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Abstract:
We study the productivity effects of R&D spillovers through imports, foreign direct investment and domestic intermediates, using a highly disaggregated data set for Norwegian business sectors. As opposed to the large body of similar studies, we explicitly analyse the importance of absorptive capacity effects, claiming that the positive contribution from R&D spillovers is an increasing function of the R&D activities of the economic units that receive the spillovers. We find strong support for the existence of R&D spillovers through imports and domestic intermediates, but no sign of such spillovers through foreign ownership. Surprisingly, we identify absorptive capacity effects relating to spillovers from imports, but no such effects with respect to domestic intermediates. One possible explanation is that the cost of learning from international R&D sources is larger than from domestic R&D sources, implying that own R&D investments can counteract the negative effect of geographical and cultural distance on R&D spillovers.

Keywords: International R&D spillovers, productivity effects, absorptive capacity, FDI

JEL classification codes: F02, F14, O32, O33

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1. Introduction

In response to the development of endogenous growth theory over the last decades, the field of applied growth research in economics has experienced a renaissance. In the path-breaking works of Romer (1986), Lucas (1988) and Romer (1990), it is hypothesised that long-run economic growth can be driven by an endogenous process of technology and knowledge accumulation. For instance, Romer (1986) allows companies to invest in R&D until the marginal profitability equals innovation costs, but this private knowledge becomes common knowledge over time. The rate of private innovation depends, on the other hand, on available common knowledge. The spillover effect hence guarantees economic growth for the whole economy. This theory is consistent with the fact that knowledge as well as R&D have the shared property of not being fully excludable. In other words, R&D must at least partly be treated as a public good. This implies that R&D performed by one firm tends to spill over to other firms over time. In an early work by Bernstein and Nadiri (1988) such spillovers were identified between industries in the US, and a significant number of other studies have confirmed this phenomenon.

R&D spillovers are not limited to a specific country, they may just as well run across borders, constituting so-called international R&D spillovers. A central study by Coe and Helpman (1995) identified strong international spillover effects when they looked at the development of R&D activities and total factor productivity (TFP) growth in 21 OECD countries. The study was limited to so-called embodied R&D spillovers, which are traced by following the trade flows between countries and relating these flows to the R&D intensity in the production of these goods. Interestingly, the authors found that in small open economies like Norway, international R&D spillovers contributed more to TFP growth than the country's own R&D. The identification of international R&D spillovers embodied through imports has been confirmed in a series of studies following Coe and Helpman. More specifically, Sakurai et al. (1996) and Keller (2000) show that such spillovers also exist when you perform an analysis on more disaggregated data. This is an important observation since the work of Coe and Helpman has been criticised for measuring spillovers in terms of macro data. There is a large risk that such figures will mis-specify the actual R&D intensity of the imported goods as all countries are assumed to import the same aggregate commodity from a given country.

There is good reason to expect that international R&D spillovers may be promoted through other channels such as foreign direct investment (FDI) and labour migration. With respect to FDI, the evidence is somewhat inconclusive. Lichtenberg and van Pottelsberghe (1998) use the same data as Coe and Helpman but add FDI flows as a channel for spillovers. They find that FDI flowing into a country does not affect productivity while outward FDI seems to have a positive productivity effect. The relatively large body of studies mapping the spillover effects of FDI suggest that it is harder to identify spillovers to less developed countries than it is to industrialised countries. Among others, Haddad and Harrison (1993) and Aitken and Harrison (1999) show that there are no significant spillover effects from FDI in developing countries. This could be driven by what Abramowitz (1986) labels the social capability of countries. In order to gain from technological progress developed outside, the country must have a sufficiently developed base of infrastructure, knowledge, and technology. This is much in line with Cohen and Levinthal (1989), who emphasise that firms will only be able to learn from external R&D if they themselves invest in R&D. Thus, the absorptive capacity of a firm is an increasing function of its own R&D investments. This explanation is given support by Jaffe (1986) in the case of the US and by Blomström, Kokko and Zejan (2000) and Keller (1996) in the case of developing countries. Also, a recent study by Griffith, Redding and Van Reenen (2000) shows that the absorptive capacity of industries in the OECD area plays a central role in their ability to catch up with the international technology frontier.[1]

The aim of this study is threefold: First, we want to study the productivity effects of R&D spillovers transmitted through several channels simultaneously in the same econometric exercise. More specifically, we are analysing whether R&D spillovers through imports, FDI and domestic intermediates affect the TFP growth in data set covering Norwegian business sectors. Most studies of this kind only focus on one channel, and the importance of extending the analysis is well described by Wolfgang Keller (2001) in his recent survey on international technology diffusion.[2] Second, we use a highly disaggregated data set that allows us to map R&D spillovers flowing

[1] Similar results are provided by Eaton and Kortum (1996) and Kinoshita (2001).

between relatively well defined entities. This way, we minimise the risk of taking into account R&D that actually has not been transported from one agent to another. We use the national account system to map spillovers running between 105 Norwegian business sectors, including several service sectors. Although there exist some studies within this field that apply firm level data, to our knowledge there are no studies that trace embodied R&D spillovers at this level of aggregation. Furthermore, there is an acute lack of studies that include service sectors, although we know that these sectors undertake a large proportion of the overall R&D activities, not least in the industrialised world. Third, we explicitly analyse the possibility of absorptive capacity effects in R&D. Although this element has been discussed in a few earlier studies, absorptive capacity effects relating to embodied international R&D spillovers have not been investigated earlier. It is important to notice that as we study several channels of R&D spillovers, we are able to distinguish absorptive capacity effects relating to different sources.

The study gives strong support to the existence of productivity-enhancing R&D spillovers transmitted through both imports and domestic intermediates to Norwegian business sectors. In addition, we find a weak positive productivity effect of own R&D investments, but this productivity effect is significantly smaller than the effects generated through R&D spillovers. Furthermore, the industry's own R&D investment appears to only be significant for the manufacturing sectors. So far, this is in line with the conclusions derived by Coe and Helpman (1995), stating that productivity in small countries is more strongly affected by the R&D activities abroad than at home. However, in our study, international R&D spillovers do not appear to be stronger than domestic spillovers, thus the outlined conclusion is modified here. This modification may simply be due to the fact that this data set enables us to explicitly analyse and compare domestic with international R&D spillovers.

