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The Logic of Technological Globalisation: Recent Evidence on R&D in the European Union

1 Introduction

The present paper sets out to review the current discussions on technological globalisation and the corresponding role of the European Union as an arena for R&D and innovation. In order to explore the logic of technological globalisation it seems to be most promising to examine specific developments in the pattern of R&D activities on a global scale. The underlying question is whether the European Union is going to emerge as a technology community, that is as a coherent territorial ensemble of technologies, institutions and organisations which plays a major role in the corporate networks and market structures of the world economy. Indeed, the fundamental problems that are currently associated with the formulation of a common European innovation policy are closely related with the international restructuring of corporate R&D (Caracostas/Muldur 1998: 81n). The available empirical evidence on R&D in the European Union suggests that scepticism on the feasibility of a politically constructed European technology community rests on solid ground, although a differentiation according to the particular specificity of countries, industries and technologies needs to be taken into account.

The structure of the paper is as follows. The first chapter introduces the internationalisation of R&D activities in the context of globalisation as a segmented economic process. It is emphasised that the notion of glo-

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1 This paper is based on the final report of a research project on the relationship between European R&D locations and production sites of German industrial enterprises, funded by the German Research Council. The author prepared that report as a research assistant with Professor Dr. Eike W. Schamp at the Institute of Economic and Social Geography of the Johann Wolfgang Goethe-Universität in Frankfurt/Main between October 1997 and April 1998.
balisation is compatible with the local agglomeration of economic activity, thus the global and the local dimension are portrayed as interdependent segments. The second chapter deals with the European Union as an institutional and organisational arena of innovation. Empirical evidence from recent studies on the role of the European Union as a terrain for the location of R&D activities is explored. The third chapter concentrates on the internationalisation of German corporate R&D by paying reference to the empirical evidence on selected science-based industries. Indeed, Germany has been portrayed as a major driving force of European integration in political as well as economical terms. The fourth chapter finally deals with an assessment of European innovation policies and further perspectives of developing a specific system of innovation on the level of the European Union. The resulting policy conclusions point at the basic problem that policies for the location of R&D will capture only reduced aspects of innovation as a source of competitiveness and economic growth. This neglects the matter of institutional and organisational variety as a condition of innovation in the European Union, facing the competitive pressures of technological globalisation.

2 The internationalisation of industrial R&D: a case of non-globalisation?

The notion of globalisation has become a most popular phrase for denoting the current structural changes of the global economy. But how is that notion of globalisation actually defined? It may be a useful device to begin with defining internationalisation as the increasing interrelationship and economic interdependence of national economies via trade, foreign direct investment and the supply of inputs (Walsh 1997: 89). Globalisation accordingly represents the latest phase of internationalisation. It encompasses three trends, consisting of the increased rate of foreign direct investment, the increasing number and volume of international mergers and acquisitions, and the growth of intra-firm trade, basically within multinational enterprises (Walsh 1997: 89n). With regard to these issues it has been underlined that the notion of globalisation implies that international flows of goods, services and resources are concentrated in specific areas. With reference to the weight of the ‘Triad’ economies of Europe, Northern America and East Asia as exposed metropolitan areas it has been suggested that a ‘Triadisation’ of the world economy has evolved (Hirst/Thompson 1996). In this context, the geographical distribution of world production exhibits a pattern that is marked by the catch-up growth of the East Asian economies. While the United States and the European Union held a world GDP share of 20.7 per cent in 1995 respectively, measured in relative prices and 1990 purchasing power standards, the East Asian economies of Japan, South Korea, Taiwan, Hong Kong and Singapore accounted for 12.3 per cent, while China held a share of 11.5 per cent (European Commission 1997: 13). Still, the European Union has continued to be the largest source of, as well as destination for foreign direct investment between 1990 and 1995: inflows of 421 billions ECU and outflows of 582 billions ECU are almost double the figures of the United States (European Commission 1997: 21).

Multinational enterprises have emerged as the decisive actors on that international theatre of investment, production and innovation. They are the indispensable organisational carriers of the flows of international trade and foreign direct investment which are fuelled by the widespread deregulation of markets. Examining the international activities of multinational enterprises in the Triad economies, one finds that their overwhelming majority locate their home bases, that is their corporate headquarter functions, within the Triad (Dunning 1993). This corresponds with an increasing intensity of locational competition, as firms and states meet on the grounds of bargaining relations that are well described by the term of a strategic ‘triangular diplomacy’. That kind of constellation is coined by the simultaneity of conflict, competition and co-operation regarding the geographical organisation of economic activity in political and economical terms. The corresponding competition for attracting international investment is said to characterise the current policy agenda of nations and regions alike (Stopford/Strange 1991). Taking into account that the generation, diffusion and actual use of technology is very much context-specific it follows that controlling the flows of technology has become a crucial topic for firms and governments alike.

