response Patterns and Representativeness of Responding Manufacturers

	Total Number Registered Firms 1995		Number of Responding Firms 1997		Represen-tativeness Ratio a
Industry Sector					
Textiles & Clothing	*72*	*(7.93 %)*	*13*	*(6.37 %)*	*18.05 %*
Food Industry	*112*	*(12.33 %)*	*24*	*(11.76 %)*	*21.43 %*
Wood, Paper & Printing	*198*	*(21.81 %)*	*49*	*(24.02 %)*	*24.75 %*
Chemicals, Plastics & Rubber	*185*	*(20.37 %)*	*38*	*(18.63 %)*	*20.54 %*
Electrical and Optical Equipment	*115*	*(12.67 %)*	*28*	*(13.73 %)*	*24.35 %*
Basic Metals and Metal Products	*108*	*(11.89 %)*	*24*	*(11.76 %)*	*22.22 %*
Machinery & Transport	*118*	*(13.00 %)*	*28*	*(13.73 %)*	*23.73 %*
Total	*908*	*(100.00 %)*	*204*	*(100.00 %)*	*22.47 %*
Employment Size					
≤ 49	*396*	*(43.61 %)*	*88*	*(43.14 %)*	*22.22 %*
50 – 99	*225*	*(24.78 %)*	*49*	*(24.02 %)*	*21.78 %*
100 – 499	*232*	*(25.55 %)*	*54*	*(26.47 %)*	*23.28 %*
≥ 500	*55*	*(6.06 %)*	*13*	*(6.37 %)*	*23.64 %*
Total	*908*	*(100.00 %)*	*204*	*(100.00 %)*	*22.47 %*

Note a: number of responding manufacturing firms divided by total number of registered firms multiplied by 100
Source: Innovation Survey 1997, Data compiled by Vera Mayer

Table 1 presents a breakdown of the sample responses and illustrates the response rates for seven industry sectors, using the standard NACE classification on the basis of information such as product description as provided by the firms, and for four firm size classes as measured by employment. The sample can be seen broadly to reflect the overall structure of the total population. As expected, the lower response rate by small local manufacturing units may be attributed to the fact that such firms are less likely to undertake any kind of formal R&D activity, since they tend to lack the resources for this. They therefore display a tendency to dismiss the questionnaire as irrelevant to their circumstances. This is a general problem and not one that is specific to this study. A telephone based survey of a small subsample of 90 non-respondents, however, indicates that the problem is not significant. The majority of surveyed firms are very small (64.7 percent less than 100 employees, compared to 68.4 percent of the identified population), and many of these (49.6 percent of those with a known starting year) have been in business since 1970. In terms of organisational status, 111 firms (55.0 percent) were independent, the remainder operated within a wider parent company group as a main plant (36.1 percent) or as a branch plant (8.9 percent).

Table 2: Selected Characteristics of Surveyed Firms (1994 – 1996)

	Firms with Continuous On-Site R&D 1997 c		R&D Personnel Ratio [a]	R&D Expenditure Intensity	Innovation Rate [b]	Share of Turnover by Product Innovations
Industry Sector						
Textiles & Clothing	2	(15.38 %)	17.76	4.69	60.43	0.23
Food Industry	3	(12.50 %)	25.48	1.72	32.33	0.31
Wood, Paper & Printing	4	(8.16 %)	11.43	1.43	25.95	0.05
Chemicals	5	(13.16 %)	52.62	4.90	22.45	0.14
Electrical & Optical Equipment	7	(25.00 %)	250.41	15.80	6.13	0.51
Basic Metals & Metal Products	2	(8.33 %)	115.07	2.17	11.71	0.51
Machinery & Transport	7	(25.00 %)	24.77	2.44	3.97	0.50
Employment Size						
≤ 49	7	(7.95 %)	51.09	2.05	105.51	0.17
50 – 99	7	(14.29 %)	29.31	2.98	75.37	0.18
100 – 499	11	(20.37 %)	31.75	3.01	6.02	0.23
≥ 500	5	(38.46 %)	136.04	7.77	2.12	0.42
Production Size						
Custom Production	11	(12.09 %)	36.40	4.49	26.75	0.27
Batch Production	6	(10.71%)	174.52	11.18	13.69	0.42
Custom & Batch Production	1	(12.50 %)	30.87	2.58	33.68	0.12
Mass Production	10	(29.41%)	66.20	6.67	5.58	0.24