Furthermore, the absorptive capacity of business sectors measured in terms of their R&D intensity seems to play an important role when it comes to international R&D spillovers, but such effects are not identified in relation to domestic R&D spillovers. As

[2] The papers by Kraay, Solaga and Tybout (2001), Lichtenberg and van Pottelsberghe (1998) and Globerman, Kokko and Sjöholm (2001) are some of the few studies that analyse several spillover channels.

described by Keller (2002), Maurseth and Verspagen (1999) and Jaffe, Trajtenberg and Henderson (1993), knowledge and technology flows are strongly dampened by geographical distance. One interpretation of this rather solid regularity is that more resources are required to enable learning from R&D activities that are undertaken far away in terms of geographical distance. This is well in line with the literature on absorptive capacity, where firms have to invest in learning capabilities in order to benefit from spillovers. In addition, the fact that we do not identify any absorptive capacity effects in domestic R&D spillovers may simply illustrate that R&D intensive sectors in Norway have little to learn from other sectors within the country, whereas less R&D intensive sectors have a lot to learn.

We are not able to find any positive productivity effects of R&D spillovers through FDI. In fact, our study points to a negative productivity effect of FDI when we measure it in terms of the R&D intensity of the foreign owners' activities at home. This negative effect may relate to the dominance of asset exploiting FDI, implying that foreign investors tend to locate activity in low-productive sectors where it is easy to take advantage of their strong competitiveness. Such behaviour is supported in the case of Norway by Grünfeld (2001), where technology spillovers are analysed as a motive for FDI.

The paper is organised as follows. The next section gives a brief introduction to the concept of R&D spillovers and absorptive capacity effects. Section 3 presents the empirical model and discusses the data and econometric issues. In section 4, we present and discuss the results and section 5 concludes and provides some policy implications.

2. A brief look at the concepts of R&D spillovers and absorptive capacity effects

In the study of R&D spillovers transmitted through domestic and imported intermediates, it is implicitly assumed that the technology or R&D results are embodied in the intermediates. Thus, such studies confine themselves to the analysis of so-called embodied R&D spillovers. In a discussion of R&D spillovers, Griliches (1992) introduces the distinction between *embodied* and *disembodied* R&D spillovers. The last category applies to knowledge and technology flows that do not relate directly to the flow of goods and services between firms. According to a large business survey by Levin et al. (1987), US business managers ranked informal conversations and technological updating through business networks and relevant literature as central sources to external technology and R&D to the firm. Furthermore, worker mobility through the labour market (see Almeida and Kogut (1999) and Møen (2001)), ownership linkages like FDI and different ways 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 R&D spillovers are due to some kind of learning or whether it relates 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. Obviously, rent spillovers are not compatible with a perfectly competitive market where firms choose an input vector in order to equate factor costs with the marginal product of the factor. But if we for instance introduce an element of monopsony power, rent spillovers become possible since the up-stream firm is able to push down factor prices and capture some of the rent that otherwise would have been absorbed by the input producer. 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.

In the analysis of productivity effects of R&D spillovers, it is common practice to focus on growth in total factor productivity, using fixed price data. This implies that the effect of rent spillovers does not affect the results directly since output and intermediates are studied in terms of volumes and not values. However, since large rent spillovers will improve firm profits, there is good reason to expect that rent spillovers affect productivity indirectly as long as firms operate with increasing returns to scale technology. That is, improved performance in terms of profits enables the firm to capture a larger market share through for instance lower prices, which again may result in higher productivity due to scale effects. This problem is rarely discussed in the empirical literature on R&D spillovers and may stem from the fact that most studies assume constant returns to scale technology, fixed factor shares and perfect competition.[3]

In this study, we analyse R&D spillovers through imports, domestic intermediates and FDI. Consequently, both embodied spillovers through intermediates and disembodied spillovers through foreign ownership are included. However, the study does not approach the problem of distinguishing between pure spillovers and rent spillovers and the analytical framework follows the mainstream tradition, assuming a Cobb-Douglas production function with constant returns to scale.

As mentioned in the introduction, there is ample evidence of spatial limitation of R&D spillovers. This can partly be explained by language and cultural barriers, limiting the interaction between firms which could generate disembodied 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 in so-called gravity equations (see e.g. Leamer and Levinsohn (1995)).

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[4] 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,

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[3] See Klette (1996) for an analysis of R&D spillovers with more flexible production functions and Bernstein and Mohnen (1998), who allow factor intensities to be determined by spillovers in the long run.
[4] See e.g. Cowan and Foray (1997) and Nelson and Winter (1982) for more on this.

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 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.

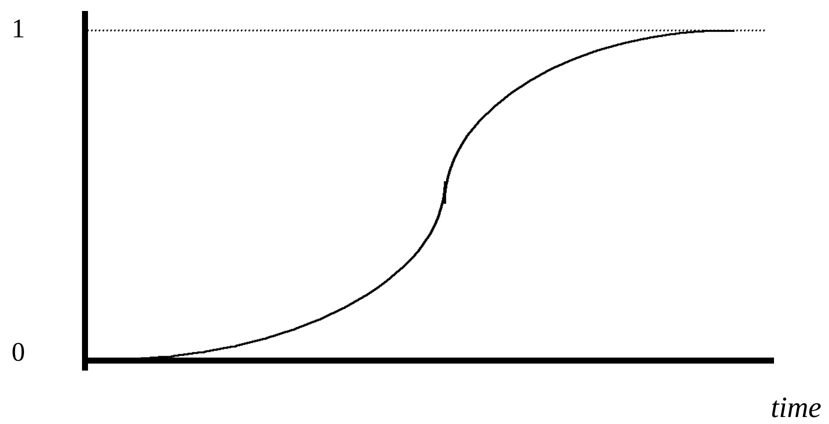
Although there exists a large pool of potentially available knowledge and technology, economic agents are not always able to benefit from these, since they lack the competencies that are required in order to search for, decodify and adapt external knowledge. This problem is discussed in the development literature where it is claimed that developing countries may get locked into a development trap since an underdeveloped knowledge base, infrastructure and institutional structure make them unable to learn from knowledge externalities. See e.g. Gerschenkron (1962) and Abramovitz (1986) for central 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, since such activities enable the firm to more easily identify, assimilate and exploit knowledge from outside. The econometric test confirmed their hypothesis and indicates 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.[5]

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-based 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.

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



[5] See also Grünfeld (2002) for a review of studies on absorptive capacity effects and spillovers.

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 strong diffusion of R&D results since firms have a high absorptive capacity.