In addition to these combined economic and political changes it has been suggested that economic globalisation decomposes the specific national growth trajectories of the industrialised economies which were based
upon structures of mass production, thus denoting the specific institutional and organisational arrangements of fordism. This decomposition implies a massive reconfiguration of the spatial structure of the economy. Post-fordist systems of production represent the drive for a territorial specialisation concerning high-skill and knowledge-intensive economic activities. These types of production systems have been analysed under the assumption that globalisation reinforces regional communities and thus may lead to the re-emergence of regional economies which had been eliminated by large-scale fordist production. The related regional industrial agglomerations are said to derive their strength from institutionally embedded learning capabilities, marked by 'untraded interdependencies' like historically rooted conventions that are based on shared experiences as well as expectations (Storper/Scott 1995). This position has been criticised for allegedly viewing globalisation as a subordinated facet of regionalisation, thus overemphasising the role of local industrial complexes (Amin 1994: 25). Understanding globalisation is accordingly said to require an analytical emphasis on the structural dominance of multinational enterprises and their global networks of production, distribution and finance which contribute to the centralisation of high value added economic activities within 'neo-Marshallian network nodes' as ensembles that are distinct from regional economic communities (Amin/Thrift 1992). Instead of providing further opportunities for a sustainable development of regions, globalisation may lead to the disintegration and weakening of regional linkages due to the potentially disembedding pressures of global standardisation. Hence what really matters for sustaining economic growth and development is access to the relevant economic networks of multinational enterprises. The aspects of control and co-ordination thus parallel each other.

This perspective seems to be quite in accordance with the suggestion that technological globalisation denotes primarily the international integration of geographically dispersed and locally specialised activities of multinational enterprises (Cantwell 1999: 238). This points once more at the role of spatial agglomerations with a high degree of institutionally embedded technological competence on a local or regional scale. Ensembles like 'technopoles', for instance, contain a specific 'milieu of innovation', defined as a 'set of relationships of production and management, based on a social organisation that by and large shares a work culture and instrumental goals aimed at generating new knowledge, new processes, and new products' which is an outcome of the capacity to generate synergy as added value resulting from the interaction of the various elements of the milieu (Castells 1996: 389n). These ensembles exhibit business command functions with a macro-regional or even global reach, as they are synonymous with the tendency for an integration of globalisation and localisation and the parallel emergence of transnational networks for production and innovation. It follows that technological globalisation is accompanied by the emergence of local 'pockets of innovation' that contain technological competence and learning capabilities, usually also represented by R&D activities.

Indeed, private and public R&D is a major factor in the evolutionary dynamics of economic development, an aspect that has been well explored in the Schumpeterian tradition of economic analysis (Ebner 2000b). The formation of science-based industries like pharmaceuticals has been primarily due to the emergence of corporate in-house laboratories. The resulting organisational combination of invention and innovation has been achieved accordingly by establishing a synthesis of professional scientific research and commercial applications (Freeman/Soete 1997). The internationalisation of R&D locations therefore reflects both the process of technological globalisation as well as the restructuring of production systems and corporate networks. The related controversy on the internationalisation of R&D is based on distinct theoretical arguments which may be portrayed as follows (de Mayer 1997).

The neoclassical approach to the choice of locations follows a common practice of neoclassical microeconomics by treating resources as initial endowments while technologies and preferences are stylised as exogenous data. The choice of R&D locations is accordingly perceived as an optimisation calculus. This mode of argumentation is of course not open to empirical falsification. An answer to that problem should be provided by the product life cycle approach, based upon Vernon's works on the industrial dynamics of locational patterns. This approach propagates a rather mechanistic perspective on the developmental stages of R&D locations. Therefore it also lacks empirical content. An alternative point of view is provided by the transaction-cost approach of the new institutional economics. The dynamics of locating R&D activities is perceived
as a result of the frictions on imperfect and incomplete markets. Asymmetric information represents a most important factor, as the minimisation of transaction costs which arise from search, implementation and control procedures constitutes a major argument for strategic decisions. Another related conceptual alternative is provided by the evolutionary perspective. It is primarily the notion of technological learning with its emphasis on the local, cumulative and tacit character of knowledge that supports an evolutionary approach to the locational dynamics of R&D. The evolution of corporate networks is interpreted as a response to the need for communicating knowledge in the context of an innovation-based market process.

The relevance of these various theories concerning the internationalisation of R&D on knowledge-intensive industries has been assessed as follows. According to Cantwell (1995) one can empirically trace a transition from the hierarchical and linear life-cycle model to a more complex approach. Therefore he suggests that the product cycle model of international R&D operations fails to account for the trend of an increasing internationalisation as well as a decentralisation of technological activities that has persisted since the 1920s, as extracted from US patent data. Indeed, the industrially differentiated internationalisation of R&D locations has been interpreted as a driving force of technological globalisation also from a historical perspective (Chesnais 1996). The need for an efficient co-ordination of R&D operations is accompanied by an intensified functional differentiation which shall increase flexibility in the innovation process. This mirrors the conceptual reorientation from a linear science-push approach to a systemic perspective which focuses on feedback loops and interactions between diverse functional units, corresponding with the segmentation and organisational decentralisation of production. Therefore the choice of R&D locations is highly dependent from the existing corporate organisation and strategic orientation (Hayter 1996).

The related issue of a centralised versus decentralised R&D organisation has been treated as follows (Howells/Wood 1993). Decentralisation generates benefits from an adaptive R&D strategy which focuses on the demand conditions of local markets and users. Moreover, the communication with other departments of the firm and external organisations as local partners in the innovation process is supported.

Indeed, decentralisation may create a competitive advantage when spatial proximity to production facilities is beneficial for product development, for instance due to the necessity of communicating tacit knowledge and other content that supports the case for direct personal contacts. Even political regulations may provide incentives for decentralisation. Furthermore, the strategy of tapping local knowledge pools and scanning technological developments in host countries supports the case for decentralisation. Still, the establishment of a centralised corporate system of R&D locations, most often focusing on the home country, may be beneficial as soon as there are certain advantages to be considered such as the national science-base or home country patterns of technological specialisation. Moreover it may be useful to economise on the co-operation with likewise centralised headquarter units. Economics of scale and scope may be achieved due to the size of centralised R&D establishments. This aspect is accompanied by the realisation of control concerns.