Note a: per 1,000 employees
Note b: denotes number of new products per 1,000 employees
Note c: percentage of all firms of the corresponding raw category
Source: Innovation Survey 1997, Data compiled by Vera Mayer

Table 2 shows a brief profile of the surveyed firms utilizing five indicators. The first three indicators attempt to capture the resources to which the manufacturing firms have access for the purposes of innovation:

- the presence of continuous on-site R&D facilities,
- R&D employment in terms of the R&D personnel ratio, and
- R&D expenditure in terms of the R&D expenditure intensity [in percent of sales turnover].

Another set of two indicators focuses on innovation activities or outcomes and includes

- the actual introduction of new products [averaged over 1994-1996] per 1,000 employees [i.e. the product innovation rate], and
- the share of turnover accounted for by new or improved products [averaged over 1994-1996].

The second of these measures is an indicator favoured by many of the management experts as a measure of a firm's innovativeness and is a widely accepted measure in the benchmarking literature (see, for example, Zairi 1992). It relates product innovations to economic activity. It is accepted that the definition of what constitutes a new or improved product is problematic and this is something what has to be taken into account when considering the figures provided in table 2. In some industry sectors such as food industry and textiles & clothing new and especially improved products may appear rapidly while in others four or five years developmental cycles may be the norm and in such as machinery and transport, for example, very long leading times are still the case.

Following Malecki and Veldhoen (1993) we classified firms as innovative, based on the following criterion: if product innovations introduced during the past three years comprised more than 20 percent of the firm's yearly turnover. Defined in this way, there were only 50 (26.5 percent) innovative firms, 64.0 percent of these were smaller than 100 employees; 16 had fewer than 50 employees. The sectoral distribution indicates a predominance of innovative firms in electrical and optical equipment (ÖNACE 30-33; 11 firms), machinery and transport (ÖNACE 29, 34-35; 11 firms) and basic metals and metal products (ÖNACE 27-28; 3 firms). These three sectors account for 50 percent of all the innovative firms. Of the non-innovative firms, 45.3 percent are engaged primarily in custom production, 26.6 percent in batch production and another 5.0 percent in custom and batch production. This suggests that flexible production, particularly of custom products for individual customers, is the norm rather than the exception among the firms surveyed, whether or not the concept of 'new/improved' products is appropriate.

R&D may be misleading or is at least incomplete as an indicator of technological capability, because it does not include network activities, learning, informal R&D and other means of enhancing a firm's knowledge base (Malecki 1997). Firm performance may be best viewed as a product of the interplay between in-house R&D efforts to innovate and external innovation networks for knowledge transfer. The knowledge needed to compete comes most often from customers, suppliers (manufacturing and producer service suppliers) and from other firms and institutions. The innovativeness supported by regional interfirm networks not only supports existing firms, it also offers opportunities to open up new businesses in order to serve newly identified markets. The importance of networks and of innovative niches sparks innovation in both high-technology industries and in traditional sectors.

Network activities of manufacturing firms in the metropolitan region are organized around five types of networks:

- *customer networks* which are defined as the forward linkages of manufacturing firms with distributors, marketing channels, value-added resellers and end users,

- *manufacturing supplier networks* which are defined to include subcontracting, arrangements between a client (the focal manufacturing firm) and its manufacturing suppliers of intermediate production inputs,

- *producer service supplier networks* which are defined to include arrangements between a client (the focal manufacturing firm) and its producer service partners (esp. computer and related service firms, technical consultants, business and management consultants, market research and advertising),

- *producer networks* which are defined to include all co-production arrangements (bearing to some degree or another on technology) that enable competing producers to pool their production capacities, financial and human resources in order to broaden their product portfolios and geographic coverage,

- *co-operations with research institutions/departments of universities* (pre-competitive stage) pursued to gain rapid access to new scientific and technological knowledge and to benefit from economies of scale in joint R&D.