There is good reason to expect that the returns to investment in absorptive capacity follow a similar pattern. Only marginal investments with the purpose of improving R&D spillovers will often render insufficient, and the returns to additional absorptive capacity investments on a very high investment level will neither be large since learning is limited by the available pool of knowledge external to the firm. In the empirical study, we model the absorptive capacity of industries as an increasing function of the industry's own R&D activities. But the marginal returns absorptive capacity is decreasing in line with the argument above.

3. The empirical model and estimation issues

This study is an empirical analysis of how international and domestic R&D spillovers affect productivity in a small open economy. We use data from the national accounts of Norway, which allows us to conduct panel data tests based on highly disaggregated data including both manufacturing industries and service sectors. The study is based on the development of TFP growth in 105 Norwegian industries over the period 1989 to 1996. In Appendix 1, we present data sources and an overview of domestic and foreign business sectors and commodities. The input-output matrix in the national account system is applied to map the flows of intermediates between these sectors. The system also identifies the share of intermediates that stems from imports. We combine this data set with information from the Norwegian current account statistics in order to identify the country composition of imports. Furthermore, R&D data from the OECD is used to calculate the R&D intensity in the foreign sectors that import products to Norway. We use the more disaggregated Norwegian R&D statistics to calculate the R&D intensities of Norwegian business sectors, and finally a unique database that covers foreign ownership shares in all registered stock companies in Norway.

The contribution of R&D spillovers to productivity is measured in terms of its statistical impact on total factor productivity (TFP), based on a simple Cobb-Douglas production function:

(1) $$X_{it} = A_{it} L_{it}^{a_i} K_{it}^{1-a_i}$$

where X_{it} is value added in sector *i* at time *t* and L_{it} and K_{it} represent labour and capital input respectively. A_{it} is a technology variable that describes the effect of productive technology and knowledge on output in the industry. Thus, we expect that the impact of R&D both through own R&D investments as well as R&D spillovers can be observed through a change in A_{it}. The parameters a_i represent sector specific factor shares which are restricted to vary between 0 and 1. Using lower case letters to describe the logarithm of the variables, the total factor productivity of an industry is given by

(2) $$a_{it} = x_{it} - a_i l_{it} - (1 - a_i) k_{it}$$

Assuming perfectly competitive markets, the sector-specific factor shares can be calculated as the labour cost share in output

(3) $$a_i = \frac{1}{8} \sum_t \frac{w_{it} L_{it}}{\tilde{X}_{it}}$$

where w_{it} represents the average wage rate in the industry and $\tilde{X}_{it}$ is value added measured in current prices. Due to relatively large variations in labour cost shares, we calculate the average share over the time period of study.[6] Since an industry's level of total factor productivity may be determined by a large set of factors that were determined before our period of observation, we concentrate on how R&D spillovers affect the growth in TFP. Sector TFP growth is modelled as a function of the following variables

(4) $$\hat{a}_{it} = a_{it} - a_{i,t-1} = f(so_{i,t-s}, sd_{i,t-s}, sf_{i,t-s}, m_{i,t-s})$$

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[6] All sectors with average wage shares larger than 1 are dropped. This is also the case for sectors dominated by negative value added figures. See Appendix 1 for more information on the construction of the data set.

The variable so_{it} represents the R&D intensity of the industry, sd_{it} captures R&D transmitted through domestic intermediates, sf_{it} represents R&D transmitted through imports and m_{it} represents R&D related to foreign ownership or FDI.[7] The variables are constructed in the following way:

(5)
$$so_{it} = \ln\left(\frac{RO_{it}}{X_{it}}\right)$$

where RO_{it} is R&D employment in the sector.

(6)
$$sd_{it} = \ln\left(\frac{1}{X_{it}}\sum_{j\neq i} u_{jit}\frac{RO_{jt}}{X_{jt}}\right)$$

Here, u_{jit} is the volume of inputs from sector j to sector i at time t. The fact that we use volumes instead of input shares implies that sectors receiving large input volumes also implicitly receive large flows of R&D.[8] The main argument for choosing volumes is that products or services produced within an industry are differentiated, implying that larger input volumes increase the probability of receiving more varieties, which again may result in larger R&D spillovers. This aspect is not taken care of if the model is based on input shares. In order to adjust for industry size, we deflate the measure by value added in the sector. R&D transmitted through imports is calculated in the following way:

(7)
$$sf_{it} = \ln\left[\frac{1}{X_{it}}\sum_{h} v_{iht}\left(\sum_{k} l_{hkt}\frac{RF_{hkt}}{X_{hkt}}\right)\right]$$

where RF_{hkt} is the R&D expenditure in sector h in country k. Notice that we operate with a different sector index h for foreign sectors (compare the sector overviews in Tables A1 and A3 in Appendix 2). This choice is driven by three limitations in available data. Comparable R&D statistics from the OECD is only available at a more aggregate level. This is also the case with international production data as well as statistics on import shares in the national account system and country-specific import data in the current account statistics. Consequently, the analysis of R&D spillovers through imports

[7] There is reason to believe that the R&D intensity of industries and the R&D contents in inputs can change the capital-labour ratio of industries. This problem has been discussed in Bernstein and Mohnen (1998).
[8] This aspect is discussed in Lichtenberg and van Pottelsberghe (1998).

is less refined compared to the analysis of domestic R&D spillovers. The parameters l_{hkt} are the shares of country *k* in imports of goods produced in sector *h* at time *t* . The parameters v_{iht} are the input volume of imports from sector *h* in industry *i* at time *t*. Consequently, the construction of *sf* implies that we are not able to trace the R&D flows through imports perfectly. In other words, all industries that import from sector *h*, receive the same country composition in imports. Although this may be regarded as a weakness in the data, we are still able to trace import flows more rigorously than most other studies of the same kind. Finally, R&D flows transmitted through FDI are calculated in the following way:

(8) $$m_{it} = \ln\left(\sum_{g \in i} \frac{1}{EQ_{gt}} \sum_{k} \frac{RF_{hkt}}{X_{hkt}} FO_{gkt} \right) \quad g \in i \in h$$

FO_{gkt} is the value of country *k*'s foreign equity share in firm *g* and EQ_{gt} is the registered total equity value of firm *g*. Notice once again that we introduce a new firm level index *g*. Our data on foreign ownership is based on a firm-level data set that maps the firm-specific ownership shares in Norway for 24 countries. Thus, we are able to identify the ownership structure of industries on a most detailed level. This is an important contribution to the study of R&D spillovers through FDI since most such studies use highly aggregate data on FDI stocks and flows. Naturally, in (8) we only study the foreign ownership structure in firms that sort under industry *i,* thus *g Î i*. In order to exclude foreign investors that have no strategic interest in firms located in Norway, we only include foreign ownership shares that exceed 10% of the firms' total equity value. The 10% limit is commonly used in the collection of FDI data, in order to distinguish between direct investments and portfolio investments. The data set also allows us to include firms that are owned by other firms (mother companies, holding companies etc.) where foreign ownership share are larger than 10%. We have no information about in which sector the foreign owners have their main activities in their home country. Thus, we have to assume that the foreign owner operates in the same sector at home and abroad. If foreign investors operate in different industries at home and abroad, this assumption will provide incorrect calculations of m_{it}. To our knowledge, there exist no empirical surveys of the country specific industry affiliation of multinational companies, thus, our approach must be treated as a best approximation. Since data on activities in foreign sectors is based on a higher aggregation level, we have that *i Î h*.

