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[629] Paper

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No. 629 August – 2002

Norsk Utenrikspolitisk Institutt

Norwegian Institute of International Affairs

Utgiver: NUPI

ISSN: 0800 - 0018

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Multinationals Searching for R&D Spillovers: A Survey of the Literature

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Abstract:
This paper surveys the literature on R&D and technology spillovers as a motive for FDI. During the last years, a growing body of theoretical studies has generated formal arguments supporting the economic rationale for such behaviour. Yet, theoretical contributions are clustered within a few schools and a wider approach is necessary in order to understand the mechanisms that relate R&D spillovers to FDI. The empirical literature is more numerous, but provides ambiguous conclusions with respect to the strength of this motive. Micro studies provide less supportive results as compared to studies based on more aggregate data. Studies based on patent information are generally supportive to the existence of this motive.

Keywords: Multinationals, FDI, R&D spillovers, technology sourcing, absorptive capacity.

JEL classification code: F21, O31, O32

Acknowledgements:
This research has been financed by the Research Council of Norway, under the project SAKI – Investeringer i forskning og kompetanse som kilde til økonomisk utvikling, grant number 124635/610, and the EU, through the targeted socio-economic research program TSER. I am grateful to Jan Fagerberg, Erik Biørn, Arne Melchior, and Rajneesh Narula. They have all given valuable comments and guidance. The usual disclaimer applies.

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1. Introduction

According to Dunning (1993), approximately 75% of world-wide business R&D is conducted within multinational companies. OECD (2001) reports that R&D activities of foreign owned companies represent a large and growing share of overall R&D activities in the industrialised countries. The value of R&D activities in foreign owned companies in the OECD area increased from 22.5 billion USD in 1991 to 36.1 billion USD in 1998.[1] The fact that multinationals tend to be technologically advanced and highly R&D intensive, has triggered a large amount of research on the existence and effects of spillovers from multinational companies to their host countries (the countries where the multinationals are located).[2] This research has devoted much of the attention to developing countries, where it is hypothesised that knowledge and technology spillovers through foreign direct investment (FDI) may play an important role in the development and growth of such countries. Blomström amd Kokko (1998 and 2001) present surveys of this literature.[3]

During the last two decades, a new strand of studies has focused on spillovers running the opposite way, that is, from the host economies to multinational firms. The number of scientific contributions to this field is small as compared to those focusing on spillovers from multinationals. However, the body of literature has now reach a critical size, where there is a growing need for a structured synthesis of the methods used and results derived so far. The objective of this paper is to meet some of these needs, by presenting a survey of the literature on technology and R&D spillovers as motives for FDI.

The growing focus on spillovers as a motive for FDI and multinationalisation of firms, has to a large extent been driven by recent developments within the fields of economics and the business sciences, where the role of industrial agglomeration and business

[1] R&D by foreign owned firms as a share of total business R&D in the country ranged from 14% in Finland to approximately 65% in Ireland. The larger OECD countries reported the following shares: US: 16% (1998), Germany: 17% (1995), France: 18% (1998), Italy: 23% (1992), UK: 32% (1999) and Canada: 37% (1998).

[2] See among others Aitken and Harrison (1996), Blomström (1989), Ethier and Markusen (1996, Kokko (1992), Mansfield and Romeo (1980).

[3] Caves (1996) presents a more general review of linkages between technology and multinational activity.

clusters has received strong attention.[4] The analysis of agglomeration is, however, not new. In his seminal work, Marshall (1891) claims that firms tend to cluster or agglomerate in certain geographical locations for three reasons. First, firms choose to locate close to each other since spatial proximity tends to increase knowledge and technology spillovers. Second, firms and workers benefit jointly from such clusters since workers one the one hand are less exposed to unemployment as the number of firms increase, while firms benefit from a large pool of workers and skills. This effect has been named *the labour market pooling effect*. Finally, agglomeration of economic activity is gainful due to forward and backward linkages. In other words, firms profit from a large variety of input suppliers, whereas the suppliers profit from a large number of demanders.[5] The strong presence of foreign companies in large industrial clusters, such as the Silicon Valley, the financial district in London and the designer industry in Milan, demonstrates that the forces of agglomeration work across borders, attracting multinational companies to foreign locations with high industrial activity. The importance of agglomeration forces for FDI has been documented in a series of studies that will be presented in later sections.

In this survey, we focus on the spillover mechanism behind agglomeration. Naturally, there is good reason to expect that labour market pooling effects as well as forward and backward linkages also work as motives for FDI. Indeed, this has been widely discussed in e.g. Markusen and Venables (1999), Markusen (1995) and Fosfuri, Motta and Rönde (2001). However, a survey including these issues is too ambitious within a single paper and is therefor left to other scholars.

The eclectic OLI approach to multinational activity introduced by Dunning (1977) has become a guiding theory for many researchers who study the behaviour multinational companies. It is important to establish in what way the motives for FDI presented here relates to Dunning's framework. In the OLI approach, it is claimed that there are three elements that must be in place for firms to go multinational. First, firms invest abroad in order to fully capture the economic gains of being the owner of a specific product or

[4] See for instance Fujita, Krugman and Venables (1996), Fujita and Thisse (1996), Porter (1985) and Porter (1998).
[5] Fagerberg (1995) presents a discussion of this element in terms of user-producer interaction.

technology (ownership advantage). Second, firms must experience a need to internalise its technology and knowledge in order avoid that this knowledge leaks out to competitors abroad. One way to internalise the knowledge, is to invest in a local subsidiary that takes care of production and sales activities (internalisation advantage).[6] Finally, firms must find it profitable to establish subsidiaries in countries that are abundant with respect to natural as well as created assets (location specific advantages). The motives discussed in this survey relate predominantly to the location specific advantages, since a positive outcome of spillovers requires the existence of assets, such as knowledge and R&D-generated innovations, that are not perfectly appropraible.

In the title of this survey, we deliberately use the term 'R&D spillovers'. We use this term because most of the empirical studies apply R&D activities as a measure of the technology and knowledge level of firms, industries and countries. One could however, equally well use the amount of innovations, the number of high-skilled employees or the presence of high-tech machinery as proxies for potential spillovers. The concept of knowledge and R&D spillovers between firms is closely related to the literature on knowledge externalities. In order to give a thorough overview of how such spillovers can motivate multinational activity, we briefly discuss this concept in Section 2, and relate it to the spatial dimension. Here we also raise questions that relate to the firms' ability to learn from or absorb external knowledge sources. The fact that many multinational firms conduct much of their R&D activities outside their home-base may indicate that they have a high absorptive capacity. Since research and technologically advanced activities are believed to enlarge the benefits from FDI, we devote some space to a discussion of such activities in foreign subsidiaries of multinationals. In Section 3, we review the theoretical contributions that model spillovers as a potential motive for FDI. Section 4 presents a survey of empirical studies and provides an attempt to compare the different results. In Section 5, we conclude and briefly discuss problems that relate to causality and simultaneity.