It needs to be emphasised that corporate technological competence exceeds the narrow area of R&D activities, for other corporate activities, especially regarding production, also provide a terrain for learning and innovation. The internationalisation of corporate R&D is indeed only a component of the technological internationalisation of firms, interpreted as process that consists of three basic dimensions (Paoli/Guericini 1997). This is, first, the international exchange of patents, licenses, personnel and the related segments of expert as well as tacit knowledge. The second aspect is the emergence of a global labour market for R&D personnel as well as the factual internationalisation of corporate R&D personnel. Third comes the organisational formation of joint ventures, consortia and other co-operative ventures, as well as the intensified participation in inter-firm research programmes. Thus not only the matter of R&D locations but also the matter of technological collaboration, strategic alliances and joint ventures hints at the ongoing international restructuring of technological activities. While the tendency for a rather general dislocation and decentralisation of R&D was dominant in the 1980s, the 1990s have been characterised by the combined internationalisation and local concentration of R&D activities in some major industries, focusing on local 'centres of excellence' with a global reach. The weakening of the relationship between production and R&D locations in favour of a concentration of R&D
gives evidence for an actually existing variety of the organisational conditions of technological innovation (Meyer-Krahmer/Reger 1998: 12n). This corresponds with the policy-related question whether the European Union will emerge as a technology community, that is as a coherent terrain for localised R&D activities in a continental policy framework, exhibiting a global reach in the Triad structure of the world economy.

3 Empirical evidence on the European Union as an emerging technology community

The role of the European Union as a technological community, that is as a territorial ensemble of institutionally embedded organisational networks that deal with technological innovation has become a controversial topic in the related debates on innovation policy. A major analytical problem concerning that topic is posed by the fact that an empirical analysis of the volume and intensity of R&D activities within the European Union as compared with the United States and Japan has to deal with major methodological problems. For instance, the fact is to be reconsidered that those multinational enterprises which have emerged from a small open economy like the Netherlands usually lean towards a long-term strategy of foreign market access which implies that a high proportion of their R&D activities is located outside the European Union (Freeman/Soete 1997: 309n). Therefore a comparison of the OECD economies, for instance, lacks from empirically convincing content. It follows that defining a general level of competitiveness for the European Union economies is only possible by consciously neglecting the analysis of these structural differences, especially concerning the degree of technological specialisation (Grupp 1995: 221). Methodological problems like these should be kept in mind when the empirical results of various recent studies on the role of R&D in the European Union are explored.

Archibugi und Michie (1995) review the empirical material on the matter of technological globalisation by focusing on patent statistics. They differentiate between the three categories of technological exploitation, technological generation and technological collaboration as facets of technological globalisation. The global exploitation of technology denotes the fact that an increasing proportion of technological innovations are exploited in international markets. Global technological collaboration points at the international inter-firm collaboration between firms, as well as modes of collaboration between firms, governments and academia. The global generation of technology then denotes the tendency that firms integrate R&D and technological activities on an international scale (Archibugi/Michie 1995: 125). Concerning the aspect of exploitation they are able to support the thesis of an OECD-wide tendency for internationalisation. Still, this trend is coined by country-specific influences. Concerning the use of domestic patents it was the German companies within the European Union that took a top position with a share of 32 per cent in 1990. In contrast to that Greek companies used the observed minimum share of 2 per cent. As the German economy is endowed with a strong domestic science and technology base it seems to be quite natural that the degree of exploiting knowledge which has been generated abroad is much higher on the European average level where only a comparatively weak national science base exists.

In this context it is noteworthy that the European Patent Office receives 45 per cent of its patent applications from non-EU countries. Additionally the transnational technological collaboration between firms, governments and research institutes has deepened since the 1980s. In industries like biotechnology, information technology and materials the European companies took part in intra-EU joint ventures with a share of 19 per cent, while EU-US joint ventures held a share of 21 per cent. Still, the dimension of the generation of technologies proves to be less globalised than the dimensions of exploitation and collaboration. The suggestion holds that European Union multinationals operate domestic R&D activities to a degree that is positively correlated with the volume of their home markets, also reflecting factors like technological expertise, infrastructures, and policy aspects. Indeed, despite the underlying tendency for an increasing internationalisation, the generation of technology by means of R&D seems to remain largely a non-globalised economic activity.

Beyond the analytical distinction between the generation, collaboration and exploitation of technology it needs to be emphasised that technological globalisation implies that the generation of technology by organisational collaboration has become more relevant than ever. Freeman and Haagedorn (1995) make use of the MERIT data pool on technologi-
cal strategic alliances in the 1980s in order to review developments in ten specific areas of technological collaboration. Knowledge-intensive industries like biotechnology, materials, chemicals, pharmaceuticals, electronics and the information and communication technologies were identified as lead industries in the expansion of technological collaboration. Almost 95 per cent of the 4192 recorded alliances were organised within the Triad economies of the United States, Japan, and the European Union. In the decade between 1980 and 1989 only 19.2 per cent of these alliances were pursued between European Union partners, while 22.4 per cent denoted a collaboration between EU companies and US companies, and a residual of 6 per cent then accounted for European-Japanese alliances.

Consequently it may be suggested that multinational enterprises originating from the European Union pursue strategies for the internationalisation of their R&D activities that are pointing either at a locational intra-EU 'Europeanisation' or at an US-related 'Atlanticisation'. The latter reflects the dominant mode of interaction, for US companies still act as the most often frequented R&D partners of European companies. This may be explained by factors such as the strong national science-base of the United States as well as the leading role of US markets for science-intensive goods and services.