Table 3: Network Activities of Manufacturing Firms

		Customer Networks		Manufacturing Supplier Networks		Producer Service Supplier Networks		Producer Networks		Co-operations with Research Institutions	
Pre-Competitive Stage			**c**		**c**		**c**		**c**		**c**
Information Exchange	**a**	199		135		165		66		61	
	b	64	(26.1 %)	45	(23.0 %)	63	(34.5 %)	27	(30.3 %)	25	(32.8 %)
Identification of New Ideas	**a**	190		122		148		64		57	
	b	57	(25.8 %)	39	(24.6 %)	57	(34.5 %)	25	(28.1 %)	20	(31.6 %)
Research and Development	**a**	179		118		148		49		56	
	b	55	(25.7 %)	37	(23.7 %)	56	(34.5 %)	20	(26.5 %)	22	(30.4 %)
Competitive Stage											
Prototype Development	**a**	175		108		96		37		47	
	b	53	(24.6 %)	34	(23.1 %)	36	(32.3 %)	16	(27.0 %)	20	(31.9 %)
Pilot Projects	**a**	167		97		101		28		47	
	b	51	(25.1 %)	30	(24.7 %)	41	(34.7 %)	12	(32.1 %)	20	(29.8 %)
Market Introduction	**a**	183		82		105		49		19	
	b	56	(26.2 %)	25	(25.6 %)	38	(34.3 %)	20	(22.4 %)	9	(31.6 %)

Note: **a** denotes the number of such network activities of the manufacturing firms (with all regions),
Note: **b** denotes the number of manufacturing firms with such network activities (with all regions),
Note: **c** denotes the share of such network activities with a focus on the metropolitan region of Vienna,
Source: Innovation Survey 1997, Data compiled by Walter Rohn

Firms pursue such co-operative arrangements in order to tap into sources of know-how located outside the boundaries of the firm, to gain fast access to new technologies or new markets, to benefit from economies of scale in joint R&D and/or production, and to share the risks for activities that are beyond the scope or capabilities of a single firm. The picture which emerges from the evidence of the current study is that of a maze of different networks. They range from highly formalized to informal network relations, from highly specialized and rather narrow networks to looser and much wider networks such as, for example, technical alliances involving firms as corporate entities, from networks focusing on the pre-competitive stage of the innovation process to those involving the competitive stage.

Table 3 provides some empirical evidence on the above five types of networks, from the point of view of the focal manufacturing firm, and highlights the fact that

- co-operation in the pre-competitive stage [i.e. in the early stages] of the innovation process is generally more common than in the competitive stage. External information tends to be particularly relevant during the early stages of the innovation process when perception of problems and evaluations of technological possibilities take place.

- Customer and user-producer [i.e. manufacturing and producer service supplier] relationships are much more frequent than horizontal co-operations such as producer networks and research institution-industry linkages. Customer networks represent the most frequent form of interfirm co-operation, with activities with customers and suppliers constituting 35.3 percent of all such activities. Manufacturing and producer service suppliers have strong incentives to establish close relationships with user firms and even monitor some aspects of their activity. Knowledge produced as a result of learning-by-using can only be transformed into new products if the producers have direct contact with users. In turn, user firms will generally need information about new products or components. This may not only mean awareness, but also quite specific inside information about how new, user-value characteristics relate to their specific needs.

- 37.7 percent of the manufacturing firms are integrated into customer networks, 27.9 percent into manufacturing supplier networks, 46.6 percent into producer service supplier networks, and only 18.6 percent have set up co-operative relations with research institutions and/or departments of universities, despite the active promotion of university-industry programmes in Austria.

