11 How International are National (and European) Science and Technology Policies?

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11.1 Introduction

The internationalization of research and development is a fact. Numerous indicators point to a strong tendency towards intensified international activities as regards the generation and exploitation of new scientific knowledge and technologies. At the same time, the corporate strategies designed to internationalize R&D activities follow ever more differentiated rationales: there is apparently no one single reason, but a whole range of different motivations for international collaborations.

The consequences for science and technology (S&T) policy should be obvious: if more and more of the activities within a given country or region are conducted by foreign-based actors, and if the home-based actors reach out further and further beyond the borders of their home country (or region), it should be self-evident that national or regional policies have reacted – one way or the other.

In this chapter we concentrate on the international activities of multinational companies (MNC) and provide some evidence for the empirical trends both as regards the technological activities of MNCs and national policies to exploit these tendencies. It will be shown that – despite the obvious trends – national policy-makers have not fully understood the necessities to tailor appropriate, comprehensive approaches and that the contexts and existing activities in different countries vary considerably. Finally, we derive a couple of principal lessons to be considered by national and European policy-makers that seek to foster and take advantage of the global optimization of R&D portfolios.

11.2 Patterns of International R & D

11.2.1 Scale and Scope of International R&D

Recent trends. There are three different dimensions to the internationalization of science and research: international exploitation of nationally generated knowledge and technology; international technological and scientific cooperation and exchange; and the international generation of knowledge and innovation (Archibugi and Michie 1995; Archibugi and Iammarino 1999; Meyer-Krahmer et al. 1998). Current data indicate a robust tendency towards growing internationalization of science and research in all three dimensions (OECD 1997a, 1998a,b,c, 1999; UNCTAD 1996; UNESCO 1998; Narula 1999). Although certain aspects of this internationalization trend are well documented, and some effects can be quantified, the overall processes are extremely complex and the outcomes/impacts are highly uncertain. The existence of the phenomenon is generally accepted, but its importance and the trends are currently the topic of a lively debate (see Kuhlmann and Meyer-Krahmer 2001). Since the early 1980s, the international generation of innovation has increased, and affected the internationalization of research and development (R&D). During earlier periods of international expansion (the 1960s and 1970s), MNCs first built up their sales, distribution and assembly operations in foreign countries. In later phases (late 1970s/early 1980s), efforts were directed towards supporting foreign subsidiaries with corresponding capacities in application engineering and applied R&D. Although initially the tasks of development departments abroad were limited to adapting product and process technologies from the home country to local production and market requirements, there was a clearly recognizable trend, from the late 1980s, towards strengthening R&D in foreign countries and extending the global competence portfolio. Increasingly, research became established at a high level in foreign locations.

If the situation up to the end of the 1970s was largely characterized by the dominance of a world centre for research and innovation (the United States in many important fields of technology, and western Europe in individual fields, such as chemistry), it is now true to say that, for the most important fields, several centres are crystallizing out within the Triad countries – and in some instances even beyond. These are in fierce competition with one another, and, from time to time, very rapid changes in ranking take place. Because of this development, enterprises that are leading performers of R&D have to demonstrate a presence in several locations at the same time, establish sufficiently competent and extensive structures

there, and react as quickly as possible to dynamic changes in relative location advantages.

For this reason, R&D centres and product development capacities were established within the same corporation at several different Triad locations as a part of entrepreneurial integration strategies. At the same time, attempts are being made, through R&D cooperations and strategic technology alliances, to form networks as quickly and as flexibly as possible between institutionally and regionally scattered centres of competence. Empirical evidence has shown that since the 1980s the number of newly established strategic technology alliances has increased considerably (see Hagedoorn and Schakenraad 1990, 1993; Narula 1999), especially in the most dynamic technology fields, such as biotechnology, new materials and, above all, information technologies.

Complex mix of motives and the role of lead markets

Obviously, in a somewhat simplified typology globalization follows *different paradigms in different entrepreneurial functions* (Gordon 1994): (1) the internationalization of markets is determined by the search for markets with high income and low price elasticities of demand in conditions of free world trade, (2) the transnationalization of production locations is driven by the regime of production possibilities (qualified workforce, supplier-producer networks, costs, other comparative advantages, closeness to market), and lastly, (3) globalization is characterized by the pursuit of system competence through global "R&D sourcing" and the orientation towards the excellence of (national) innovation systems and related institutions[1].