Patel (1995) draws the following conclusions from a survey of the empirical literature on technological globalisation. First, foreign R&D activities of multinational enterprises are pursued primarily for the motive of adapting products to local markets. Second, political factors like laws, regulations and incentive schemes play a decisive role in the choice of R&D locations. Third, the increasing quantity of the R&D activities of multinational enterprises has been paralleled by massive qualitative changes in the functional composition of R&D since the 1980s. This points at an earlier study on that topic, where data of the US Patent Office on the 686 leading multinational companies between 1969 and 1986 were analysed (Patel/Pavitt 1992). The earlier conclusion had emphasised that the majority of R&D activities of multinational enterprises were not only concentrated in their particular home countries but reflected also the industrial specialisation of these particular economies, thus possibly denoting a specific type of non-globalisation. Patel’s more recent follow-up study is based on a sample of

569 international companies (Patel 1995). Their R&D activities are examined by analysing data of the US Patent Office, the US National Science Foundation and the Science Policy Research Unit in Sussex, UK.

The exploration of these data aims at uncovering relationships between patent applications in the United States and international R&D activities. Patel shows that the process of corporate internationalisation is primarily due to organisational concentration, basically by mergers and acquisitions. Concerning the extent of technological globalisation it is suggested that those industries with the highest share of 15 to 30 per cent of foreign R&D activities are not to be found in high-tech industries but rather in consumer goods industries. Pharmaceuticals are mentioned as the only high-tech industry which exhibits a high share of foreign R&D. This may be due to a necessary adaptation to local consumption patterns, medical regulations and the standardisation of sales conditions. It is then maintained that the relevance of the European Union as a continental terrain of R&D basically results from the constructed ‘political factor’ of the European common market.

The role of R&D as means of local adaptation as well as the tapping of local knowledge pools are both to be identified as the major motives for the internationalisation of R&D, as a follow-up study suggests (Patel/Vega 1997). Here, US patent data of 220 multinational enterprises have been explored for the period between 1990 and 1996. The degree of an actual internationalisation of R&D operations is highest for European Union firms, followed by US and Japanese firms respectively. Concerning R&D activities the distribution within the Triad economies is as follows: USA 40.9 per cent, Germany 16.8 per cent, Great Britain 11.6 per cent, France 6.9 per cent, Japan 5 per cent. It is noteworthy that the three European economies that are examined equal a share of 35.3 per cent, thus reflecting the weight of the European Union economies as well as the continuous dominance of the United States. A related comparison of the Triad economies comes to similar conclusions (Pavitt/Patel 1999). Japanese firms remain the least globalised and European firms the most globalised with one sixth of their innovative activities located in the United States. In the European context, Belgian and Dutch firms exhibit the highest degree of internationalisation, while Germany is the most favourite host country for the location of R&D. It is noteworthy that the impact of the technological specialisation of the firms which usually reflects the
corresponding technological specialisation of their home countries remains the major shaping factor for the locational pattern of R&D, exhibiting a stronger influence than the specialisation of the host countries. It is thus concluded that the non-globalisation of innovative activities persists.

All these studies mentioned above have focused on an aggregate level of analysis. An industry-specific perspective has therefore become necessary as a complement. Based on the methodology of Patel’s studies which focus on US patents as indicators, but using instead data of the European Patent Office, a study by Duysters (1996) has examined the internationalisation of R&D in information and communication technologies. This study wants to identify the European specificity of R&D internationalisation, as the data are aggregated on the EU level. Furthermore, in contrast to Patel’s focus on large firms, the patent applications of small and medium enterprises are also included. This procedure implies the result of a comparatively lower level of internationalisation right from the outset. Duysters concludes that companies originating from the European Union exhibit a relatively low level of aggregate technological internationalisation as compared with companies from the United States in the period between 1980 and 1991.

The thesis of a successful catch-up growth and development path of European firms seems to rest on the rather weak foundation of a methodologically biased and thus overestimated internationalisation process within the European Union. This result has been corroborated by further explorations of MERIT data on technological alliances in the information and communication technology industry. It is shown that the number of intra-European alliances amounted to 14.9 per cent between 1986 and 1993, which was less than the corresponding number for the period between 1978 and 1985, then amounting to 21 per cent. The numbers of US-EU alliances were decreasing to a less impressive degree: the shares amounted to 21.2 per cent between 1978 and 1985 and 18 per cent between 1986 and 1993 respectively (Duysters 1996: 192).

Sharp (1996) has examined the internationalisation of R&D in the industry of biotechnology, based on the data sets and publications by firms, business associations and government agencies. A major research question pointed at the continuing relevance of the national science-base. The business activities of German companies like Bayer and BASF in the United States are accordingly interpreted as a means of gaining access to the science and technology competence in biotechnology, where the contract research of small firms, that is the specific type of ‘dedicated biotechnology firms’, plays a prominent role. This co-operative approach is typical for European pharmaceutical and chemical firms, while comparable Japanese activities in that industry remain weakly developed. Still, there is no explicit transfer of knowledge from the United States to the European Union observable, for the relevant transfer is organised only from the US science-base to the particular R&D branch units of European companies that are located in the United States. Consequently, most of the knowledge remains in the United States. At this point the matter of an emerging European system of innovation proves its importance once again. This shall become even more transparent when the special case of the internationalisation of German industrial R&D is taken into account, for the German economy with its strong role of science-based industries and its specific export orientation is not only a leading Triad economy, but also a constitutive political component of European integration.