- The data clearly suggest that the significance of metropolitan co-operation among firms should not be overestimated. Spatial proximity is one, but not a decisive criterion for innovation-oriented, even for personal relationships. The building up and fostering of mutual trust is possible without the precondition of spatial proximity.

As in other studies (see, for example, Meyer-Krahmer 1985) three clusters of manufacturing firms may be distinguished. The first cluster, characterized by a high outward orientation, frequently utilizes the whole range of possibilities in obtaining external knowledge. Firms in this cluster share widespread network activities in both the pre-competitive and the competitive stage of the innovation process, also with research institutions. Spatial proximity to the co-operation partners is irrelevant. Competence and excellency tends to be the decisive criterion. The second cluster of firms is characterized by medium outward orientation and seems to rely more on in-house problem solving strategies. Such firms tend to have regular contacts with customers and suppliers. Linkages with research institutions and universities are less common. Geographic proximity to co-operation partners is less important. The third cluster relies almost entirely on in-house problem solving techniques. It includes less innovative firms with less complex products and highly specialised firms that operate in small market niches. Even though the latter are quite innovative, few have network activities in the competitive stage of the innovation process.

7. Conclusions and Outlook

The most important general conclusions from the above discussion may be summarized as follows:

First, the centrality of knowledge spillovers in the innovation process is at the heart of network building.

Second, intrafirm and interfirm networking is a central element in the process of technological innovation.

Third, networking should not be explained primarily in terms of costs, whether transaction costs or others, but rather in terms of strategic firm behaviour, appropriability, technological and other complementary assets.

Fourth, we need to know more about the variety of organisational – especially informal – forms and interfirm relationships, about trust and power relationships etc. Such issues are difficult to measure, but no doubt would ask for in-depth interviews with key firms and institutions in the region.

Fifth, interorganisational linkages show several features that make the network mode a distinct form of economic transactions [in the context of knowledge and innovation diffusion] operating alongside and in combination with the two forms of governance: market transactions and 'hierarchies' as recognized by economic theory.

Sixth, the picture which emerges from the evidence described is that of a maze of different networks. Networks focusing primarily on the early stages of the innovation process are more common in the metropolitan region as do vertical in comparison to horizontal co-operations.

Seventh, innovation-oriented relationships are much less territorialized than generally assumed in the literature. In many cases, interregional and international orientation is much more important, especially for technology-intensive firms.

Economic analysis generally views networks to represent a type of arrangements lying somewhere between discrete market transactions and the highly centralised firm. This view, however, fails to capture the complexities of knowledge exchange in innovation and calls for developing a more fully fledged economic theory of networks that may complement the Coase-Williamson theory of markets and hierarchies.

Acknowledgements: This contribution draws on work undertaken for an international project on 'The Regional Innovation Potential and Innovative Networks in Metropolitan Regions' of the German Research Association [DFG], for which the Institute of Geography at the University of Hannover is responsible. That research is conducted through a partnership of four research institutions: University of Hannover, Royal Institute of Technology Stockholm, Polytechnical University of Catalunia and the Austrian Academy of Sciences. The author of this contribution thanks Javier Revilla Diez (University of Hannover) for his comments at the various stages of the research. Vera Mayer, Walter Rohn (both Austrian Academy of Sciences) and Ingo Liefner (University of Hannover) have provided fundamental help in conducting the postal survey. Vera Mayer and Walter Rohn have assisted in computing the tables.

References

Andersson A. 1985. Creativity and regional development, *Papers of the Regional Science Association*, **56**: 5-20.

Chesnais F. 1988. *Technical Co-operation Agreements between Firms*, STI Review, No. 4, OECD, Paris.

Cohen W. M., Levinthal D. A. 1989. Innovation and learning: The two faces of R&D, *Economic Journal*, **99**: 569-96.

DeBresson C., Amesse F. 1991. Networks of innovators: A review and introduction to the issue, *Research Policy*, **20**: 363-79.