However, there is growing evidence that the "three worlds" postulated in the above "three-different-paradigms" approach repeatedly impinge on one another, so that the various paradigms merge again to some extent – markets and the excellence of innovation systems are taken into consideration *together*: recent studies on determinants of location factors of the internationalization of research and development (Reger et al. 1999; Jungmittag et al. 1999) show that in different key technologies the three paradigms play varying roles. Differences between sectors regarding the degree of liberalization of international trade, the regulation of streams of direct investments, specific features of regional demand, economies of scale in production and the internationalization of technological knowledge, result in different levels of internationalization. Surveys in three selected technology fields indicated that the internationalization of R&D is mainly influenced by three factors, namely:

[1] In management theories these terms „transnationalization" and „globalization" are used the other way round (see, e.g., Bartlett and Ghoshal 1989).

- early linkage of R&D activity to leading, innovative clients ("lead users") or to the "lead market";
- early coordination of the enterprises' own R&D with scientific excellence and the research system;
- close links between production and R&D.

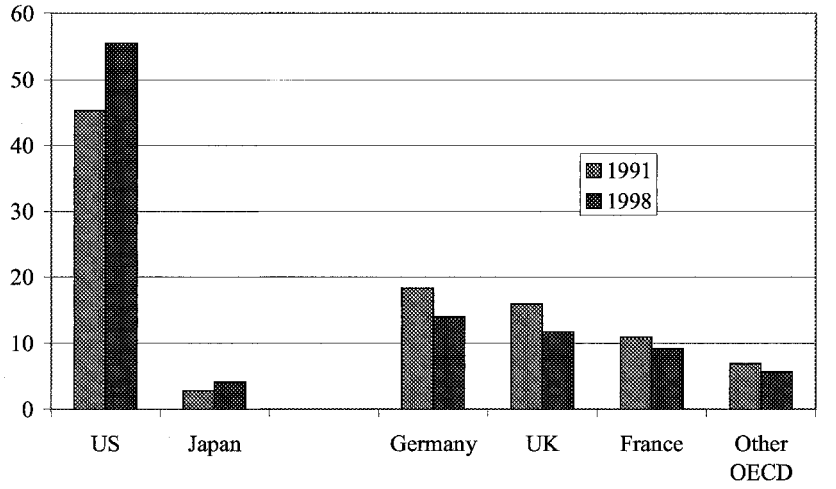
Different patterns within Europe

Within Europe, the degree of internationalization varies considerably. The roles of a home for international expansion and a host for foreign R&D laboratories are mostly concentrated in a few countries – mainly Germany, France and the United Kingdom. Within the European Union, three main clusters of countries – which are related to the companies' strategies – can be identified:

- *small, highly developed European countries*, such as Belgium, Sweden or the Netherlands (also Switzerland), where global players perform up to more than half of their R&D activities outside their home country. These countries have a relatively small pool of domestic R&D resources; firms therefore invest heavily in the international generation of innovations;
- *large European countries* with large technology bases and markets, such as Italy, Germany, and France, and where "their" MNCs perform between one-fifth to one-third of their R&D activities abroad. Nevertheless, many large enterprises in these large European countries, particularly in the machinery, transportation and electrical engineering sector, tend to concentrate a significant part of their research in the country of origin;
- *"intermediate countries"*, such as Spain, Portugal and Ireland, participate somehow differently in the new international division of labour. These countries lack well-equipped technological infrastructures and resources and are characterized by high foreign inward R&D investment and very low outward R&D investment. On the one side, MNCs contribute, quantitatively and qualitatively, to a great extent to the technological efforts of these countries. On the other side, there are, firstly, a considerable number of innovative domestic companies which do not internationalize (neither via exports nor foreign direct investment (FDI)). Secondly, most domestic firms operating in international contexts use exports as the basic and almost unique way of internationalization.

The (decreasing) weight of Europe as host to international R&D

The significance of the big European countries playing host to international R&D is qualified if one compares their weight as host to that of other regions in the world, mainly the US. In the course of the 1990s the attractiveness of Europe as a location for foreign companies declined. Of all R&D expenditure *under foreign control* in the manufacturing industry *within the OECD countries*, the share that is spent in the US has grown from 45.3% to 55.5%, the share of Japan has grown from 2.8% to 4.1%, while the share of Germany, France, the UK and the rest of the OECD countries has declined (OECD 2001; p. 26, fig. 10).