The reader should notice that the subject of spillovers or technology sourcing as a motive for FDI is rarely studied separately. Both theoretical and empirical contributions often

[6] See Horstman and Markusen (1987) for a formal approach to the internalisation problem.

study several motives simultaneously, and much of the work in writing this survey is related to identifying and separating out the spillover motive for FDI in the literature. A survey of this format will necessarily not be covering the complete literature on this field. Being an economist, I suffer from not being completely updated on the relevant research within other fields at all times. Yet, I have at least tried to include the central studies published within other academic fields.

During the last years, a growing body of theoretical studies on R&D spillovers as a motive for FDI has generated formal arguments supporting the economic rationale for such behaviour. Yet, theoretical contributions are clustered within a few schools and a wider approach is necessary in order to understand the mechanism that relate R&D spillovers to FDI. The empirical literature is more numerous, but provides ambiguous conclusions with respect to the strength of this motive. Micro studies provide less supportive results as compared to studies based on more aggregate data. Studies based on patent information are generally supportive to the existence of this motive.

2. The concept of R&D and technology spillovers

There is ample evidence showing that R&D spillovers are limited by geographical distance. This can partly be explained by language and cultural barriers, limiting the interaction between firms that could generate spillovers. Furthermore, we also know that there exists a strong negative correlation between geographical distance and international trade and FDI, a relationship which is commonly described as the gravity effect (see e.g. Leamer and Levinsohn (1995)). Based on US patent registers, Henderson, Jaffe and Trajtenberg (1993) and Jaffe and Trajtenberg (1996) show that patents are cited more often when the patentee and the citing firm are located in the same state or nation. This finding is confirmed by Maurseth and Verspagen (1999) using the European patent database, and Keller (2002) where the analysis is based on R&D activities in OECD countries.[7] The geographical limitation of spillovers gives a clear incentive to establish subsidiaries close to locations where other knowledge and technology intensive firms are

[7] Keller (2002) finds that the amount of spillovers is halved at a distance of 1200 kiometers. Mauseth and Verspagen (1999) finds that a one percent increase in the distance between the region that patents and the region that cites the patent, contributed to a 0.3 percent decrease in the number of citations.

located. In an international context, this incentive will result in movements of capital form one country to another in the form of FDI.

In the study of R&D spillovers transmitted through international trade, see e.g. Coe and Helpman (1995) and Papaconstantinou et al. (1996), it is implicitly assumed that the innovations and quality improvements derived through R&D investments are embodied in the traded product, generating *embodied R&D spillovers*. In the case of R&D spillovers through FDI, there is reason to believe that spillovers also relate to the establishment of international joint ventures, interaction through the local labour market, informal contacts between firms or active surveillance of the activities, including R&D, of other firms. In this way, we are rather speaking about *disembodied R&D spillovers*. In a conceptual discussion of R&D spillovers, Griliches (1992) introduces this distinction between *embodied* and *disembodied* R&D spillovers. According to a large business survey reported by Levin et al. (1987), US business managers ranked informal conversations and technological updating through business networks and relevant literature as central sources of external technology and R&D appropriation. Based on these findings, one may claim that disembodied spillovers work as an important mechanism for transmission of knowledge and technology between firms. Furthermore, worker mobility through the labour market (see Almeida and Kogut (1999) and Møen (2001)), ownership linkages like FDI and different forms of cooperation between firms also appear to be important sources through which knowledge and technology may be transmitted. All these elements point to the presence of so-called disembodied R&D spillovers.

A clear difference between embodied and disembodied R&D spillovers is related to the fact that embodied R&D spillovers are linked to a distinct economic transaction whereas this is not necessarily the case for disembodied R&D spillovers. Whenever there is an economic transaction linked to the diffusion of knowledge and technology, one must ask oneself whether the gains from these transactions are due to R&D spillovers, or whether they relate to the ability to reap the benefits or rents derived by the R&D activities of other firms. This identification problem is also discussed in Griliches (1992), who introduces the two categories *rent spillovers* and *pure spillovers*. Rent spillovers describe the positive externalities that arise when the value of an input to the firm

exceeds the input cost. This way, the buying firm captures some of the rent associated with the development and production of the product.[8] Pure spillovers on the other hand are defined by the positive externalities that relate to the spread of R&D results, technological, organisational and marketing competencies as well as knowledge in general. It is important to keep this distinction in mind in a review of the effects of R&D and technology spillovers on multinational firms, since rent spillovers are rarely mentioned in the theoretical and empirical contributions surveyed below.

The question of how tacit the R&D generated knowledge is, appears to be one of the most important issues in the study of R&D spillovers[9] Some innovations, for instance within the chemical and pharmaceutical industries, are relatively easy to understand and copy, and are consequently often commercially protected through patents. Activities and practices within service sectors are often based on long experience and complex organisational structures that are highly tacit. Learning from these activities often required direct participation and frequent interaction. Other innovations, for instance within the software industry or the advanced materials industry, are hard to disclose, either because they are coded in some way or because the apparatus needed to conduct successful reverse engineering or copying is complex and expensive. In order to analyse the empirical importance of tacit and codified knowledge for R&D spillovers, it is in principle not sufficient to study R&D investments as a uniform activity. More detailed information is necessary, describing the form of R&D activities and the efforts invested in protecting and codifying the innovations.

Although there exists a large pool of potentially available knowledge and technology, economic agents are not always able to benefit from these, since they lack the competencies that are required in order to search for, decodify and adapt external knowledge. This problem is extensively discussed in the development literature where it is claimed that developing countries may get locked into a development trap since an

[8] Obviously, rent spillovers are not compatible with a perfectly competitive market where the marginal product if the input is equal to factor costs. But if introduce imperfect competition, for instance an element of monopsony power, rent spillovers become possible since the down-stream firm is able to push down factor prices and capture some of the rent that otherwise would have been absorbed by the input supplier.

[9] See e.g. Cowan and Foray (1997) and Nelson and Winter (1982) for more on this.

underdeveloped knowledge base, infrastructure and institutional structure make them unable to learn from knowledge externalities. See e.g. Gerschenkron (1962), Abramovitz (1986) and Keller (1996) for contributions to this field.

Studies of knowledge externalities on the firm and industry level confirm that these competencies are also important when we look at spillovers at a more disaggregated level. Cohen and Levinthal (1989) performed an econometric study on the firm level, based on the idea that R&D spillovers (domestic in this context) were a function of the absorptive capacity of firms. The authors argued that this capacity is a function of the firms' own R&D activities, since such activities enable the firm to more easily identify, assimilate and exploit knowledge outside the firm. Their hypothesis was confirmed in an empirical analysis that showed that successful technology appropriation requires significant R&D investments that enable the capacity to absorb.