As outlined in the introduction and in section 2, the aspect of absorptive capacity is believed to play a central role in the understanding of how R&D spillovers affect productivity. In their study of how absorptive capacity affects the ability to catch up with the industry-specific international technology front, Griffith, Redding and Van Reenen (2000) apply an econometric specification where productivity growth is a function of the last period productivity gap and a term where the R&D intensity of the laggard industry is interacting with this productivity gap. Thus the absorptive capacity element enters the specification as a multiplicative term.[9] This implies that there is no opening for decreasing returns to absorptive capacity in R&D investments. In our study, we find no significant absorptive capacity effects when this method is used. Based on the discussion in section 2, we thus implement an absorptive capacity structure that allows for decreasing returns in R&D. As outlined earlier, a logistic transformation is desirable, but it is possible to satisfy this requirement with the following simpler hyperbolic transformations:

(9) $$Aso_{it} = \frac{so_{it}}{1 + so_{it}} \qquad Am_{it} = \frac{m_{it}}{1 + m_{it}}$$

Here, Aso_{it} represents the absorptive capacity driven by the industry's own R&D investment activities.[10] In addition, we also test whether the R&D intensity of foreign owners in a sector affects the absorptive capacity. The is represented by the variable Am_{it}. The intuition here is straightforward. If the presence of knowledge intensive foreign owners is large in an industry, there is good reason to expect that this knowledge will be transferred to managers and technicians in the respective industry, which again will enable them to more easily take advantage of R&D spillovers. This should not at least be relevant for international R&D spillovers through imports as foreign owners may hold information that is more relevant and compatible with foreign knowledge and technology.

[9] The same method is used in Kinoshita (2001), where the R&D intensity of firms interacts with the presence of foreign ownership in the firms or alternatively with the presence of FDI in the respective industry sector.
[10] Notice that so_{it} and m_{it} are always larger than zero.

In order to take industry-specific effects into account, we design a fixed effects econometric specification where we also introduce time dummies in order to adjust for time dependent effects. This gives us the following empirical specification:

(10)
$$\begin{aligned}\hat{a}_{it} = k + j_i + b_1 so_{i,t-s} + b_2 sd_{i,t-s} + b_3 sf_{i,t-s} + b_4 m_{i,t-s} \\ + b_5 Aso_{i,t-s} sd_{i,t-s} + b_6 Aso_{i,t-s} sf_{i,t-s} \\ + b_7 Am_{i,t-s} sd_{i,t-s} + b_8 Am_{i,t-s} sf_{i,t-s} + e_{it}\end{aligned}$$

where φ_i are industry specific effects. Consequently, we only use the variation within sectors to estimate the *b*-coefficients. The absorptive capacity element enter the specification through four elements. As described above there are two ways an industry can affect the absorptive capacity, through own R&D investments or through the R&D investments of the foreign owners. These effects may again promote learning through domestic and international R&D spillovers. Thus, we are left with four interaction terms.

The specification in (10) leaves open the question of lag structure. There is reason to expect a significant lag from the time when the R&D is undertaken until it spills over to other firms, industries and countries. As outlined in section 2, this diffusion process affects firms and industries at different lags in time, depending on their capacity to absorb. This mechanism is also supported in Griffith, Redding and Van Reenen (2000), where international technology gaps are shown to close faster if industries have a higher absorptive capacity. Thus, ideally, one should implement an endogenous lag structure which is a function of the R&D intensity of industries. In our model specification, we try to take care of this problem through the absorptive capacity terms. However, the fact that firms with a weaker absorptive capacity still may learn, but with a longer lag, is not considered in our study. Depreciation of R&D-generated knowledge and technology is another complex question that relates to the choice of lags. On the one hand, it takes time to absorb and utilise external knowledge and innovations, but at the same time, the value of these innovations is reduced as new knowledge and technology come into use. Consequently, we are confronted with two rivaling effects, implying a concave lag distribution in the spillovers. So far, research on R&D depreciation rates and spillover lags has not provided any strong guidance as to what lag structure is the optimal one. Consequently, the chosen lag varies considerably from study to study. As compared to many other studies of R&D spillovers, our data set spans a relatively short time period, thus in order to not reduce the data set too much, we follow the practice in Griffith, Redding and Van Reenen (2000) and Kinoshita (2001) where a one year lag is used. In Appendix 3, we present additional regressions where both 1 year lags and 2 year lags are included. We find that except for domestic spillovers, none of the explanatory variables with a 2 year lag are significant. Neither does the inclusion of these variables affect the coefficients for variables lagged one year in any significant way. This finding supports our choice of lag structure.

The existence of economic shocks that affect both productivity and R&D investment may seriously weaken the validity of the empirical tests since the exogeneity assumption will be violated. Using lagged explanatory variables as instruments is one way of avoiding this problem, unless the future expectations of firms are perfect. Another econometric problem relates to whether the variables are cointegrated or not. A unit root test on panel data is now available and described by Levin and Lin (2002), but since our study has a relatively short time span, the predictability of this test is low. Over the period of interest, there is little reason to expect that TFP growth was non-stationary since this implies accelerating productivity. However, with considerable economic growth over the period, one should expect that both the flow of intermediates, R&D investments and foreign ownership intensity climbed fast. Consequently, the problem of cointegrated time series remains unsettled.