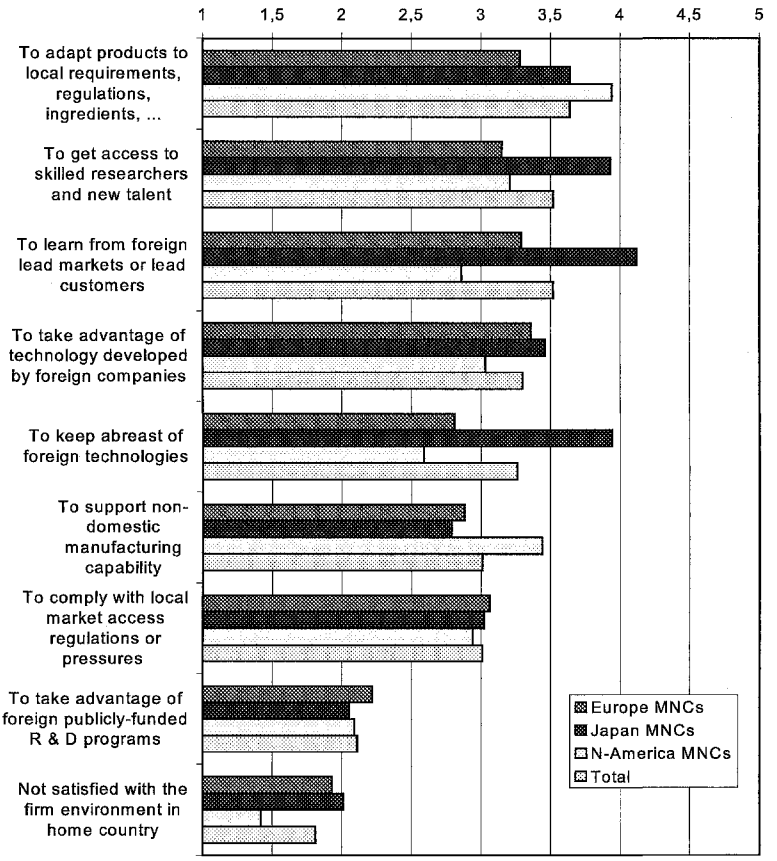


Source: OECD (2001).

Fig. 11.1. Share of R&D expenditure under foreign control in the manufacturing industry in selected OECD countries

11.2.2 Lessons on Location Factors of MNCs

The multitude of studies that have been produced in the last five to ten years has shown that R&D is motivated by a very broad variety of factors[2]. For example, Edler et al. (2002) have identified a whole range of reasons that drive internationalization.



1 = not important at all, 5 = very important
Source: Edler et al. (2002).

Fig. 11.2. Motivations for MNCs from the Triad regions to invest in R&D abroad

[2] See Criscuolo et al. (2001) for an overview.

Figure 11.2 shows, that despite this variety, the most important reasons can be grouped into two basic motivations: *knowledge exploiting* vs. *knowledge augmenting*[3].

Knowledge exploitation (R&D abroad to meet the peculiarities of foreign markets)

- *Mode*: Knowledge exploitation encompasses all motives that are related to R&D work done in order to adjust the existing technologies, products, and processes to meet the needs of local demand, supply, regulation (standards, etc.). In this mode, the major knowledge is generated in the home country, and, in a second step, exploited abroad by fine-tuning technological developments towards different needs and to support foreign production and marketing.
- *Empirical evidence*: For most companies, the bulk of activity is still the support of local production and marketing abroad (Cantwell 1995; Cantwell and Kosmopoulou 2001; Patel and Vega 1999; Patel and Pavitt 2000; Serapio and Dalton 1999). For example, for German MNCs various studies (Legler et al. 2000; Beise and Belitz 1998; Belitz 2002; Edler 2003) have shown that the technological areas developed abroad are very similar to those at home, indicating that companies mainly adapt what they have developed at home. This also means that for the bulk of R&D investment in a given host country the characteristics of its internal market (size, advanced users, advanced suppliers, product or process regulations) are more important than the quality of the science and research system.

Knowledge augmenting

- *Mode:* Knowledge augmenting, on the other hand, means that the international arena is used to generate new knowledge. Innovation is more and more knowledge- and speed-driven, MNCs are forced to be quick and excellent at the same time. Therefore, MNCs have perfectly genuine motives to tap into existing, forefront knowledge centres of excellence abroad and to take advantage of them. This might be done through simple monitoring activities, through integrating into existing scientific networks, or through employing scientific talent. In this paradigm of in-

[3] This is confirmed by a very broad range of recent studies, see, e.g., Dunning andNarula (1995), Meyer-Krahmer et al. (1998); Edler et al. (2001); Meyer-Krahmer (1997); Niosi (1999); OECD (1999); Pearce (1999); Pearce/Singh (1992); Criscuolo et al. (2001); Boutellier et al. (1999), Kuemmerle (1999) and Kumar (2001).

ternational R&D, the search for excellent research centres around the globe and the build up and re-transfer of knowledge are major tasks for "globally learning companies" (Meyer-Krahmer et al. 1998).

- *Empirical evidence:* a growing number of studies finds the knowledge augmenting mode becoming more and more important (Florida 1997; Koopmann and Münnich 1999; Boutellier et al. 1999; Cantwell 1995; Edler et al. 2001; Dunning and Wymbs 1999; Granstrand 1999; Pearce and Singh 1992; Pearce 1999; Criscuolo et al. 2001; Narula 1999). It has been shown that knowledge seeking and generating abroad correlates with
  - the knowledge intensity of the technological area[4],
  - the intensity and scope of the corporate R&D,
  - the perception of researchers and managers that the knowledge base of the host country is more advanced.