4 Exploring the internationalisation of corporate R&D: the case of German industry

Basically due to the industrial latecomer situation it was the German economy that pioneered various organisational forms such as the research-oriented university and the in-house R&D laboratory of science-based industries in the 19th century (Keck 1993: 115n). While Germany experienced a seemingly ‘miraculous’ export-oriented mode of growth since the 1950s, the national institutional and organisational framework for the support of innovation was marked by the flexibility of a federal government structure that allowed for decentralised innovation policies on a local and regional level. It may be argued that this specificity represents another major advantage in the context of globalisation. The strong German science-base as well as the role of the German economy as the major national market in Europe may both account for the fact that Germany dominates the national dimension of research and innovation in Europe. In fact, more than 40 per cent of innovation-related activities in the European Union are located in Germany, thus lending Germany the status of the most favoured R&D host
country for firms from other European economies as well as for the European R&D operations of multinational enterprises in general. The remarkable exception is firms from Great Britain which continue to favour the United States (Pavitt/Patel 1999: 114n).

Policy-related research on the position of the German industry in the process of technological globalisation has intensified in the 1990s. The economic situation had been coined by the fact that the R&D intensity of the German economy, defined as gross domestic expenditures on R&D as percentage of the gross value added, declined rapidly in the beginning of the 1990s. This tendency seemed to be reversed since the middle of the decade. The German economy accounted for 8.5 per cent of the total expenditures on R&D that were spent by the OECD economies of the Triad, representing an R&D structure with a comparatively high degree of government activity (BMF 1998: 80n). Indeed, based on a research project concerning the technological capability of the German economy that was initiated by the former Federal Ministry for Education, Science, Research and Technology, a comprehensive study was designed to account for the recent internationalisation of German R&D until 1993 (Straβberger et al. 1996). One of the most severe methodological problems was provided by the fact that there were no complete data sets available on the R&D activities of foreign firms with German capital shares, while country statistics were at least available for the United States, France, Great Britain, and Japan. A valid analysis of the international R&D activities of German companies thus had to be based on diverse proxies like the notion of a R&D capital stock.

Regarding the matter of international R&D capital flows it has become obvious that German industries were a net exporter of R&D, a pattern dominated by the industries of mechanical engineering, electronics and chemicals. R&D and foreign direct investment often run parallel with each other. The economies of the European Union received the largest share of 35 per cent of the foreign direct investment of German manufacturing industries, well ahead of the United States, with the chemical industry holding a share of 32.8 per cent and electronics 36.4 per cent. This corresponds with a general increase of the share of employees in foreign locations and turnover in the foreign markets of German manufacturing industries. Regarding the internationalisation of employment it is the chemical industry which has taken a leading position with a 46 per cent share of foreign employees in 1993. R&D intensity and the internationalisation of the workforce seem to accompany each other. Industries like chemicals, electronics, and mechanical engineering which exhibit a relatively high degree of R&D activities also hold the highest shares of foreign employment. It is noteworthy that this results basically from acquisitions which are a major vehicle of the internationalisation of technological activities. Firms of the German chemical industry have expanded primarily in the United States while other industries focused on the Western European economies. It is generally suggested that the share of foreign R&D by German firms ranges from 11 to 20 per cent, with a high organisational concentration on large firms in chemicals and electronics, as supported by their strategy of acquisitions.

In accordance with its role as a terrain for global ‘centres of excellence’ in R&D, the United States receive the highest share of the foreign R&D activities of German firms. German R&D expenditures in the United States amounted to 2.3 billion US-Dollars in 1993, that is about two thirds of the total expenditures on German foreign R&D. Dominant industries are electronics and industrial chemicals. It is noteworthy that most of these increases of German R&D presence in the United States have resulted primarily from the voluminous acquisitions by German firms, especially in the science-intensive industry of pharmaceuticals (BMF 1998: 87n). On average, the R&D expenditures of German industrial companies in foreign economies, according to purchasing power parity, amounted to a 15 per cent share of the domestic R&D expenditures. Well above that average are the chemical and pharmaceutical industries with a share of 30 per cent. This points once more at the unique role of the US-American national system of innovation, especially regarding advantages in building inter-organisational relations between universities and industries as expressed by the high volume of contract research in the United States (BMF 1996; BMF 1997).

The basic structure of R&D in the German chemical and pharmaceutical industries may be differentiated according to domestic and foreign contributions in the 1990s. Concerning the turnover structure it is noteworthy that about 29 per cent remained domestic and 71 per cent foreign. The international distribution of the employed personnel points at a share of 55
per cent domestic and 45 per cent foreign, with the R&D personnel
distributed according to a pattern of 75 per cent domestic and 25 per cent
foreign. Finally, the R&D budget was allocated according to a pattern that
exhibited shares of 68 per cent domestic operations and 32 per cent foreign
operations (Beckmann 1997: 162).

The obvious discrepancy between the relative share of foreign
personnel and foreign R&D personnel on the one hand, and between the
latter and the foreign R&D budget on the other hand, is not industry specific.
It corresponds with the general trends of the internationalisation of German
R&D (Dörrenbächer/Wortmann 1991). A related study of the internationalisation
of R&D in the German pharmaceutical and chemical industries, that
is those industries which acted as the major forces in the drive for an interna-
tionalisation of German R&D since the 1980s, has been prepared by
Beckmann and Fischer (1994). Their methodological basis is provided by
qualitative explorations of R&D strategies that cover 12 of the 13 largest
German companies in these particular industries. Four types of foreign R&D
locations are distinguished:

- Local adaptive development as a location that serves the needs of
  adapting production to the needs of local markets.
- Regional development departments as locations that proceed with
  rather autonomous projects for local and regional markets.
- Development centres as locations for the solution of development
  problems concerning supra-regional markets or complete business
  units.
- Research centres as locations that deal with applied research in
  general.