4. Empirical results

Before we present the results from the econometric exercise, we briefly look at the descriptive statistics outlined in Tables 1 and 2, in order to gain some insight to what the sector distribution of R&D activities and R&D spillovers looks like. In Table 1, we present the sectors that operate with the highest R&D intensity and the sectors that receive the highest R&D content through domestic and imported intermediates, as well as foreign ownership. As expected, the most R&D intensive sectors are found among high-tech manufacturing industries, but some of the natural-resource-based industries also rank high on this scale. The computer service industry is the only service sector that ranks among the top 10 R&D intensive sectors.

The ranking with respect to the highest R&D content in domestic intermediates is not widely different from the R&D intensity ranking. Notice though that the telecommunication service sector has a relatively high R&D content and that pharmaceuticals drops out of the list (index value 25.1). Also some of the natural resource based sectors switch places with similar industries. It is also important to mention that all of the 20 bottom ranking industries are service sectors, indicating that the magnitude of domestic R&D spillovers to service sectors is small.

When we turn our focus to R&D contents in imports, the picture changes. First of all, the vehicle-related industries are extremely import intensive in the use of highly R&D intensive machinery and electronics. In this respect, they represent outlayers in the sample. Further down the list, the variance in the R&D content drops dramatically. None of these industries are service sectors and many of the R&D intensive natural-resource-based industries fall out as other manufacturing industries, like producers of engines, machinery and technical tools use more R&D intensive imported inputs. Once again, among the 20 bottom ranking sectors on this index, 18 are service related. Finally, the intensity of R&D relating to foreign ownership is also extremely high in the production of vehicles, where the degree of foreign ownership is large. The strong degree of foreign ownership in the pharmaceutical industry brings this sector back among the top 10 sectors. Notice also that service sectors like insurance, wholesale trade and ocean transport get a high rank on this index since their degree of foreign ownership is large.

Table 1: The 10 sectors with highest R&D intensity and R&D contents

10 most R&D intensive sectors *R&D staff as % of total staff*		***Highest R&D content through domestic intermediates*** *(sd_i)*	*Index **
Radio and TV equipment	*19.7 %*	*Plastic*	*100.0*
Pharmaceuticals	*12.3 %*	*Weapons etc.*	*96.3*
Communication equipment	*11.8 %*	*Communication equipment*	*88.0*
Weapons etc.	*8.8 %*	*Refined petroleum products*	*66.8*
Chemical products	*7.5 %*	*Radio and TV equipment*	*55.4*
Non-ferro metals	*6.1 %*	*Animal foods*	*36.4*
Medical instruments	*5.4 %*	*Pulp and paper*	*34.2*
Paint products	*5.2 %*	*Telecommunication*	*28.5*
Chemical raw materials	*4.9 %*	*Medical instruments*	*28.2*
Computer services	*4.4 %*	*Ship building*	*25.9*

Highest R&D content through imports *(sf_i)*	*Index **	***Highest R&D content through FDI*** *(m_i)*	*Index **
Vehicle repair	*100.0*	*Vehicle production*	*100.0*
Vehicle production	*53.1*	*Chemicals*	*16.3*
Ship building	*7.1*	*Communication equipment*	*9.6*
Electrical engines	*5.6*	*Life insurance*	*7.9*
Communication equipment	*4.6*	*Wholesale trade*	*3.0*
Rubber and plastic products	*3.6*	*Other machinery*	*2.5*
Metal founding	*3.3*	*Medical instruments*	*2.2*
Radio and TV equipment	*3.2*	*Domestic Ocean transport*	*1.9*
Other machinery	*3.1*	*Pharmaceuticals*	*1.4*
Construction tools	*3.0*	*Construction tools*	*1.2*

A closer look at sector-specific TFP growth in Table 2 reveals a highly heterogeneous pattern with strong variance. First, although the arithmetic mean of TFP growth is negative for many years, this does not necessarily imply that total economy TFP growth was negative during these years. According to Statistics Norway (2002), aggregate TFP growth in Norway averaged 1.1% over the period 1991 to 1995. However, TFP growth in the manufacturing sectors which dominate in our data set, was as low as 0.4% during that period, and even lower during the years following our observation period. The heterogeneity attached to TFP growth also seems to apply to the distribution of R&D activities. 27 out of 105 sectors were registered with no own R&D activities. Furthermore, the data-processing service sector and the telecommunication services sector were the ones with the largest R&D employment. However, since these sectors are large, the R&D intensities are fairly low. This picture also applies to the oil and gas exploration sector which devotes large resources to R&D.

Table 2: Summary statistics on TFP growth and R&D employment

TFP growth					
Year	*Number of sectors*	*Mean*	*Standard deviation*	*Min*	*Max*
1990	*105*	*0.37 %*	*0.154084*	*-47.06 %*	*58.96 %*
1991	*105*	*-0.40 %*	*0.122302*	*-42.07 %*	*50.49 %*
1992	*105*	*1.32 %*	*0.14617*	*-56.60 %*	*90.18 %*
1993	*105*	*2.35 %*	*0.198289*	*-38.77 %*	*104.83 %*
1994	*105*	*2.46 %*	*0.12101*	*-33.02 %*	*51.99 %*
1995	*105*	*-1.35 %*	*0.194511*	*-67.94 %*	*58.42 %*
1996	*105*	*-1.90 %*	*0.224196*	*-94.52 %*	*106.65 %*
Number of R&D employed					
1989	*105*	*55.0*	*125.9*	*0.0*	*802.0*
1991	*105*	*60.9*	*141.3*	*0.0*	*721.7*
1993	*105*	*71.0*	*176.6*	*0.0*	*1227.0*
1995	*105*	*86.1*	*193.0*	*0.0*	*1179.5*

In Tables 3 and 4, we present the econometric. The regressions in Table 3 are based on the full panel, while Table 4 is restricted to manufacturing sectors only. First, we identify significant and positive R&D spillover effects both through domestic intermediates and imported inputs. This finding is robust for all alternative model specifications and applies both to the full sample and the manufacturing industry regressions. From Table 3, it is evident that the elasticity of TFP growth with respect to domestic R&D spillovers is larger with respect to international R&D spillovers. On average, the elasticity of TFP with respect to the R&D content of domestic inputs is somewhere between 0.1 and 0.15. In comparison, the elasticity with respect to the R&D content of imports is only 0.05. This is only half of the elasticity found by Coe and Helpman (1995), and could indicate that the use of macro data may overestimate the importance of international spillovers since the R&D content of imports is not well identified. Our findings are also in line with the empirical observations relating to the deteriorating effect of geographical distance on R&D spillovers. If geography matters, one should expect stronger domestic R&D spillovers than international spillovers.