Secondary location factors

Beyond the two major strands of motivations a set of other location factors can be defined, the meaning of which, as identified in surveys, is in most cases lower than the meaning of the two sets of reasons just discussed.

- Vertical *cooperation* with local partners (suppliers, (lead) customers). The importance of vertical integration has grown, and so has the inclination of MNCs to locate parts of their R&D close to their most important suppliers and/or customers (Just 1997).
- *Efficiency (research costs)*: in some areas of research, the actual costs of performing it play a major role. It has been shown that if the level of expertise needed is available for less cost, and if the infrastructure limits transaction costs, research also follows efficiency (Gerybadze et al. 1997).
- *Follow the competitor*: in some cases, mainly in oligopolistic markets, a "follow the leader" effect has been observed even for R&D activities (Kumar 2001; Pearce and Singh 1992).
- *General political and financial framework conditions*: in none of the recent studies does the general political framework or a different financial

[4] A recent study on German MNCs abroad and foreign MNCs in Germany has shown a clear correlation between knowledge intensity of a technological field (average number of cited publications in a patent) and degree of international activity (Edler 2003).

framework (venture capital etc.) play a significant role as a driving force for R&D investment[5].

- *Public RTD policy*: all studies reviewed (including especially Kumar 2001; Edler et al. 2002 and Edler et al. 2003) find that public policy (R&D programmes, patent regime, some kind of indirect supporting schemes, etc.) are *not* a major determining factor, they are far less important than market size and requirements, or the various forms of knowledge supply.
- *"Side effects"*: finally, in interpreting data on R&D internationalization it is important to note that the build up of foreign research capacity is very often the by-product of merger and acquisition activities that are not driven by R&D considerations (Boutellier et al. 1999). As Archibugi (2000) has stressed, and as has recently been shown for German MNCs abroad (Edler et. al. 2003), the R&D intensity of foreign subsidiaries tends to be smaller than that of domestic companies. Therefore, it is true that external growth in R&D capacity by foreign firms through "side effects" increases the share of international R&D activities, however, in the medium and long run, such "side-effect" R&D capacities are often reduced if not closed down. Moreover, there are instances where existing linkage to the local knowledge base dissolves after post acquisition re-organizations[6].

11.3 Existing Policy Activities for Internationalization

Governments act on the increasing internationalization of science and technology, albeit slowly. Edler and Behold (2001) studied national public policies to exploit international science and industrial research. They analyzed strategies and initiatives set in motion by key actors in science and technology policy in eight countries (USA, Japan, France, United Kingdom, Netherlands, Switzerland, Malysia, South Korea)[7]. These activities could be directed at attracting or absorbing foreign knowledge or carriers

[5] However, in most cases where big MNCs are analyzed, different cultures of venture capital provision may play a very different role for small and young companies.

[6] An important issue for future research on foreign R&D investment will be what kind of *negative* effects might occur for local or regional innovation systems in the long run.

[7] Unfortunately, Germany was excluded from the empirical analysis that was conducted on behalf of the German Ministry for Education and Research.

of knowledge. The study found that, although there is awareness of a general leverage for policy, few countries develop an integrated policy strategy to address these issues. Nevertheless, the study identified a number of interesting initiatives that can serve as "benchmarks" for policy-makers elsewhere.

Following Meyer-Krahmer and Reger (1999), Edler and Behold see the rhetoric on internationalization as aiming either at enhancing the inward activities of foreign actors (attractiveness) or the outward activities of national actors to exploit knowledge generated abroad or to contribute to this generation (absorption). The following problems are typically identified:

- lack of attractiveness or insufficient national supply of scientists and industrial R&D in certain fields;
- brain drain; and/or
- isolation from, or lack of integration into, processes of international generation of knowledge.

From the strategic documents[8], five principal strategies were identified, which, without being all-embracing, cover the major strategic efforts of national administrations:

1. attraction of foreign scientists;
2. attraction and integration of foreign industrial R&D;
3. improvement of access to foreign knowledge and to technological lead markets;
4. targeted learning from administrative and management practices abroad; and
5. support for the international networking efforts of firms and scientists.

On the basis of these three problem dimensions and five strategic trajetories, Table 11.1 shows the characteristics of the countries.

[8] These are principal policy papers coming from research or economy ministries or state agencies. For an illustration, see, in the case of Japan e.g. Science and Technology Agency (Hg.) (1995) or Ministry of International Trade and Industry (MITI) (annually), or in the case of the USA e.g. Department of Commerce (1998, 1999).