The concept of absorptive capacity is developed and predominantly discussed within the management literature. Clearly, the relationship between R&D investments and absorptive capacity is complex. R&D and knowledge investments in general will not always contribute to a firm's absorptive capacity. Cohen and Levinthal (1990) and Nelson and Winter (1982) present discussions on the organisation of such investments, and point out some central features in organisations that are able to develop their absorptive capacity successfully.

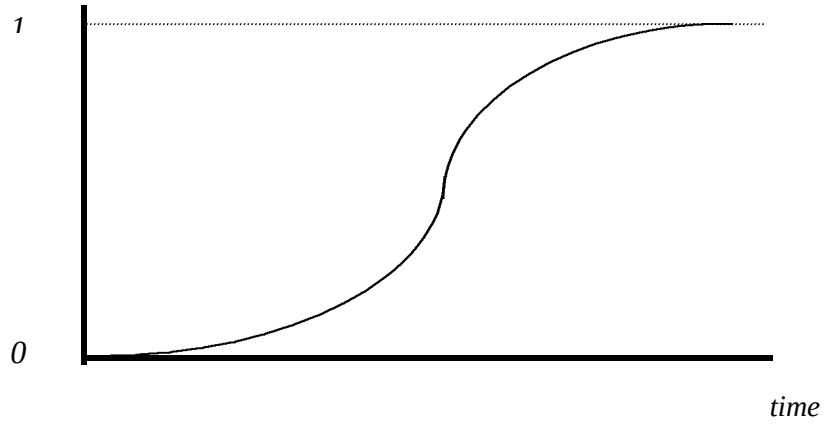
First, it is claimed that the capacity to absorb and utilise external knowledge and R&D results is strongly related to the willingness to invest in broad-based knowledge. Many firms tend to focus exclusively on the specific technology that runs their production activities. Such a narrow focus may turn the attention away from relevant complementary knowledge and technology, and since such complementarities often play an important role in the development of the technology front, a narrow-focused knowledge base is often detrimental to the learning and performance of firms. Cockburn and Henderson (1998) represent one of the few studies that explicitly analyse how firms invest in order to absorb external knowledge. In a study of the pharmaceutical industry, they show that firms with a high innovation rate spend much resources on collaboration

with public sector research measured in terms of the number of co-authorships. This form of activity is not necessarily directly linked to the core research activity in the firm.

Second, Cohen and Levinthal (1990) emphasise the importance of efficient exchange of information within the organisation. Although a firm is actively spending resources on the search for knowledge outside the firm walls, the gains from such investments can only be realised if this knowledge is transferred to the sub-units that actually take this knowledge in use. Consequently, absorptive capacity is to a large extent related to the internal organisation of firms.

As outlined in Karshenas and Stoneman (1995), the diffusion of R&D results between firms, industries and countries is often observed to follow a logistic pattern through time, much in line with epidemic models (see Figure 1). This implies that the firms with the largest absorptive capacity adopt the new technology first, followed by firms with a lower absorptive capacity. Also, industries where firms are highly R&D and innovation-intensive, will experience a relatively fast diffusion of R&D results since firms have a high absorptive capacity. As outlined in the introduction, multinationals are highly R&D intensive and conduct considerable amounts of R&D abroad. Consequently, there is reason to expect that multinationals have a high absorptive capacity, which suggests that that R&D spillovers are particularly important for multinational firms.

Figure 1: Proportion of firms that have absorbed and utilised an innovation



3. Theories on FDI motivated by R&D spillovers

According to Fujita, Krugman and Venables (1996), formal theoretical modelling of spillovers as an agglomeration force is complicated since the concept of spillovers is vaguely defined. Consequently, this agglomeration force has almost been ignored in the theoretical modelling of agglomeration described in the new economic geography and new international trade literature. However, this reluctance to model the location behaviour of firms based on spillovers has not been equally dominating in other theoretical fields. The majority of formal theories that consider spillovers as a motive for FDI, are found within the industrial organisation literature, but evolutionary models also exist.

In the school of industrial organisation, the main focus is on strategic interaction between firms that compete in a market. There exists a large body of studies that analyse the impact of R&D spillovers in a strategic setting,[10] but the number of theoretical contributions that focus on links between FDI and spillovers is relatively small. These studies are almost exclusively based on strategic interaction in Cournot duopoly games where the R&D activities of firms either contribute to reduced production costs (process innovations) or improved demand (product innovations). Some of the models take the R&D activities or technology level of firms as given while others explicitly model the R&D and technology investment decision in the game. Furthermore, most of these models describe two entry strategies into foreign markets, either through exports or through FDI. Exports incur trade costs that raise the varable costs of firms while FDI is associated with a fixed investment cost relating to the establishment of a foreign subsidiary.

In Fosfuri and Motta (1999), the commonly held view that firms undertake FDI in order to exploit their competitive advantages in foreign markets, similar to the ownership advantage in Dunning (1977), is challenged. In other words, they claim that we may observe multinationals with a relatively low technology level, motivated by localised spillovers. This result is based on a two country Cournot duopoly model where firms may choose to service the foreign market either through exports or FDI. The relative

[10] See e.g d'Aspremont and Jacquemin (1988), Simpson and Vonortas (1994), and Suzumura (1992).

technology level of firms is exogenous in this model. Technology or alternatively R&D results are believed to spill over to the technology follower with a certain probability, as long as the follower goes multinational. There are, however, no spillovers through exports. The model is solved using numerical simulations, where the technology gap and the relative size of the markets in the two countries play a central role. The model shows that for certain relative market sizes, both the technology leader and the technology follower will chose to service the foreign market through FDI. The leader is motivated by its technological advantage in the foreign market, while the follower is searching for spillovers. Bjorvatn and Eckel (2001) provides a similar model, but allows the technology leader to chose entry strategy first. They also assume that there are costs relating to the transfer of knowledge between the foreign subsidiary and the home base of the firm. In this setting, the technology leader may find it optimal to chose FDI in order to deter the follower from investing abroad in search for spillovers.