Table 3: Full sample regressions (both manufacturing and service industries)

Models with sector fixed effects

	Model 1			Model 2			Model 3			Model 4		
so	0.0032	(0.0054)		0.0033	(0.0054)		0.0034	(0.0055)		0.0044	(0.0055)	
sd	0.1261	(0.0246)	***	0.1346	(0.0255)	***	0.1292	(0.0254)	***	0.1473	(0.0265)	***
sf	0.0547	(0.0160)	***	0.0435	(0.0164)	***	0.0538	(0.0167)	***	0.0432	(0.0169)	**
m	-0.1285	(0.0078)	*	-0.0149	(0.0078)	*	-0.0121	(0.0080)		-0.0123	(0.0082)	
Aso-sd				-0.5044	(0.2070)	*				-0.6513	(0.2254)	***
Aso-sf				0.6696	(0.2346)	**				0.8554	(0.2592)	***
Am-sd							-0.0815	(0.1642)		-0.0801	(0.1666)	
Am-sf							0.044	(0.1395)		-0.0564	(0.1445)	
1990										0.0163	(0.0269)	
1991										0.028	(0.0264)	
1992										0.0263	(0.0268)	
1993										0.0066	(0.0268)	
1994										-0.0207		
Constant	-0.3135	(0.0704)	***	-0.3383	(0.0705)	***	-0.3079	(0.0720)	***	-0.3278	(0.0733)	***
N	731			731			731			731		
Prob>F	0			0			0			0		
R2	0.085			0.096			0.085			0.11		
Sigma u	0.199			0.2104			0.2029			0.2122		
Sigma e	0.2189			0.2178			0.2192			0.2179		

Standard errors in parenthesis

* siginificance at 10%   ** siginificance at 5%   *** siginificance at 1%

Looking at the manufacturing industry regressions, the difference in coefficient sizes is not similarly robust. However, models 2 and 4 which include absorptive capacity effects, fully confirm the findings in Table 3.

When we turn to the impact of R&D spillovers through foreign ownership or FDI, we actually identify a significant negative effect on TFP growth. This finding is somewhat unexpected but could be explained by the fact that foreign investors in Norway tend to invest in sectors with low productivity, possibly in order to capture the gains from strong competitiveness, as described in Grünfeld (2001). Thus, there may exist

Table 4: Manufacturing industry regressions

Models with fixed effects

	Model 1			*Model 2*			*Model 3*			*Model 4*		
so	0.0179	(0.0093)	*	0.0138	(0.0095)		0.0176	(0.0093)	*	0.0148	(0.0096)	
sd	0.1008	(0.0344)	***	0.1328	(0.0391)	***	0.091	(0.0371)	**	0.1507	(0.0408)	***
sf	0.1037	(0.0293)	***	0.0597	(0.0339)	*	0.119	(0.0330)	***	0.0678	(0.0358)	*
m	-0.0139	(0.0078)	*	-0.0147	(0.0077)	*	-0.0131	(0.0081)	*	-0.0135	(0.0081)	*
Aso-sd				-0.4691	(0.2123)	**				-0.7275	(0.2326)	***
Aso-sf				0.6103	(0.2394)	**				0.875	(0.2621)	***
Am-sd							0.1261	(0.2166)		0.145	(0.2203)	
Am-sf							-0.1646	(0.1932)		-0.2762	(0.1999)	
1990										0.0012	(0.0296)	
1991										0.048	(0.0293)	*
1992										0.0393	(0.0293)	
1993										0.0356	(0.0302)	
1994										-0.0469	(0.0296)	
Constant	-0.378	(0.0917)	***	-0.4077	(0.0922)		-0.361	(0.0933)	***	-0.4125	(0.0986)	***
N	452			452			452			452		
Prob>F	0			0			0			0		
R2	0.11			0.122			0.11			0.16		
Sigma u	0.1812			0.1751			0.2029			0.2076		
Sigma e	0.1919			0.1908			0.2192			0.1884		

Standard errors in parenthesis

* siginificance at 10%   ** siginificance at 5%   *** siginificance at 1%

spillovers, but these are outweighed by the skewed distribution of foreign investments towards low-productive industries. Also, if absorptive capacity matters, such sectors are not equally able to learn from the R&D-generated knowledge held by foreign direct investors. Our finding conforms with a similar study by Braconier, Ekholm and Knarvik (2001) based on Swedish data where no spillovers through inward foreign direct investment were identified.

Based on the full panel, we find no significant effects of own R&D investment on TFP growth. However, such effects are identified when we confine our attention to manufacturing industries. In general, the service industries are much less R&D intensive and many of them are recorded without any R&D activities at all. It is important to notice that the elasticity of TFP growth with respect to own R&D investments in the manufacturing industries is low in comparison to the spillover elasticities. If interpreted correctly, this implies that learning through R&D externalities or spillovers can be more productive than the own R&D activities conducted by the industry itself. This observation increases the relevance of investigating the absorptive capacity of industries.

The importance of absorptive capacity effects is confirmed in this study. However, at the first look, the results are rather surprising. When we focus on absorptive capacity generated through own R&D activities, we find significant positive absorptive capacity effects relating to R&D spillovers from imported inputs, but the effect is negative when it is linked to domestic R&D spillovers. One way to interpret this, but probably not correct, is simply to conclude that R&D investments reduce the capacity to learn from other firms and sectors in the same country. However, there is an alternative interpretation that is not equally counter-intuitive: Industries with a high R&D intensity often operate close to the technology frontier and find only productive spillovers from firms or industries that are equally advanced or even closer to the technology front. If such firms or industries are predominantly located abroad, which is probably the case for Norway, being a small country, there is little to learn from domestic sources. Thus, the more R&D intensive the industry is, the less it has to learn through interaction with domestic suppliers, and absorptive capacity effects are negative. Also, the fact that we find a positive absorptive capacity effect relating to international spillovers fits well with the literature on geography and knowledge spillovers as outlined in section 2. If learning is hampered by geographical distance due to transaction costs, cultural differences, language barriers, etc. one should expect that investments in learning capacity would help to overcome these obstacles. Within a country, however, these barriers are much smaller and give smaller productivity gains from investing in absorptive capacity.