Table 11.1. Strategic country characteristics

	USA	UK	CH	F	J	NL	SK	MY
Problem areas								
Lack of attractiveness for international scientists and industrial R&D capital	+	–	–	++	++	++	++	++
Brain drain	–	(+)	(+)	+	–	+	++	+
Insufficient integration into and exploitation of the global generation of knowledge	+	–	++	++	+	+	+	–
Strategic trajectories								
Attraction of foreign scientists	+	–	+	+	+	+	(+)	+
Attraction and integration of foreign industrial R&D capacities	+*	++*	–	–	–	+	(+)	++
Better access to foreign knowledge and technological lead market	+	++	++	–	+	+	++	–
Targeted learning from foreign administrative and management practices	+	+	–	–	+	++	–	–
Support of individual firms and scientists in international networking efforts	–	–	++	++	++	++	+	+

– no problem awareness/no strategic measures, (+) some problem awareness/no explicit measures yet, + some problem awareness/some measures taken, ++ high level of problem awareness/targeted strategic measures, * in the USA and in the UK attraction policies are mainly undertaken by the states and regions
Source: Edler and Boekholt 2000

In principle, three types of countries with similar strategic positioning can be defined, with the Netherlands being a special case. First, Switzerland, the USA, and the UK can be considered as a group of countries where policy-makers and administrators alike are convinced that their home country is attractive for foreign knowledge seekers. The overarching strategic orientation in these countries is towards the established strengths of the national innovation system, where world-class excellence will generate sufficient attractiveness. These countries concentrate on absorption. Switzerland, albeit developing a foreign science policy, has no explicit

public strategy to attract foreign researchers, especially for industrial R&D. Internationalization of academia is largely based on decentralized initiatives.

Second, despite their obvious differences, Japan and France have shown a lack of attractiveness and in addition even face a brain drain. In both countries, administrations have recognized that foreign scientists face a range of disincentives to integrate in their national innovation systems. Incentives for immigration are seen thus as strategically important.

Third, Malaysia and South Korea face the key challenge of catching up with the OECD economic and innovation systems. However, their strategies to exploit international science and research (S&R) are different. Apart from following a strategy of imitating foreign-developed technologies and products, South Korea has put little emphasis on international S&R, but has rather supported students and senior scientists in going abroad. Malaysia has chosen to concentrate on attracting foreign industry.

The Netherlands are a special case. The national economy and the innovation system have traditionally been very open and internationally integrated. Also, research policy and industrial policy have traditionally been linked. Consequently, the internationally oriented activities of the country mainly aim at pushing for more international integration of the national industry, both within the country (attraction schemes) and abroad, and the country has indicated its willingness to import best organizational practice to that end.

11.4 Consequences and Issues for Technology Policy in Europe

What does all this mean for a more appropriate technology policy in Europe? As a general consequence of this situation, the premise of national science and technology policy encountered in many countries that the main benefit from the public allocation of resources in this policy area flows into the national economy, is progressively dissolving. Not only the know-how produced in the national innovation system, but also other public investments, for instance in training and education, are increasingly being swept into the stream of the international exchange of knowledge. This development enlarges the focus of policy: it is not simply the appropriation of nationally generated knowledge that is involved, but the strengthening of a generally beneficial, interactive transactional exchange of knowledge. It is possibly as important to absorb knowledge that has been generated worldwide, as it is to support the production of knowledge in one's own

country. This statement is very important for technology policy on the national as well as the European level.

As a consequence of this analysis of the changes in the innovation strategies of large MNCs there are at least four dimensions that should be kept in mind by national and European policy-makers (Meyer-Krahmer and Reger 1999):

- strengthening European absorptive capacities and cooperating with non-European countries;
- attracting innovative companies from non-European countries;
- lead markets and learning for the mastery of complex innovations;
- integrating different policies towards an innovation policy in Europe.

To meet the challenges that arise within these four dimensions, policy-makers need to draw the appropriate conclusions from analysis of the location factors identified above. After all, policy needs to appeal to the decision-makers within these corporations. For heuristic reasons, the distinction between "market adaptation" and "knowledge creation" is initially maintained, while it is clear that a combination of measures to foster both modes at the same time are the most promising.

11.4.1 Policy Challenges Stemming from the Market Adaptation Mode

- Companies can be driven into investing in R&D if they sense a market to be a lead market requiring R&D presence alongside production or sales. This can be caused simply by different local demand (taste, tradition, etc.), by technologically advanced public or private demand, by advanced regulation or future oriented standards. If – in addition – a market is of a certain critical size, the adaptation to those local conditions triggers R&D investment. Therefore, European policy should identify and foster possible lead market areas, i.e., areas in which the end-user market is regarded as a trendsetter internationally. Especially in these markets, standards-setting regulations will drive European and non-European companies into research and development activities (Meyer-Krahmer and Reger 1999). Candidates for such lead markets in Europe could be in the field of pharmaceuticals, mobility (especially cars), (mobile) communication, and "sustainable" products and energy (especially fuel cell) (see Meyer-Krahmer (2004)).