Siotis (1999) takes this model one step further, allowing both the technology leader and the follower to take advantage of localised R&D spillovers. The paper identifies three effects of spillovers that affect the decision on whether to export or go multinational. First, a FDI-enhancing effect which increases with the rate of spillovers whenever the technology difference between firms is small. This effect relates to the fact that the costs of relatively similar firms are reduced as spillovers grow since they share more of the technology, driving up profits for both firms. The second effect is a dissipation effect of spillovers that reduces a strong technology leader's gains from investing abroad. When a firm is a strong technology leader, spillovers will reduce his ownership advantage since the competing firm has a lot to learn from while there is little to learn from the foreign sources. This drives down profits relative to the case where exports is chosen. Finally, a sourcing effect of spillovers is identified that relates to trade costs. In the case where trade costs are small and investment costs are relatively large, the presence of spillovers may still make it profitable to chose FDI since this strategy allows the firm to cut costs through technology sourcing.

Petit and Sanna-Randaccio (2000), propose a duopoly model where firms first decide upon the foreign market entry mode. Thereafter, they choose the optimal R&D investment level, and finally they compete in outputs in the two countries. Consequently,

the relative R&D or technology level of firms is determined endogenously in the model. As opposed to the models mentioned above, this model assumes that spillovers are equally strong whether you export or invest abroad. Therefor, the model does not explicitly assume that spillovers are localised. Once again, export incur additional transport costs, while FDI requires fixed investment costs, and R&D and spillovers contribute to reduced production costs. Since firms and markets are symmetric, the model only predicts symmetric foreing entry strategies in equilibrium. That is, either both firms export or invest abroad. The study provides two important messages that relate to spillovers and multinationals. First, they show that firms will invest more in R&D if both firms chose FDI as compared to exports, even though the spillover rate is the same under both strategies. They explain this based on the qualitative difference between export and investment related costs. More R&D investments contribute to reduced marginal costs, driving up the equilibrium output. If firms export, there is a constant trade cost associated with the higher output, under FDI however, the fixed cost is spread out over more products as output grows, driving down marginal costs. Thus, R&D will be higher under FDI. Second, stronger spillovers give an incentive to export instead of choosing FDI. This effect is driven by the fact that stronger spillovers drive down the incentive to invest in R&D in symmetric models with strategic interaction as outlined by e.g. d'Aspremont and Jacquemin (1988).[11] Thus, as the R&D investment falls, firms are more inclined to service the foreign market through exports, in line with reasoning above. This effect of spillovers, however only play a role on the margin, where firms are allmost indifferent between exports and FDI. The conclusions drawn in this paper implies that strong spillovers actually may discourage FDI, however, the model is based on symmetric firms and similar spillovers through exports and FDI.

In Grünfeld (2002), the assumptions of symmetry and similar spillovers are relaxed. Here, a foreign and a domestic firm compete in a market, where the foreign firm may service the market either through exports or FDI, whereas the domestic firm only supplies its home market. As in the model developed by Petit and Sanna-Randaccio (2000), firm play a three-stage game, where the foreign firm first chooses its entry

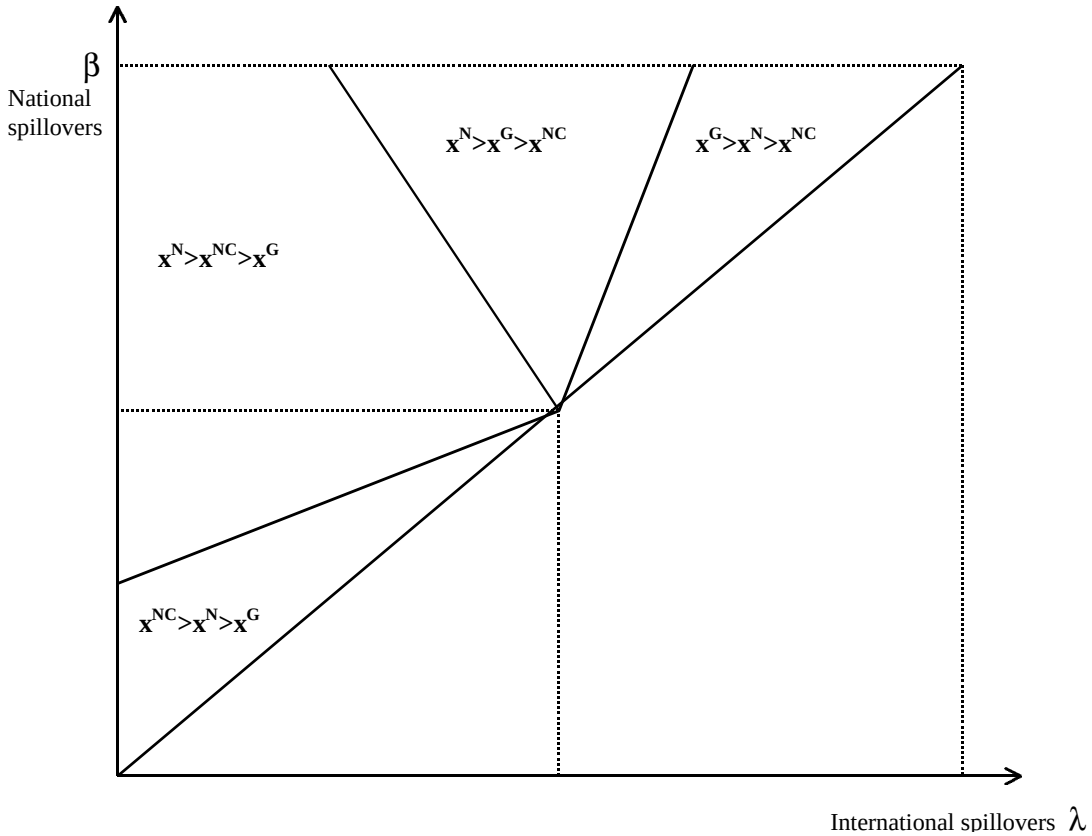
[11] As the strength of spillovers increase, the over-investment in R&D at the first stage in these models, due to commitment effects, gradually fades out. In other words, the strategic gains from over-investing in R&D fall as the outcome of R&D investments is shared between firms.

strategy. Thereafter, firms set their optimal R&D level, and finally firms compete in outputs. However, spillovers are only present when the foreign firm goes multinational. In this model, the foreing firm will always be the technology leader in terms of R&D investments since it is servicing two markets in stead of one. As in the model mentioned above, this one also predicts that the foreign (or multinational) firm cuts down on R&D investment when the strength of spillovers increase. Also the effect spillovers on the entry mode is only present on the margin. However, the study brings the outlined model one step further, as it introduces the effect of absorptive capacity. As the multinational firm is the technology leader, it has a stronger absorptive capacity than the domestic firm. It follows that the multinational gains from a stronger flow of spillovers than the domestic firm, which again makes it more profitable to go multinational. If the effect of R&D on absorptive capacity is very strong ,however, this advantage disappears and the gains from going multinational are weakened. Consequently, the model predicts that firms will go multinational if the strength of spillovers are not too small or not too large. Notice that this model predicts that multinationals may still take advantage of spillovers even though they are technology leaders. This contrast the assumptions in the model by Fosfuri and Motta (1999), and seems to correspond well with the fact that multinationals are highly R&D intensive.