Finally we are not able to find any positive absorptive capacity effects driven by the home-based R&D activities of foreign owners in Norwegian industries. In other words, there is no significant signs of improved learning ability through direct foreign ownership on the industry level. The fact that we assume that the foreign owner has the same sector affiliation at home and abroad may distort our results. Also, notice that although there are no significant effects on the industry level, there may still exist positive absorptive capacity effects of foreign ownership on the firm level. That is, this effect can be limited to the firms that actually have foreign direct owners, implying that there is no spread of learning effects to other firms in the same industry.

5. Conclusions and policy implications

This study gives empirical support to the existence of international R&D spillovers through imports, based on a highly disaggregated data set for Norwegian business sectors in the 1990s. However, our investigation indicates that the effect of such spillovers on productivity growth in small open economies is over estimated in the studies based on macro data, as is the case in e.g. Coe and Helpman (1995). We find that domestic R&D spillovers through the use of intermediates have a significantly stronger impact on productivity. We argue that this is well in line with the empirical findings on the relationship between knowledge spillovers and geographical distance. Spatial proximity between firms and industries appears to improve the flow of knowledge and technology, increasing the productivity effect through R&D spillovers. Thus, there is good reason to expect stronger domestic than international spillovers.

Our results with respect to absorptive capacity effects also fit well into this picture. We find that the absorptive capacity of an industry, measured in terms of its R&D intensity, helps to take advantage of the R&D content flowing to the industry through imports. Thus, the study gives support to the importance of learning ability in the search for international R&D spillovers. However, this is not the case for domestic R&D spillovers. Consequently, we argue that the negative effect of geographical distance for spillovers can be counteracted by R&D investments that improve the absorptive capacity. This issue is not equally relevant for domestic spillovers since the geography effect plays a less important role.

The aspect of absorptive capacity is strongly related to policy in more than one way. First of all, the presence of a strong public R&D sector in the form of universities and public R&D institutes that generate easily available knowledge to private firms seems to be a prerequisite for developing a successful absorptive capacity base among firms. Based on our results, it is reasonable to claim that the public sector should invest intensively in or alternatively give subsidies to R&D activities that bring foreign knowledge closer to domestic firms, since such activities may raise the productivity of firms more than collaboration with and learning between domestic firms. Many policy makers stress the importance of organising well functioning knowledge clusters that are based on geographical proximity. One may claim that this view is supported in this study. But there is reason to claim that it is even more important to generate learning environments that interact efficiently with foreign R&D milieus. One way to promote such activity is to support firms that engage in R&D collaboration abroad, or alternatively locate some of its R&D activities in other countries in order to more easily gain from R&D spillovers. The presence and importance of this learning channel is well documented by Globerman, Kokko and Sjöholm (2000) for the case of Sweden.

In order to improve the insights to the issues raised in this paper, one should specifically look closer at two important aspects: First, geographical distance to exporter should be included as an explicit variable in the empirical exercise. This would provide a better understanding of the how geography actually matters. This has already been done by Keller (2002), but more studies need to be undertaken in order to provide a more rigorous knowledge base for policy makers. Second, an analysis of policy effects should take industry-relevant public R&D activities and subsidies into account. This matter has been discussed in Klette, Møen and Griliches (2000) but the combined focus of public R&D activities and subsidies on the one hand and domestic, and international R&D spillovers on the other, still remains to be analysed.

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Appendix 1: Data sources and description of variables

Economic activity data:

Norwegian National Accounts Statistics: Annual statistics covering economic activity and input-output flows on the 3 digit national account sector classification level. For more information, see http://www.ssb.no/english/subjects/09/01/nr_en/

Varibles:

X_{it}	=	Value added in fixed prices in sector *i* (1000NOK).
$\tilde{X}_{it}$	=	Value added in current prices in sector *i* (1000NOK).
L_{it}	=	Total employment in sector *i*
K_{it}	=	Total value of capital in fixed prices in sector *i* (1000NOK).
w_{it}	=	Average wage costs per employee in sector *i* (1000NOK).
u_{ijt}	=	Volume (value in fixed prices) of inputs from sector *j* to sector *i* (1000NOK).
v_{hit}	=	Volume of imported inputs from import sector *h* to sector *i* (1000NOK)

Norwegian Current Account Statistics: Annual statistics covering current account transaction, including both commodity and service trade using. Data is converted into the NACE 2 digit classification.

Variable:

l_{hkt}	=	The share of country *k* in imports produced in import sector *h* at time *t*.

OECD Industrial Structure Statistics (STAN): Annual statistics covering economic data at the ISIC rev. 2 industry level over the period 1990 to 1996 for most OECD countries. Observations have been reclassified and aggregated according to the NACE-ISIC concordance tables.

Variable:

X_{hkt}	=	Value added in current prices and local currency for industry *h* in country *k*. Defined on the NACE 2-digit level.

R&D statistics:

Norwegian R&D Statistics: Bi-annual statistics covering the R&D activities of all Norwegian companies with more than 50 employees during the period 1989 to 1997. Firms with lower employment participate in a survey consisting of 35% of all manufacturing firms. The statistics covers both internal and externaly provided R&D, both measured in terms of R&D expenditures and in term of employment. To obtain annual data, missing observations (1990, 1992, 1994, 1996) are constructed using linear intrapolation. For more information on this data, see http://www.ssb.no/english/subjects/10/03/foun_en/

Variables:

RO_{it}	=	Number of R&D employees in sector *i* (both internal and external R&D).

OECD BASIC Science and Technology Statistics:
Annual statistics on the R&D activities of OECD countries, including business enterprise R&D expenditures. Data has been reclassified to fit the NACE 2-digit industry classification.

Variable:

RF_{hkt}	=	Business enterprise R&D expenditures in industry *h*, country *k* (current prices and local currency).

<u>Foreign ownership:</u>

SIFON: Registry covering the value of foreign held equities in firms located in Norway, specified for owners from 24 countries over the period 1990 to 1996. The data set allows us to identify the ownership share held by the largest single foreign owner in the firm. The registry also contains information on the total equity value of firms and an industry classification on the NACE 5-digit level (rev. 1). For more information on this data base contact Statistics Norway or see http://www.ssb.no/english/subjects/10/07/indutleie_en/

Variables:

FO_{gkt}	=	Value of foreign owned equities in firm *g* held by foreign owners from country *k* with more than 10% of total equity value (1000NOK).
EQ_{gt}	=	Total value of firm equities (1000NOK).

<u>Important index notation:</u>

i = index over 3 digit National accounts sectors (roughly similar to NACE 3 digit sectors), Number of sectors =105.

h = index over 2 digit NACE sectors (27 sectors) derived through concordance tables with ISIC rev 2.

g = index over firms in the SIFON register $g \subset i \subset h$.

t = time (1989-1996).

k = index over countries (16 countries).