- In this market adaptation – and similarly in the lead market oriented mode – direct policy measures seem to be less effective. Nevertheless, policy must ensure that those foreign companies that are willing to exploit a lead market and learn within lead markets – thus creating value within a host country – have access to cooperation partners, especially lead users. Here, public support schemes – including public procurement to trigger innovation – should not be discriminatory.

11.4.2 Policy Challenges in the Knowledge Creation Mode

- The greatest challenge, obviously, is to make a country or region scientifically or technologically attractive. Attractive locations for MNCs investing in the generation of new forefront knowledge are characterized by an excellence science system (excellent human capital, especially talent) that is accessible to foreign companies. European policy must foster the existence of, and accessibility to, scientific excellence and scientific-technological networks, including eagerness of universities and institutes to cooperate with (foreign) MNCs, including long-distance cooperation.
- As the necessity to integrate knowledge from very diverse technological areas into the industrial R&D process increases, and the absorption of knowledge from neighbouring fields becomes more important, locations that can offer accessibility to a wide scope of scientific and technological activities will become more attractive in the future. To ease the access to this wide scope within Europe would be an important element of any scheme to attract foreign MNCs to Europe.
- The enabling infrastructure, most importantly ICT networks, must be excellent, as coordination with the headquarter for reasons of integrating knowledge globally is crucial in this mode.

For the sake of analysis, the market adaptation and knowledge creation modes are mostly dealt with separately. The most important policy advice to be given, however, is that in order to attract foreign industrial R&D it is increasingly necessary to develop policy schemes that integrate the requirements of both modes, as the combination of advanced conditions to generate knowledge that feeds into innovation with a market that is able to absorb these innovations (lead markets) obviously has the greatest – and most likely sustainable – attractiveness for multi-national enterprises (Manes). At the same time the host country benefits, not only from ad-

vanced R&D activities and related networking, but also from value adding production activities.

Furthermore, some additional policy principles can be derived from the secondary location factors. As companies tend to follow the technological leader, the attraction of the prime players in the market should be a major goal, as this might more easily lead to agglomeration effects within a given region. In addition, as vertical cooperation is a major reason for many companies, it is important to ensure that access to local industrial clusters is not hindered for foreign MNCs. Finally, as public monetary incentives are of relatively minor importance for foreign MNCs, the issue is not whether the MNCs are eligible to receive additional money, but whether existing support schemes – and their regulations (exploitation, appropriation) – diminish the possibility of foreign MNCs to enter into technological or scientific cooperation schemes. However, from the importance that foreign MNCs attribute to integration into the local innovation systems, public policy can have a detrimental effect if it leads to the exclusion of foreign MNCs from certain cooperation schemes. This is perhaps the greatest problem with RTD support schemes, which are not open to companies from other countries, public policy should re-consider their openness. Therefore, it would be of major importance to have a new look at the openness issue, as the last comprehensive overview was OECD (1997b).

11.4.3 Limitations and Counterproductive Tendencies

The conclusions derived in this chapter are based on the empirical evidence of international R&D and the premise that policy needs to be tailored to meet the needs of internationally active MNCs. However, in order to avoid a somewhat naïve approach to appropriate policy-making, we conclude by pointing towards potential dangers.

Firstly, MNCs do not seem to rate direct policy measures geared towards R&D investment in their potential host countries as being a mature location factor. By far more important are the market and/or knowledge generation conditions. This means that expensive schemes seeking to attract companies simply by providing some kind of monetary or fiscal incentives might be a waste of money.

Second, there is tendency for winners to win and losers to lose and for attraction schemes in any form to create even more concentration and agglomeration within Europe, conflicting with cohesion policies. Therefore, it seems sensible that centres of excellence in Europe should rather be virtual, and characterized by new schemes of long-distance cooperation. The logic of the European Research Area (ERA), to combine complementary

excellence throughout Europe, could result in a new mode of attractiveness. The idea of building up a critical mass of excellence in any given technological area through having competence centres cooperate and exchange, as is the major goal of the ERA, might be a major step in that direction. The question, however, would be how accessible these (virtual) centres would be foreign MNCs.

Third, making European companies re-locate existing R&D capacity back to Europe through some kind of incentive schemes could backfire. Either to accompany local production or tap into knowledge structures abroad, the reasons for locating R&D capacity in foreign markets are reasonable and, after all, serve the needs of the parent company in Europe. Rather than thinking of attraction schemes, Europe has to make sure that, especially for knowledge centres and lead markets, it builds up more reasons for MNCs to come back simply for their own good, not to assist public policy.