In a paper by Brod and Shivakumar (1997), a model is developed in order to study the equilibrium R&D investment outcome under different regimes of national and international cooperation. The model allows for both national and international R&D spillovers, specifying one parameter for national spillovers (β) and one parameter for international spillovers (λ). In this model, firms are not multinational in the sense that they supply several markets through local subsidiaries. The objective of the study is to investigate whether the establishment of an international research joint venture (RJV) is more profitable than other ways of organising R&D. An international RJV is often regarded as a sort of multinational activity since it involves owner interests representing more than one country. The model is not open for strategic interaction between firms in different countries in terms of sales, and only two symmetric national firms compete in each country. However, the firms in one country are affected by the R&D activity of

firms in other countries through international R&D spillovers. On the basis of the results in Coe and Helpman (1995), the authors claim that national spillovers are stronger than international spillovers, assuming that $\beta>\lambda$. The game in this model opens up for three different strategic outcomes: A non-cooperative R&D strategy (*C*), a national RJV (*N*), and finally an international RJV (*G*). The study contains an instructive diagram (Figure 1) where the equilibrium R&D investment of firms (x) is depicted as a function of the strength of both national and international spillovers. If both national and international spillovers are large, the highest R&D level will be reached in an international RJV where all firms cooperate with respect to R&D. This is directly in line with the previously mentioned effect of spillovers on R&D investment in models with strategic interaction. Strong spillovers lead to under-investment when firms do not cooperate in R&D. If only national spillovers are large, the highest R&D level will be reached through national RJVs, since the international spillovers do not drive down R&D in any significant manner. If both spillovers are small, R&D will be highest if none of the firms cooperate. As outlined by d'Aspremont and Jacquemin (1988), a RJV will enlarge profits when spillovers are large, thus this model predicts that firms will find it profitable to engage in multinational activity through international RJVs if both national (local) spillovers and international spillovers are large. Consequently, the negative effect of geographical distance on spillovers discussed in Section 2, must not be too strong if firms are to go multinational through RJVs.

Figure 1: Equilibrium R&D investment under alternative forms of organising R&D.



The growing number of economists that approach economic activity from an evolutionary perspective, has vitalised the question of whether FDI behaviour can be understood as a result of evolutionary mechanisms. It is often hard to identify a specific set of assumptions that rule the evolutionary approach, but according to Hagedoorn and Narula (1996), there exist some key behavioural patterns and economic mechanisms that apply to the case of FDI. First of all, firms that invest abroad do not behave rationally in the sense that they invest to maximise a profit function which is defined over the full set of all thinkable investment possibilities. Rather, firms tend to satisfy and invest incrementally according to their restricted and local set of information or knowledge. Many researchers refer to such behaviour as routinised behaviour with learning. Hence, you usually observe an investment pattern that spreads through space and cultures over time. Furthermore, when foreign investment has become a core activity in the strategy of a firm, the investment incentives will gradually move from asset exploiting to asset

exploring. In other words, at the earlier stages of the FDI process, firms primarily go multinational in order to take advantage of some firm specific resource, procedure or technology that gives them a competitive advantage. As the firm becomes more mature in operating as a multinational, it will increasingly engage in the process of seeking new knowledge and acquiring resources abroad that contribute to improved competitiveness. The concept of "asset exploring FDI" appears to be highly similar to what we here name *spillovers as a motive for FDI*. However, for the theory to be purely evolutionary, we also need to see some form of behavioural diversity in the population of foreign direct investors, i.e. dissimilar routines. And this diversity must also be treated in an economic process that is described by a selection mechanism which defines the fitness of different investment strategies, where the best strategy survives. It is reasonable to interpret the propositions presented in Hagedoorn and Narula (1996) as a description of some winning or surviving FDI strategy, implicitly claiming that firms that deviate strongly from this investment strategy tend to lose competitiveness.

In Perez (1997), a full analytical evolutionary model of FDI is presented, which includes the effect of spillovers. Based on a large set of empirical studies, Perez presents a short list of important empirical regularities observed in the investment and production behaviour of both domestic and multinational firms. The list contains the following 4 regularities: First, spillovers are found to depend on the absorptive capacity of firms. Second, technology imports by foreign firms (multinationals) increase when the technology gap between foreign and domestic firms is reduced, assuming that the multinational is the technology leader. Third, the development of a firm's market share is positively influenced by its technological standing relative to its competitors. Finally**,** the size of the market grows with national income according to a Keynesian demand function.

The model is built around three dynamic functions, describing the development of market shares, labour productivity and wages in two firms representing the groups of domestic and multinational firms in a country. Market shares of both domestic and multinational firms are determined by their relative price competitiveness, and FDI undertaken by the multinational firm is determined by the real national product of the last period. Firms set prices according to a mark-up rule and employees either work in production or imitating

activity, which is conveniently referred to as technology sourcing, driving the spillovers between firms. Productivity growth in the domestic firm is determined by the amount of technology sourcing and the technology or productivity gap between domestic and foreign firms in the previous period. The chosen functional form assures that technology sourcing is less effective when the GAP is large or small. Thus, if a firm is poorly developed with respect to technology, it has a low absorptive capacity whereas firms with similar technologies have relatively little to learn from each other.

Perez runs the model over 30 periods and finds that the initial productivity gap between the domestic and the multinational firm has a strong effect on how firms perform with respect to productivity and output. The technology gap is also crucial when it comes to the success of increased FDI by the multinational. The model predicts that an increase in FDI is most profitable when the technology gap between the investing firm and the domestic firm is at an intermediate level. In other words, if the foreign investor has knowledge that provides a small efficiency advantage, the investment decision is most gainful. With equal technology, the domestic firm receives large productivity gains and investment profitability is close to its minimum. This story tells us that although technology spillovers from local firms may be gainful for multinational firms, the domestic firms' ability to imitate or replicate the foreign firms' technology may counteract the positive effect of technology sourcing through FDI and reduce the competitive positioning of the multinationals firm over time.

4. Empirical studies

Compared to the limited amount of theoretical contributions on this subject, the number of empirical studies is large. As the reader may have noticed, most of the relevant theoretical studies have been published in the nineties, and this is also the trend for the empirical studies. A rigorous empirical analysis of R&D spillovers as a motive for FDI requires data that both specifies FDI flows, preferably on the firm level, and information covering both host and home country characteristics, such as the technology base and R&D activities. With a few exception, such data has not been available until recently. The lack of a good statistical sources covering international FDI flows, as well as technology and knowledge indicators, has forced researchers to focus on a small set of

country specific data sources. One group of researchers has published extensively on the basis of data covering Japanese investments in the US.[12] Another group has utilised the rich information on the foreign activities of Swedish firms.[13] A third group has chosen to use international statistics on patent citations as a means to map international technology flows and their link to multinational affiliates.[14] Lately, some researchers have merged several data sources in order to provide multi-country studies of R&D spillovers as a motive for FDI.