These types of R&D locations are said to correspond with specific incen-
tives and motives regarding strategic decisions on the internationalisation
of R&D. Most relevant in terms of employment effects has been the
type of local adaptive development, followed by the development centres,
while regional development units and research centres have generated less
convincing employment effects. Concerning the combined regional and
functional distribution of R&D locations it is the United States economy
that has been identified as the most favoured recipient of investment, es-
specially for the location type of the research centre, while the European

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Union ranked highest regarding development centres and Japan regarding
regional adaptive activities. Taking into account that the German industry
has been endowed with an economic core function in the making of an
European innovation system it is quite remarkable to notice that promi-
nent role of the United States as a terrain for R&D locations. Whether this
development indicates a new international division of competence, with
the United States as the decisive terrain of R&D, constitutes a decisive
challenge for European innovation policies.

5 Approaching a European community of research and
innovation?

The position of the European Union in the process of technological glo-
balisation is marked by the fact that input and output indicators on research
and innovation activities lag behind the corresponding indicators of the
United States. This tendency has persisted although the European Union
remained an important terrain of R&D activities. Still, the decisive aspect
of achieving a degree of institutional and organisational coherence that would
characterise the European Union as a technology community is far from
being accomplished yet. Therefore the innovation policy approach of the
European Commission has been marked consistently by an intensification
of efforts in the areas of R&D, science as well as training and education.
Innovation is appreciated as the decisive source of competitiveness, and thus
as the driving force of economic growth and employment (European
Commission 2000: 7). Indeed, annual spending on Community research and
technological activities, not counting the Structural Funds, has risen from
1.6 per cent of the of the total budgetary appropriations for R&D by the then
twelve member states in 1985 to 4.1 per cent in 1996 (Caracostas/Muldur

Table 1 indicates that the race for increasing R&D expenditures since
the 1980s sees the United States continuously holding the leading position,
in spite of a gradual decline in the first half of the 1990s. Per capita gross
expenditures on R&D in the European Union, expressed in purchasing power
parities, also lag behind the United States and Japan. Gross expenditures on
R&D as a percentage of GDP show the same pattern. In the European Union
this measure of R&D intensity amounted to 1.8 per cent as compared with 2.5 per cent in the United States and 2.8 per cent in Japan in 1996, while even the East Asian economies of Japan, South Korea, Taiwan, Singapore and Hong Kong accounted for an intensity of 2.2 per cent (European Commission 1997: 40n). Similarly, the European Union lags behind concerning other research and innovation input indicators like the numbers of employed scientists and engineers (European Commission 1997: S-33).

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Source: European Commission (1997: S-8);
* excluding Luxembourg, *current expenditures only, †series adjusted by OECD

Table 1: Gross Domestic Expenditures on R&D in the Triad, 1980-1995, (Million 1990 PPS)

Another aspect of technological globalisation is highlighted in table 2, where the number of patents granted by the US Patent and Trademark Office, the USPTO, is depicted by priority year with reference to the origin of the applicants. It is noteworthy that Germany-based applicants accounted for about two fifth of the US patents that were granted to applicants from the European Union in the covered period. The strength of the related Japanese activities is mirrored by the fact that they are well ahead of the total number of granted patents of the European Union, and about ten times the German amount in 1994, while the United States of course hold the most impressive leading position, almost 25 times the German amount in 1994. It should be added that the trend of European R&D has been towards an increasing role of intra-EU inventions that are patented in the United States. Consequently the share of USPTO patents that cover inventions from within the European Union has almost doubled between 1985 and 1995 (European Commission 1997: 222n).

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<tr>
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<td>12853</td>
<td>16839</td>
<td>16244</td>
<td>15097</td>
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<tr>
<td>- Germany</td>
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<td>7345</td>
<td>6485</td>
<td>6137</td>
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<tr>
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<td>- Great Britain</td>
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<td>Japan</td>
<td>10795</td>
<td>16962</td>
<td>22550</td>
<td>21579</td>
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Source: European Commission (1997: S-72);
* excluding Greece, Luxembourg and Portugal.

Table 2: Number of USPTO Granted Patents, by Priority Year

In order to assess these developments appropriately it is necessary to emphasise that the matter of innovation should not be reduced to the exclusive impact of corporate R&D activities, usually measured by indicators like granted patents which will grasp the essential features of many product and process innovations only marginally (Grupp 1998: 149n). Tacit and informal dimensions of innovation need to be considered additionally, for they are especially relevant in small enterprises which operate in traditional industries, where informal learning procedures tend to dominate the formation of skills and knowledge as prerequisites of innovation. It was small and medium-sized enterprises that generated the major employment effects in the European Union since the 1980s. Consequently, innovation policies need to take notice of the fact that the various types of innovation result from diverse organisational and institutional settings, types of business firms and entrepreneurship, as well as modes of learning beyond well-defined R&D activities (Ebner 2000b). This position is not only in accordance with the observation that production often stimulates R&D, but also with the suggestion that the development of tacit technological capability tends to enable the actual emergence of corporate R&D. Moreover, what matters for a positive innovation performance is not necessarily a volume of R&D as an input factor, but basically...
the entrepreneurial capability of transforming new knowledge in marketable goods and services that meet the needs of the demand side.