For the time being, one might even help companies, even smaller ones, to integrate into international knowledge creation structures, since the generation of forefront knowledge fosters competitiveness at home as well (absorption). For example, policy could assist companies to install knowledge management practices that ensure re-integration of knowledge.

11.5 References

Archibugi D, Michie J (1995) The globalization of technology: a new taxonomy. Cambridge Journal of Economics 19: 121-140.

Archibugi D, Iammarino S (1999) The policy implications of the globalisation of innovation. In: Archibugi D, Howells J, Michie J (eds.) Innovation policy in a global economy. Cambridge University Press, Cambridge, pp. 242-271.

Archibugi D (2000) The globalisation of technology and the European innovation system. Paper prepared as part of the EU Project: Innovation Policy in a Knowledge Based Economy.

Bartlett CH, Ghoshal S (1989) Managing across borders: the multinational solution. Bartlett CA; Doz Y.; Hedlund G (eds.) Managing the Global Firm. Routledge, London.

Beise M, Belitz H (1998) Trends in the internationalisation of R&D – the German perspective. Vierteljahreshefte zur Wirtschaftsforschung des DIW 67(2): 67-85.

Belitz H (2002) Deutschland als Forschungsstandort multinationaler Unternehmen, DIW-Wochenbericht 16/02.

Boutellier R. Gassmann,O. von Zedtwitz,M.(1999) Managing global innovation. Uncovering the secrets of future competitiveness. Springer, Heidelberg.

Cantwell JA (1995) The globalisation of technology: what remains of the product cycle model? Cambridge Journal of Economics 19: 155-174.

Cantwell J, Kosmopoulou E (2001) What determines the internationalisation of corporate technology. In: Forsgren M, Havila V, Håkansson, H (eds.) Critical Perspectives on Internationalisation. Pergamon, Amsterdam, pp 305-334.

Criscuolo P, Narula R, Verspagen B (2001) Measuring knowledge flows among European and American multinationals: a patent citation analysis. Paper presented at the The Future of Innovation Studies conference, Eindhoven.

Dunning JH, Wymbs C (1999) The geographical sourcing of technology-based assets by multinational enterprises. In: Archibugi D, Howells J, Michie J (eds.) Innovation policy in a global economy. Cambridge University Press, Cambridge, pp. 185–224.

Dunning J, Narula R (1995) The R&D activities of foreign firms in the United States. International Studies of Management & Organization 25(1-2): 39-73.

Edler J, Boekholt P (2001) Internationalisierungsstrategien in der Wissenschafts- und Forschungspolitik, Study for the German BMBF, Bonn.

Edler J, Meyer-Krahmer F, Reger G (2001) Managing technology in the top R&D spending companies worldwide - results of a global survey. Special Issue of the Engineering Management Journal, Managing High Technology Research Organizations 13(1): 5-11.

Edler J, Meyer-Krahmer F, Reger G (2002) Changes in the strategic management of technology - results of a global benchmarking study. R&D Management Special issue 32(2): 149-164.

Edler J, Döhrn R, Rothgang M (2003) Internationalisierng industrieller Forschung und grenzüberschreitendes Wissensmanagement. Eine emirische Analyse aus der Perspektive des Standortes Deutschland, Karlsruhe.

Edler J (2003) International research strategies of multinational corporations: A German perspective. Technological Forecasting and Social Change 71: 599-621.

Florida R (1997) The globalization of R&D: results of a survey of foreign-affiliated R&D laboratories in the USA. Research Policy 26: 85-103.

Gerybadze A, Meyer-Krahmer F, Reger G (1997) Globales Management von Forschung und Innovation, Schaeffer-Poeschel, Stuttgart.

Gordon R (1994) Mastering globalisation. Seminaron The Future of Industry in Europe, Brussels.

Granstrand O (1999) Internationalization of corporate R&D: a study of Japanese and Swedish corporations. Research Policy 28: 275-302.

Hagedoorn J, Schakenraad J (1990) Inter-firm partnerships and co-operative strategies in core technologies. In: Freeman C, Soete L (eds.) New explorations in the economics of technical change. Pinter Publishers, London, pp. 3-37.

Hagedoorn J, Schakenraad J (1993) Strategic technology partnering and international corporate strategies. In: Hughes K (ed.) European competitiveness. Cambridge University Press, Cambridge, pp. 60-86.

Jungmittag A, Meyer-Krahmer F, Reger G (1999) Globalisation of R&D and technology markets - trends, motives, consequences. In: Meyer-Krahmer F

(ed.) Globalisation of R&D and technology markets: consequences for national innovation policies. Physica-Verlag, Berlin, pp. 37-78.

Just RW (1997) Die Internationalisierung der Unternehmensbereiche Forschung und Entwicklung: Theoretische Erklärungsansätze, Determinanten und Indikatoren unter Berücksichtigung des Wirtschaftsstandortes Deutschland. Lang, Frankfurt.