In this section we review three kinds of studies. We first focus on studies that directly investigate R&D spillovers (or alternatively technology sourcing) as a motive for FDI. Thereafter, we review a group of studies that approach this issue indirectly through productivity studies. These papers try to map whether FDI works as a channel for R&D spillovers which improves home country productivity. Finally, we briefly survey some central studies that look at agglomeration in general as a driving force behind FDI.

4.1. Empirical studies of R&D spillovers as a motive for FDI

The most frequently cited analysis of FDI driven by R&D spillovers is an econometric study by Kogut and Chang (1991) where Japanese FDI into the US is evaluated on the background of Japanese and US industry characteristics. The dependent variable is the number of new Japanese entries in US industries between 1976 and 1987. Japanese and US R&D expenditures as percentage of total sales represent the main explanatory variables. The difference between these two components (Japanese minus US R&D intensity) represents the R&D spillover motive for FDI if the coefficient is negative, and motives relating to the exploitation of technological capabilities abroad if the coefficient is positive. The sum of these two components is a measure of the effect of overall R&D on FDI, that may represent the effect of R&D rivalry on foreign entry. In addition, the empirical model also includes variables like the US innovation frequency, Japanese and US industry concentration, US advertisement as a measure of the degree of competitiveness, shipment as a measure of size, import as a measure of exposure to foreign influence and finally, trade restrictions which motivate investment as a tariff-

[12] Anand & Kogut (1994), Kogut and Chang (1991) and Head, Ries and Swenson (1995)
[13] Braunerhjelm and Svensson (1996,1998), Fors (1996, 1998)
[14] Cantwell (1989) and Cantwell & Janne (1999)

jumping strategy. The analysis indicates that R&D in US industries has a positive impact on the number of Japanese firm entries. This is also the case for Japanese R&D as well as the sum of the two components. However, the results shows no significant impact of R&D differences on FDI, hence, R&D spillovers as a motive for foreign entry is not supported. Among the controlling variables, export restrictions, industry concentration in both countries and Japanese R&D growth came all out with significant and expected coefficients. Since there is reason to believe that the mode of Japanese entry has an impact on the transfer of technology, Kogut and Chang (1991) splits the sample into acquisitions, joint ventures and new plants. Now, the coefficient for the R&D difference variable is negative and significant for joint ventures, giving support to technology sourcing through FDI by Japanese firms.

In a similar study by Anand and Kogut (1997), the sample is expanded to also include German and British firm entries into the US. The inclusion of these countries did not alter the results found in Kogut and Chang (1991). R&D differences remain insignificant as an explanatory variable, even when the sample is specific for each of the three countries. In addition, this study concludes that R&D spillovers are not even relevant when you study joint ventures separately. The authors strongly emphasise the fact that industry concentration and thus rivalry is a highly important factor behind FDI. Low home country concentration drives investors out of the country, while high host country concentration contributes to a larger number of new foreign entries.

With respect to geographical coverage, Neven and Siotis (1996) presents the most ambitious empirical analysis of technology sourcing through FDI. In this study, the FDI flows between Japan, the US, UK, Germany, France and Italy were investigated based on data covering 8 industry sectors. In other words, the data enables the authors to look at FDI with its home base in specified industry in country *A*, flowing to a specified industry in country *B*. The FDI flows were regressed upon the R&D intensity of both the host and the home industry. As in Kogut and Chang (1991), the paper also tests a specification with R&D differences and sums. In addition, a set of alternative explanatory variables is included in order to capture the more traditional motives or FDI. The results showed that US and Japanese foreign investment are motivated by technology sourcing, but in the cases of intra-European FDI, there was no evidence of such a motive. The

authors argue that the single European market program could be one explanation for why R&D spillovers are less important among European countries. If the program has helped to reduce barriers that obstruct knowledge and technology flows, then firms will have less incentive to invest abroad in order to capture the knowledge and R&D externalities in Europe.

In Barrell and Pain (1999), US foreign direct investment activity is analysed as a function of agglomeration in European countries. The study is based on a panel data set covering 5 manufacturing sectors in 6 European countries. R&D activities in the host industry enter as an explanatory variable in their empirical models, measured in terms of the R&D intensity of an industry in one country relative to the same industry in other countries. This variable has a significant positive effect on the stock of US FDI in European countries. However, the study does not present results based on the relative R&D intensity in the home and host industries of the US foreign investor. Thus, to conclude that R&D spillovers work as a motive for US FDI in Europe is to stretch the results too far. The study provides an interesting experiment where competing motives for US FDI are specified for France, UK and Germany. The experiment shows that the advantage of low labour costs in the UK is fully counteracted by the low R&D intensity of UK manufacturing industries relative to Germany. On the other hand, in Germany the high R&D intensity of industries compensates for much of the labour cost disadvantage, when it comes to attracting FDI.

In a study of the determinants of foreign ownership in Norway, Grünfeld (2001) applies firm level panel data, containing foreign ownership shares (the single largest foreign owner in the firm) in all manufacturing firms during most of the nineties. These shares are regressed upon the relative R&D intensity of the industry where the firm is located, relative to the R&D intensity of the foreign owners home base. Here, it is shown that R&D spillovers represent a significant motive for foreign ownership when the empirical model is based on levels of foreign ownership. However, the models based on changes in foreign ownership shares over the period do not support this motive. On the contrary, these models find some support for FDI motivated by ownership advantages or asset exploiting behaviour. Since the models based on changes in foreign ownership shares are

believed to be most appropriate for a study of R&D spillovers as a motive for FDI, it is concluded that this motive is not observed among foreign investors in Norway.

Martin and Velazquez (1997) applies macro data from the OECD to test an econometric model for FDI flows between 24 countries. Bilateral FDI flows are modelled as functions of among other things, the source country as well as the host country GDP level and the relative R&D intensity of these countries. The study indicates that higher relative R&D intensities are accompanied by more FDI. In other words, FDI flows from countries with a high R&D intensity to countries with a lower R&D intensity. This observation is incompatible with our motive. However, the study shows that host country transport infrastructure and human capital, measured by educational attainment tend to attract FDI. Narula and Wakelin (1997) also use macro data in their study of US foreign direct investment flows into 6 European countries and Japan. FDI flows are treated as a function of country size, labour costs, exports from the US to the host country, the exchange rate and finally the relative technological competitiveness, measured in terms of the number of patents granted in the US patent database to the country, relative to the number of patents granted to US companies. When it comes to technological competitiveness, their results are inconclusive. For UK, France and Japan, FDI tends to increase when the host country has a technology disadvantage, whereas the opposite is true for the other countries. Narula and Wakelin (1998), provide somewhat stronger evidence supporting R&D spillovers as a motive for FDI.