Dosi G. 1988. Sources, procedures, and microeconomic effects of innovation, *Journal of Economic Literature*, **26**: 139-44.

Freeman C. 1986. The role of technical change in national economic development, in Amin A., Goddard J. eds. *Technological Change, Industrial Restructuring and Regional Development*, Allen & Unwin, London, 100-14.

Freeman C. 1991. Networks of innovators: A synthesis of research issues, *Research Policy*, **20**: 499-514.

Hall P. 1986. The theory and practice of innovation policy: An overview, in Hall P. ed. *Technology Innovation and Economic Policy,* St. Martin's Press, New York, 1-34.

Johannisson B. 1991. University training for entrepreneurship: Swedish approaches, *Entrepreneurship and Regional Development,* **3**: 67-82.

Kline S. J., Rosenberg N. 1986. An overview of innovation, in Landau R., Rosenberg N. eds. *The Positive Sum Strategy*, National Academy Press, Washington, 275-305.

Lundvall B.-A. 1988. Innovation as an interactive process: From user-producer interaction to the national system of innovations, in Dosi G., Freeman C., Nelson R., Silverberg G., Soete L. eds. *Technical Change and Economic Theory*, Pinter, London, 349-69.

Lundvall B.-A. ed. 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter, London.

Malecki E. J. 1997. *Technology & Economic Development,* Longman, Essex (2nd edition).

Malecki E. J., Veldhoen M. E. 1993. Network activities, information and competitiveness in small firms, *Geografiska Annaler,* **75B**: 131-47.

Mansfield E. 1968. *Industrial Research and Technological Changes*, W. W. Norton, New York.

Mansfield E., Romeo A., Schwartz M., Teece D., Wagner S., Brach P. 1982. *Technology Transfer, Productivity, and Economic Policy,* Norton and Co., New York.

Meyer-Krahmer F. 1985. Innovative behaviour and regional indigenous potential, *Regional Studies,* **19**: 523-34.

Myers M. B., Rosenbloom R. S. 1996. Rethinking the role of industrial research, in Rosenbloom R. S., Spencer W. J. eds. *Engines of Innovation: US Industrial Research at the End of an Era*, Harvard Business School Press, Boston, 209-28.

Nelson R., Winter S. 1982. *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge (MA).

OECD 1992. *Technology and Economy: The Key Relationships*, Organisation for Economic Co-operation and Development, Paris.

Porter M. E., Fuller M. B. 1986. Coalitions and global strategy, in Porter M. E. ed. *Competition in Global Industries,* Harvard Business School Press, Boston, 315-43.

Powell W. W. 1990. Neither market nor hierarchy: Network forms of organization, in Staw B. M., Cummings L. L. eds. *Research in Organizational Behavior,* JAI Press, Greenwich, CT, 295-335.

Romer P. 1990. Endogenous technical progress, *Journal of Political Economy,* **98**: 71-103.

Saviotti P. P. 1988. Information, entropy and variety in technoeconomic development, *Research Policy*, **17**: 89-103.

Saviotti P. P. 1998. On the dynamics of appropriability of tacit and of codified knowledge, *Research Policy,* **26**: 843-56.

Storper M. 1997. *The Regional World. Territorial Development in a Global World*, The Guilford Press, New York and London.

Suarez-Villa L. 1989. *The Evolution of Regional Economies. Entrepreneurship and Macroeconomic Change*, Praeger, New York.

Teece D. 1981. The market for know-how and the efficient international transfer of technology, *Ann. Am. Acad. Polit. Soc. Sci.*, **458**: 81-96.

Teece D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy, *Research Policy*, **15**: 285-305.

Tijssen R. J. W. 1998. Quantitative assessment of large heterogeneous R&D networks: The case of process engineering in the Netherlands, *Research Policy*, **26**: 791-809.

Zairi M. 1992. *Competitive Benchmarking: An Executive Guide*, TQM Practitioner Series, Technical Communications (Publishing) Ltd., Letchworth.