Koopmann G, Münnich F (1999) National and international developments in technology. Intereconomics 34(6): 267-278.

Kuemmerle W (1999) Foreign direct investment in industrial research in the pharmaceutical and electronics industries – results from a survey of multinational firms. Research Policy 28: 179-193.

Kumar N (2001) Determinants of location of overseas R&D activity of multinational enterprises: the case of US and Japanese corporations. Research Policy 30: 159-174.

Kuhlmann S, Meyer-Krahmer F (2001) Internationalisation of innovation, interdependence and innovation policy for sustainable development. In: Sweeney G. (ed.) Innovation, economic progress and the quality of life. Edward Elgar Publishing. Ltd., Brookfield, pp. 86-110.

Legler H, Beise M, Gehrke B, Schmoch U, Schumacher D (2000) Innovationsstandort Deutschland. Chancen und Herausforderungen im internationalen Wettbewerb. Moderne Industrie, Landsberg/Lech.

Meyer-Krahmer F (1997) Konsequenzen veränderter industrieller FUE-Strategien für die nationale Forschungs- und Technologiepolitik. In: Gerybadze A, Meyer-Krahmer F, Reger G (eds.) Globales Management von Forschung und Innovation. Schäffer-Poeschel, Stuttgart, pp. 196-215.

Meyer-Krahmer F, Reger G (1999) New perspectives on the innovation strategies of multinational companies: lessons for technology policy in Europe. Research Policy 28: 751-776.

Meyer-Krahmer F (2004) Vorreiter-Märkte und Innovation. Ein neuer Ansatz der Technologie- und Innovationspolitik. In: Steinmeier F-W (ed.) Made in Germany '21. Hoffmann & Campe Verlag, Hamburg, pp. 95-110.

Meyer-Krahmer F, Archibugi D, Durand T, Molero J, Pavitt K, Soete L, Sölvell Ö, Reger G (1998) Internationalisation of research and technology: trends, issues, and implications for science and technology policies in Europe. ETAN Working Paper.

Ministry of International Trade and Industry (MITI) (published annually) Trends and future tasks in industrial technology (White Paper).

Narula R (1999) Explaining the growth of strategic R&D alliances by European firms. Journal of Common Market Studies 37(4): 711-723.

Niosi J (1999) The internationalisation of industrial R&D: from technology transfer to the learning organisation. Research Policy 28: 107-117.

OECD (1997a) National Innovation Systems. OECD, Paris.

OECD (1997b) Access of foreign firms to publicly-funded European RTD programmes (OECD/GD(97)). OECD, Paris.

OECD (1998a) Facilitating technology co-operation: proceedings of the Seoul conference. OECD, Paris.

OECD (1998b) Internationalisation of industrial R&D. Patterns and trends. OECD Paris.
OECD (1998c) Main science and technology indicators. OECD, Paris.
OECD (1999) Globalisation of industrial R&D - policy issues. OECD, Paris.
OECD (2001) Measuring globalisation. The role of multinational in the OECD economies. OECD, Paris.
Patel P, Pavitt K (2000) National systems of innovation under strain: the internationalisation of corporate R&D. In: Barrell R, Mason G, O'Mahony M (eds.) Productivity, innovation and economic performance. Cambridge University Press, Cambridge, pp. 217-235.
Patel P, Vega M (1999) Patterns of internationalisation of corporate technology: location vs. home country advantages. Research Policy 28: 145-155.
Pearce RD, Singh S (1992) The globalization of research and development, London.
Pearce RD (1999) Decentralised R&D and strategic competitiveness: globalised approaches to the generation and use of technology in multinational firms. Research Policy 28: 157-178.
Reger G, Beise M, Belitz H (1999) Internationalisierung technologischer Kompetenzen. Trends und Wirkungen in den Schlüsseltechnologien Pharmazeutik, Halbleiter und Telekommunikation. Physica, Heidelberg.
Science and Technology Agency (Hg.) (1995) Kagaku Gijutsu Kihonhô ni tsuite: The Science and Technology Basic Law, Law No. 130 of 1995, Tokyo.
Serapio M, Dalton D (1999) Globalization of industrial R&D: an examination of foreign direct investments in R&D in the United States. Research Policy 28(2-3): 303-316.
US Department of Commerce (Technology Administration) (1998) International plans: the global context for U.S. technology policy. Department of Commerce, Washington, DC.
US Department of Commerce (Technology Administration) (1999) Globalizing industrial research and development. Department of Commerce, Washington, DC.
UNESCO (1998) United Nations Educational, Scientific and Cultural Organisation, World science report 1998. United Nations, New York.
UNCTAD (1996) United Nations Conference on Trade and Development, World investment report 1996. United Nations, New York/Geneva.