In Globerman, Kokko and Sjöholm (2000), patent citations are used as a measure of technology spillovers and link this measure to the multinational activity of Swedish firms. They find that multinationals have a higher rate of patent citations from countries where they have invested. The study also gives support to the negative effect of geographical distance for the probability of observing a patent citation. This is used as an argument supporting the existence of R&D spillovers flowing from the host country to the multinational. In other words, one may argue that such spillovers work as a motive for FDI. This finding is supported by Almeida (1996) who also applies patent citations in order to analyse knowledge sourcing by foreign owned firms in the semiconductor industry in the US. This study also contains interviews that supplement the quantitative

analysis. Here it is shown that foreign firms use local knowledge more frequently than domestic firms.

In a study based on patents, Cantwell and Janne (1999) tests whether MNEs tend to explore technological assets abroad. They hypothesise that firms on the international technology frontier tend to focus on technological developments in slightly different areas when they invest abroad. Firms that operate below the technology frontier are believed to invest abroad in search for technology within the same activity or technology group. They use US panel data in order to construct an index for the revealed technological advantage (RTA) of multinational firms in their home country, and the countries where they have affiliates. The study is based on two industry classifications, one with 18 technology sectors and one with 56. The results are presented in terms of pairs of European countries, and give support to the outlined claims. Consequently, firms appear to search for technology and innovations through multinational activity, but the kind of technology they search for depends on their technological advantage. Patel and Vega (1999) study the patenting behaviour of large companies as an indication of the motives behind FDI. They find some evidence suggesting that firms invest in small scaled R&D activities abroad in order to follow the local technological development.

Fors (1998) looks at adaptation and knowledge seeking as a motive for locating R&D activities abroad, based on a large firm level panel data set covering the majority of Swedish multinationals. Fors calculates the relative R&D intensity of industries in different countries as well as the proportion of production in Swedish MNE's produced by their foreign affiliates. Both factors are believed to contribute positively to the location of R&D abroad, the first due to technology sourcing and R&D spillovers, and the second due to size effects and the need to adapt products to local standards and preferences. A two-stage model is designed to both analyse the probability of observing R&D activities by the multinationals affiliates, and the impact on the *amount* of R&D activities undertaken by the affiliate. The study indicates that the relative size of affiliate production is increasing the probability that the MNE engages in R&D abroad. Also, an increase in this variable raises the amount of R&D activities by the affiliate. The relative R&D intensity of the host industry does not have an impact on whether or not the MNE locates R&D activities abroad, but this variable has a significant effect on the *amount* of

R&D located there. Thus, given that the multinational has already established R&D facilities in a country, this study gives support to the R&D spillover motive for FDI.

Table 1: List of relevant studies and their results

Studies	*R&D spillovers as a motive for FDI*	*Gegraphical coverage FDI:*	*Data*	*Comments*
Almeida (1996)	*Yes*	*into US*	*Patent citations by foreign firms*	*Includes interviews with foreign firms*
Anand & Kogut (1997)	*No*	*into US*	*Entry of foreign firms*	*Home and host industry concentration matters*
Cantwell & Janne (1997)	*Yes*	*Western European*	*Patents and revealed*	*Focus on search for similar or antecedent*
Barrell & Pain (1999)	*(Yes)*	*into Europe*	*FDI and R&D on industry level*	*Measures only the R&D intensity in the host*
Fors (1998)	*Yes*	*From Sweden*	*Firm level FDI and industry R&D*	*Focus on multinational R&D activity*
Globerman, Kokko & Sjöholm (2000)	*Yes*	*From Sweden*	*Patent citations and firm level*	
Grünfeld (2001)	*(No)*	*into Norway*	*Firm level foreign ownership shares and industry R&D*	*Yes, if the motive is analysed using level of foreign ownership*
Kogut & Chang (1991)	*(No)*	*into US*	*Entry of foreign firms*	*Yes, if you only focus on joint ventures*
Martin & Velazques (1997)	*Yes*	*between OECD countries*	*Macro level FDI and R&D*	*Host country human capital and*
Narula & Wakelin (1997)	*(No)*	*into selected OECD countries*	*Macro level FDI and R&D*	*Yes for some countries and no for others*
Narula & Wakelin (1998)	*Yes*	*into selected OECD countries*	*Macro level FDI and R&D*	
Neven & Siotis (1996)	*Yes*	*between selected OECD countries*	*Industry level FDI and R&D*	*No for intra-European spillvoers*

In Table 1, we summarise the evidence provided by the reviewed studies. It is evident that studies based on firm level data are generally not supporting the existence of R&D spillovers as a motive for FDI. Studies based on more aggregated data are more supportive, though.

4.2 The productivity effects of outward FDI

In the search for international R&D spillovers and the effect of such spillovers on the productivity of firms, industries and countries, some researchers have focused on whether outward FDI flows promote home country productivity. The existence of such effects does not directly imply that multinationals are motivated by R&D spillovers, but if

firms or industries in the home country gain from their outward FDI activities, there is reason to claim that firms will start to focus on R&D spillovers through FDI as something gainful. Hence, it is natural to review some of this literature.

Lichtenberg and van Pottelsberghe (1998) and van Pottelsberghe and Lichtenberg (2001), are studies that extend on the investigation of international R&D spillovers by Coe and Helpman (1995). They regress the total factor productivity of OECD countries on the counties' own R&D levels and the R&D of all other OECD countries weighted by their share in the imports to the country. This way, one accounts for the embodied diffusion of R&D through imports. Lichtenberg and van Pottelsberghe extend this analysis by including variables containing the R&D activities behind foreign investors, both in terms of inward FDI and outward FDI. The results are striking. Inward FDI does not appear to diffuse R&D to domestic firms since the effect on productivity is insignificant. However, outward FDI is found to contribute strongly to domestic productivity through R&D spillovers. The estimated elasticity relating to this channel of spillovers is found to be almost as large as the elasticity with respect to spillovers through imports. For some of the major OECD countries, it was actually found to be larger.

Braconier, Ekholm and Knarvik (2001) use firm level panel data, covering the multinational activities of Swedish firms. They study the productivity effects of spillovers both through inward and outward FDI, and conduct empirical tests both on the firm and industry levels. The study gives no evidence supporting R&D spillovers through outward or inward FDI, neither on the firm nor the industry level.