The so-called ‘European paradox’ illustrates that point. Regarding key technological areas like information and communication as well as biotechnology it has been observed that research organisations from the European Union perform quite well regarding scientific output although a lack of commercialisation seems to prevail, as many of these scientific endeavours are not transformed to technological innovations (European Commission 1997: 100). Innovation is more than a simple output of R&D, seemingly to be supported by increasing the supply of R&D inputs. Nevertheless, R&D activities matter not only as a source of new knowledge that may be applied to the design, production and commercialisation of new goods. Moreover, innovation processes are marked by feedback links between R&D and other corporate functions like production and marketing. In general, the pool of competence based on knowledge and skills within the firm is supported by R&D operations. R&D thus strengthens the organisational and technological problem-solving capability of the firm (Cantwell 1999: 236n).

Innovation and R&D are the decisive interrelated factors of an emerging European technology community. Four basic functions that can be performed by the European Union in the area of research and innovation have been identified (Caracostas/Muldur 1998: 35n):
- Awareness creation by helping to pool visions and expectations.
- Structural design by supporting modes of international and inter-regional co-operation.
- Catalysis by heightening the international public profile of innovative activities.
- Mobilisation by pooling resources in order to tackle shared problems.

The European Union may be perceived as a geographical and political ensemble of local innovation arenas, defined by the localisation of communication patterns, search and scanning procedures, invention and learning patterns, knowledge sharing, as well as the innovation performance of firms (Howells 1999: 82n). Firms do not operate in isolation. Production and innovation as well as the entrepreneurial impulses that constitute the factor underlying their competitive dynamics are to be understood as economic activities that are necessarily embedded in a certain institutional setting, reflecting historically rooted national or regional specificities that coin a related ‘economic style’ (Ebner 1999). It may be argued that non-tradeable and immobile features of an economy, such as conventions and institutions, have become even more relevant as factors of national or regional competitiveness in the context of globalisation. The neo-Schumpeterian systems of innovation approach hints at the constitutive role of embedded organisational networks in the generation, modification and diffusion of new technologies. In this context, the matter of a ‘Europeanisation’ of R&D activities has been discussed with reference to supranational interactions. A point of departure is provided by the thesis that the R&D and innovation incentive schemes that are managed by the European Union may support intra-European transnational collaboration and thus lead to an expansion as well as intensification of intra-European innovation networks. The European Commission has come forward with these research and innovation support programmes only quite recently in December 1995, pointing both at the supranational and interregional levels of co-operation. Experiences with these programmes are of course too fresh to allow for a generalising interpretation of their evaluation.

Caracostas and Soete (1997) maintain that the core of the emerging system of innovation of the European Union consists of cross-border collaborative ventures, organisations and support schemes. Especially programmes like SPRINT, COMETT, ESPRIT and BRIT/EURAM are said to exhibit an integrative function. Nevertheless, this integration effect does not imply a national convergence towards a common European innovation policy. Even in this area it is rather the persistence of institutional variety, denoting diverse local, regional and national systems of innovation, which is reproduced, as the additional effects of subsidiarity mechanisms need to be reconsidered. This assessment corresponds with the fact that the character of the ESPRIT-programme is oriented towards the support of basic research which is typical for these types of programmes. The international co-operation of firms engaged in applied research shall be supported by complementing national and regional R&D programmes. Instead of focussing only on the technological competition between large firms it is therefore suggested that a more network oriented approach is necessary which integrates the innovation efforts of small and medium-
sized enterprises by balancing policy strategies for diversity and connectivity. In accordance with that position, Niosi and Bellon (1996) characterise the European Union as a prototype of a supra-national innovation system, that is as an institutional and organisational ensemble which corresponds with the restructuring of national and regional systems.

Pavitt and Patel (1999) come to the rather pessimistic conclusion that the non-globalisation of technology is mirrored by the persisting dominance of national innovation systems in Europe, as education and training, corporate governance, consumer's tastes and defence procurement practices which are portrayed as decisive components of an innovation system seem to remain under the influence of national institutions and organisations in the near future. Moreover, they suggest that an European innovation system would have to be built in structural and institutional accordance with the role model of the German national innovation system. This perspective explicitly contradicts the notion of institutional inertia and the persisting divergence of national systems. A like-minded assessment of the development potentials of an innovation system on the level of the European Union has been presented by Gregersen and Johnson (1997). Their argumentation is built on the thesis that European integration should be understood less as a convergence process but rather as a process of institutional learning with a cumulative and interactive character. Thus they suggest that the various research and innovation assistance schemes may prove to be beneficial for the catch-up growth of economies from the European periphery. Still, networks for technology transfer and collaborative R&D on the level of the European Union do not necessarily imply the emergence of an European system of innovation. While institutional incentives that are provided by national and regional systems of innovation will continue to be of major importance for European R&D activities it is concluded that a coherent European system of innovation will emerge in the long run only, if ever. This position is also maintained by Amable, Barré and Boyer (1997), who emphasise the persisting variety of national institutional regimes within the European Union, as economic convergence may lead to the further intensification of an institutional and organisational divergence of the national innovation systems.