Appendix 2

Table A1: List of national account sectors (*i*)

	Sector List N = 106		
111	*Oil and gas*	*321*	*Communication equipment*
112	*Oil and gas services*	*323*	*Radio, TV and video equipment*
140	*Mining*	*331*	*Medical instruments*
151	*Meat products*	*334*	*Optical instruments*
152	*Processed fish*	*340*	*Vehicles*
153	*Fruit and vegetables*	*351*	*Ships and ship repair*
154	*Food oils*	*352*	*Oil platforms*
155	*Diary products*	*353*	*Trains etc.*
156	*Ore and cerals*	*354*	*Airplains*
157	*Animal food*	*355*	*Other transport vehicles*
158	*Other food products*	*361*	*Furniture*
159	*Beverages*	*362*	*Juvelry, coins etc.*
160	*Tobacco*	*363*	*Other industrial products*
170	*Textiles*	*401*	*Electricity*
180	*Clothes*	*402*	*Power transport*
190	*Shoes etc*	*403*	*Electricity trade*
201	*Processing of Wooden products*	*405*	*Distant heating*
202	*Wooden fibers etc*	*451*	*Basic contruction*
203	*Prefabricated houses*	*452*	*Construction*
204	*Other wooden products*	*453*	*Other construction*
211	*Paper raw materials*	*454*	*Instalation*
212	*Pulp and paper*	*501*	*Retail sales machinery*
213	*Paper products*	*502*	*Vehicle repair*
221	*Publshing*	*505*	*Gas sales*
222	*Printing*	*510*	*Wholesale trade*
232	*Refined petroleum products*	*521*	*Retail trade*
241	*Chemical raw materials*	*527*	*Household appliance repair*
242	*Fertilizers*	*551*	*Hotel*
243	*Paint*	*553*	*Restaurant*
244	*Pharmaceuticals*	*602*	*Bus transport*
245	*Household appliances*	*603*	*Taxi transport*
246	*Chemical products*	*604*	*Other transport*
247	*Plastic*	*608*	*Pipeline transport*
250	*Rubber and plastic products*	*611*	*Ocean transport domestic*
261	*Glass*	*620*	*Air transport*
262	*Cheramical products*	*631*	*Other transport services*
265	*Cement*	*632*	*Ofshore transport services*
266	*Mineral products*	*641*	*Post and mail distribution*
271	*Steel, iron and ferro metals*	*642*	*Telecommuncation*
273	*Aluminum*	*652*	*Bank services*
274	*Non-ferro mettals*	*661*	*Life insurance*
275	*Metal founding*	*662*	*Pension funds*
281	*Metal constructions*	*663*	*Damage insurances*
286	*Household metals*	*700*	*Real estate services*
287	*Metal products*	*704*	*Own house services*
291	*Other machinery*	*711*	*Transport rentals*
293	*Construction tools*	*713*	*Rental of machinery and equipment*
296	*Weapons and ammunition*	*720*	*Data processing*
297	*Household machinery*	*730*	*R&D*
300	*Computers and office machinery*	*742*	*Architects and technical drawings*
311	*Electrical engines and generators*	*744*	*Advertising*
313	*Cables*	*747*	*Cleaning services*
314	*Electrical machinery*	*748*	*Other business services*

Table A2: Country list (*k*)

Australia	***Japan***
Belgium	***Netherlands***
Canada	***New Zeeland***
Denmark	***Portugal***
Finland	***Spain***
France	***Sweden***
Germany	***UK***
Italy	***USA***

Table A3: List of import categories / sectors (*h*)

Current Account import categories		*ISIC rev. 2 sectors*
1	*Primary goods*	*1*
10	*Oil, gas and mining*	*2*
15	*Food*	*311+313+314*
17	*Textiles and clothing*	*321 to 324*
20	*Wood and wood products*	*331*
21	*Paper*	*341*
22	*Publishing and printing*	*342*
23	*Coal and petroleum products*	*353+354*
24	*Chemicals and chemical products*	*351+352*
25	*Rubber and plastic products*	*355+356*
26	*Other mineral products*	*36*
27	*Metals*	*37*
28	*Metal products*	*381*
29	*Machinery and machinery equipment*	*382-3825*
30	*Office and computer machinery*	*3825*
31	*Other electrical machinery*	*383-3832*
32	*Radio and communication equipment*	*3832*
33	*Medical and optical instruments*	*385*
34	*Motor vehicles*	*3845*
35	*Other transport equipment*	*384-3843*
36	*Furniture etc.*	*332+39*
40	*Electricity, gas and water distribution*	*4*
45	*Cosntruction*	*5*
50	*Retail and wholesale trade*	*61+62+63*
60	*Transport and tele communication*	*71+72*
65	*Financial services*	*81+82*
75	*Other private services*	*83*

Appendix 3:

Table A4: Full sample regression with both 1 and 2 year lags

Model with sector fixed effects

	Coefficient	St. error	
so (t-1)	0.0077232	(0.00765)	
sd (t-1)	0.2350574	(0.03635)	**
sf (t-1)	0.0548617	(0.02038)	**
m (t-1)	-0.020788	(0.01206)	*
so (t-2)	0.0016548	(0.00773)	
sd (t-2)	-0.078213	(0.03599)	**
sf (t-2)	-0.015503	(0.01913)	
m (t-2)	0.0166901	(0.01108)	
Aso-sd (t-1)	-0.90161	(0.29622)	***
Aso-sf (t-1)	0.9407045	(0.33837)	***
Am-sd (t-1)	-0.039717	(0.22783)	
Am-sf (t-1)	-0.075077	(0.189)	
Aso-sd (t-2)	0.2004456	(0.38125)	
Aso-sf (t-2)	-0.14283	(0.39722)	
Am-sd (t-2)	0.1740514	(0.2623)	
Am-sf (t-2)	-0.087693	(0.21798)	
1991	0.0761593	(0.03697)	**
1992	0.0981262	(0.03454)	***
1993	0.0735781	(0.03265)	**
1994	0.0591898	(0.03235)	*
1995	0.0157855	(0.03214)	
Constant	-0.320959	(0.09966)	***
N	626		
Prob>F	0		
R2	0.145		
Sigma u	0.2267		
Sigma e	0.2219		

Standard errors in parenthesis

* siginificance at 10% ** siginificance at 5% *** siginificance at 1%

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