Sjøholm (1997) applies data from a sample of 8 manufacturing industries in 6 OECD countries to test whether industries become more productive when they undertake FDI in R&D intensive sectors. The econometric specification allows R&D to spill over through domestic intermediates, imports as well as outward FDI. It is assumed that the distribution of FDI from an industry in country A to an industry in country B, follows the same pattern as the FDI flows between nations. FDI directed towards technology advanced industries has a strongly positive effect on the total factor productivity of industries, both with and without country and industry dummies.

The relevant results from the studies of productivity effects of R&D spillovers through outward FDI are summarised in Table 2:

Table 2: Productivity effects of spillovers through outward FDI: Elasticity Estimates

	Lichtenberg et al. (1996)	***Sjöholm (1997)***	***Braconier, Ekholm & Knarvik (2001)***
Own R&D	*0.017*	*0.0003*	*0.045*
Foreign R&D spillover through imports	*0.100*	*0.001*	*na*
Spillover through inward FDI		*na*	
Technology sourcing (outward FDI)	*0.072*	*2.32*	*-0.038*
Adjusted R^2	*0.857*	*0.14*	*0.50*

Only significant elasticities are reported. na = not available

4.3 Empirical studies on agglomeration as an incentive for inward FDI

As outlined in the introduction, the forces of agglomeration may play an important role in the flow of FDI between countries. However, agglomeration is believed to be driven by many different mechanism, not only spillovers between firms. Consequently, empirical studies that analyse the relationship between FDI and foreign agglomeration may identify mechanisms that do not relate directly to spillovers. Nevertheless, we find it necessary to present some of these studies since they may shed light on mechanism that relate to spillovers.

In a study of the location choice of Japanese manufacturing firms in the US, Head, Ries and Swenson (1995) finds that these firms are attracted to locations where there are disproportionately many US firms. Thus, agglomeration appears to drive FDI. The study also shows that Japanese firms are attracted to locations in the US where other Japanese firms operate. This also applies to the presence of other firms within the same Japanese keiretsu, implying that the supply relationship between Japanese firms in a US location increases its attractiveness. However, this variable is sensitive to small changes in the sample. The importance of agglomeration for FDI in the US is supported in a study by

Coughlin and Segev (2000), based on a sample of foreign firms that is not restricted by home country affiliation.[15]

Shaver and Flyer (2000) argue that firms operating on the technology frontier will experience a negative effect from agglomeration since they have relatively little to learn from other firms in the agglomeration. This argument goes hand in hand with the technology and R&D spillover concept where the technology follower has more to learn from the leader than the other way around. The study is based on the economic performance of foreign greenfield establishments in 1987 in the US manufacturing sector, where performance is analysed in terms of the survival of these establishments over time. The empirical analysis gives support to the outlined hypothesis.

In order to investigate whether multinational firms are attracted to important industries or clusters abroad, Braunerhjelm & Svensson (1996) applies data on foreign affiliate sales by Swedish multinational. The core explanatory variable is *agglomeration*, measured as the industry's share of total employment in the country in focus. The study also investigates the effects of agglomeration in terms of the number of *scientists, engineers* etc. in the industry, and finally the amount of *exports* going from the MNE to the country in focus. The problem is approached using a two step estimation procedure, where the probability of observing foreign sales or not is estimated first. Thereafter, an econometric model is estimated to identify how the amount of sales (for those who sell) is affected by the mentioned variables. The relative size of the host industry (agglomeration) has a significant effect on foreign affiliate sales in that country, and so does the number of scientists, engineers and technicians. It follows that the study supports the idea that foreign activity is attracted by industrial agglomeration in the host country as well as high knowledge levels in terms of skilled labour. It is important to notice however, that Braunerhjelm and Svensson (1996) do not analyse FDI directly, but focus on affiliate sales.[16]

[15] See also O Huallachain and Reid (1997) for more on how agglomeration affects the mode of foreign entry by Japanese firms.

5. Conclusions and a note on causality

This survey has been motivated by the growing number of contributions to the study of R&D spillovers as a motive for FDI. The body of theoretical models gives a formal argument supporting the economic rationale for such behaviour and recent theoretical developments show that technology or R&D sourcing FDI can be observed among multinationals even tough they have a technological advantage. The empirical evidence this far, however, is not unambiguously supporting the existence of this motive. Apparently, the evidence provided depends more on what kind of data you use than on the methodological nuances. Broadly, we find that studies based on firm level data do not support the motive. On the other hand, studies based on more aggregated data and studies based on patents and patent citations tend to support the existence of R&D spillovers as a motive for FDI. The intensity of patent citations between firms is regarded as a good approximation to the strength of spillovers, and studies of this kind probably contain better information on spillovers than studies that are based on relative R&D activities at home and abroad. However, both approaches are widely used, and a clear conclusion on the relevance of this motive requires more evidence using both kinds of data. The interest in understanding how FDI is driven by technology, knowledge and R&D is relatively new, and the presence of highly divergent empirical results justifies even more intense research on this issue in the future.

The idea that firms increase their ability to learn from foreign knowledge through FDI, regardless of the form of investment is not particularly appealing. There is reason to expect that the absorptive capacity of a multinational firm is not only dependent the R&D activities at home but also on the research and knowledge base in the subsidiary abroad. The evidence provided by Fors (1998), indicates that multinationals realise this aspect of spillovers, yet more research has to be done on this field. Recently, a working paper by Sanna-Randaccio and Veugelers (2002) approaches this issue in a game theoretic model that sorts out the effects of locating R&D at home or abroad when R&D spillovers matter.

[16] Evidence of FDI attracted by agglomeration is also given in the case of Portugal, see Guimaraes, Figueiredo and Woodward (2000).

Several studies have focused on the domestic response to increased inward FDI. For instance, Bertschek (1995) constructs a model that allows her to test whether FDI affects the product and process innovations of domestic firms. The panel data covers 1270 firms in the German manufacturing industry from 1984 to 1988. The results indicate that FDI has a positive effect on both product and process innovations. If this study reflects a true tendency,[17] the measurement of technology sourcing through FDI confronts a causality or simultaneity problem. Is FDI driving the technological development in the host industry or is FDI attracted to highly developed industries? Clearly, both forces may work simultaneously. This simultaneity problem can be solved by e.g. using instrumental variable models or specifying a dynamic model that defines the most plausible direction of causality over time. As far as we are concerned, there have been no attempts to approach this problem formally.[18]

[17] The study contrasts the results presented in Veugelers and Vanden Houte (1990) as well as de Bondt, Sleuwaegen and Veugelers (1988).
[18] Barrell and Pain (1997) also provide evidence showing that industry productivity is an increasing function in FDI inflow lagged 4 years.

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