National institutions do not seem to provide the most promising building-blocks for an European innovation system. Hence a focus of related policy initiatives should aim primarily at the intensification of European innovation networks between firms and other organisations. Consequently, it is necessary to examine whether those programmes in the field of technological innovation that are managed by the European Union should be interpreted as a basis for a strengthened intra-European co-operation regarding R&D and innovation. In this context, the design of transnational European oligopolies has recently constituted an important policy objective. Mytelka (1995) has analysed the impact of ESPRIT on the development of European oligopolies in the area of information and communication industries. Her conclusion suggests that these politically supported projects were bound to fail due to the market power of US-American and Japanese firms which were able to dominate the international process of standardisation. Accordingly, the major European multinationals in the information technology industry were forced to enter co-operation agreements with these US-American and Japanese firms, while following a corresponding logic of restructuring their R&D locations. Esser (1997) has come to similar conclusions as he reviews the results of the RACE-programme in the information and communication technology industry.

The evolution of a specific European pattern of technological collaboration continues to be unlikely. It is true that concentration tendencies have coined the development of information and communication technology industries in Europe since the early 1980s. Nonetheless, the resulting corporate alliances were soon striving for a deepening of their collaborative efforts with partners from the other Triad economies. This point of view corresponds with the results of Duysters (1996) who mentions the decreasing volume of strategic alliances within the European information and communication technology industry. This pattern of intensified corporate relations within the Triad, especially regarding R&D, has also been observed in other industries. The co-operative behaviour of firms in the electronics industry, for instance, shows that attempts of excluding US-American and Japanese firms from European Union funded projects like the HDTV-programme have proven to be inefficient and costly (Bloom 1994). Dunning (1993: 325n) maintains that ESPRIT failed to establish a stable and sustainable European base for science and technology. He concludes that rather the types of applied programmes such as EUREKA are going to play an important role for the formation of European corporate
alliances in the areas of R&D and innovation. All of this casts doubts on the feasibility of nurturing or constructing an European system of innovation. A simultaneous business presence of multinational enterprises in all the Triad economies has been prescribed as a strategic necessity that corresponds with the actual flow of resources. Technological collaboration is a matter where the complete Triad of Northern America, Europe and East Asia serves as the major playing field for strategic interaction. Thus it has been suggested that European innovation polices should put more weight on the role of extra-European R&D co-operation and knowledge exchange as an indispensable complement to the support of intra-European innovation networks (Meyer-Krahmer/Reger 1998: 18n).

Nonetheless, the contours of a supranational system of innovation on the level of the European Union seem to exhibit some influence on the distribution of European R&D locations at least on a regional level. Voyer and Roy (1996) suggest that the research programmes of the European Union have successfully contributed to an increasing ‘Europeisation’ of some regions as R&D locations, for these regions evolved as the European centres of gravity for corporate locational choices, supporting the ongoing formation of European high-technology clusters. This kind of regional impact has also been observed in the evaluation of European Union innovation programmes and their impact on the R&D activities of the German industry. Reger und Kuhlmann (1995) portray the corresponding erosion of the technology policy competence of regional governments versus the policy level of the European Union. They come forward with the observation of a strengthened inter-regional as well as transnational pattern of R&D co-operation on an European scale. Whatever shape the future European system of innovation may take, it seems to be most convincing to assume that the persistence of various levels and modes of interaction will contribute to its further development. The logic of technological globalisation points at an increasing role of local factors in the innovation process. This implies that the project of strengthening local as well as regional policy levels and the formation of an European system of innovation need to reinforce each other.

6 Conclusion

Summing up the discussion, it may be concluded that multinational enterprises originating from the European Union follow distinct strategies for the internationalisation of their R&D and innovation activities which are either pointing at an intra-EU ‘Europeanisation’ or at an US-European ‘Atlantisation’ of interactions within the Triad structure of the world economy. The notion of technological globalisation is thus only a useful device if it is combined with more specific qualifications. These tendencies may be understood as an expression of the idea that multinational enterprises should follow the strategy of a simultaneous insider presence on all the relevant Triad markets of Europe, Northern America and East Asia. The corresponding logic of technological globalisation is based on patterns of technological specialisation that are typical not only for certain national or regional economies but increasingly also for the related organisational behaviour of multinational enterprises which strive to economise on these patterns. It is true that it is firms, not countries, which compete on the global markets. Nonetheless, the income and employment effects of growth-inducing business activity on the one hand, as well as the institutional embeddedness of innovation on the other hand illustrate the economic impact of globalisation. Indeed, a major factor of the tendency for an ‘Atlantisation’ of European R&D co-operation is provided by the fact that the United States have developed a strong national science-base in expanding industries like biotechnology. While some industries centralise their basic research activities in the United States it seems that a kind of international division of knowledge generation and modification is evolving with local ‘pockets of innovation’ and ‘centres of excellence’ within the United States taking the global lead.

What does this mean for an European innovation policy which may constitute the basic components of a supranational system of innovation? Changes in the set-up of national production and innovation systems do not necessarily imply a complete economic and institutional convergence. This is basically due to the impact of historically rooted institutional ensembles that are not to be easily reconstructed by policy design. The Schumpeterian credo of integrating theory and history refers to these complex issues which are also reflected by the systems of innovation
approach (Ebner 2000a: 369n). Consequently, the convergence of some parts of an institutional configuration may result in the unintended consequence of a divergence of other parts of the institutional set-up, while diverging institutional configurations may produce converging economic results (Boyer 1993). Institutional variety, including the various forms of entrepreneurship and modes of innovation that characterise the European economies, thus seems to shape the future development of the European Union. It may be suggested that the logic of technological globalisation corresponds with an evolutionary logic of creating innovation by maintaining variety. Therefore, a feasible European technology community will be necessarily based on a negotiated delicate balance between regional, national and global economic concerns within the Triad structure of world markets.

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**Bibliography**


