THE RESEARCH INSTITUTE OF INDUSTRIAL ECONOMICS

Working Paper No. 553, 2001

Does FDI Work as a Channel for R&D Spillovers? Evidence Based on Swedish Data

by Henrik Braconier, Karolina Ekholm and Karen Helene Midelfart Knarvik

IUI, The Research Institute of Industrial Economics
P.O. Box 5501
SE-114 85 Stockholm
Sweden

Does FDI Work as a Channel for R&D Spillovers? Evidence Based on Swedish Data*

Henrik Braconier[†], Karolina Ekholm[‡], and
Karen Helene Midelfart Knarvik[§]

April 26, 2001

Abstract

Multinational enterprises (MNEs) are important in transmitting technology across national borders. Not only do they allow for transfer of technology within the firm, but it is also believed that they are important channels for international R&D spillovers as well. This paper analyzes empirically whether inward and outward foreign direct investment (FDI) work as channels for international R&D spillovers. We utilize firm-level as well as industry-level data for Swedish manufacturing in the analysis. We find no evidence of FDI-related R&D spillovers – neither at the firm-level nor at the industry-level in Swedish manufacturing. The only variable that consistently affects total factor productivity is own investment in R&D.

Keywords: Multinational enterprises, Foreign direct investment, spillovers, Research and development

JEL codes: F23, O32, O33

*We would like to thank participants at the TMR workshop on FDI and the Multinational Corporation in Athens and the ETSG conference in Rotterdam, both in September 1999, for useful comments. We would also like to thank Marie Hesselman for excellent research assistance. Braconier and Ekholm thank the Marianne and Marcus Wallenberg Foundation and the Bank of Sweden Tercentenary Foundation for financial support, while Midelfart Knarvik thanks the Research Council of Norway (grant no. 124559/510). Financial support from the European Commission (TMR) is also gratefully acknowledged.

[†]The Research Institute of Industrial Economics (IUI), Stockholm.

[‡]Stockholm School of Economics and CEPR.

[§]Norwegian School of Economics and Business Administration, Bergen, and CEPR.

1 Introduction

The hypothesis that international transactions, such as cross-border trade and foreign direct investment (FDI), are important channels of international technology diffusion has recently been subject to significant attention and research. A number of studies have addressed the issue of whether trade and/or FDI seem to facilitate international R&D spillovers (e.g. Coe & Helpman, 1995; Lichtenberg & van Pottelsberghe de la Potterie, 1996; Braconier & Sjöholm, 1998; Keller, 1998; Baldwin *et al.*, 1999).[1] However, as pointed out by e.g. Keller (1998), there are inherent problems with respect to methodology and data coverage associated with these studies. For instance, Keller (1998) shows that using the unweighted foreign R&D stocks rather than the trade-weighted stocks actually improves the explanatory value of these stocks. Furthermore, the empirical analysis in the aforementioned studies is performed at the aggregated country or industry level, which means that important aspects of technology diffusion at the firm level remain unexplored.

Studies that focus on FDI as a potential channel for spillovers face a specific problem due to the lack of reliable data on the foreign operations of multinational firms. A drawback with all existing studies of FDI-related R&D spillovers is that they use macroeconomic investment data on FDI to measure the extent of the foreign operations of multinational enterprises (MNEs). Because these FDI data only measure financial flows between countries, they tend to be rather poor measures of activity levels of MNEs.[2]

In this paper, we investigate the existence of R&D spillovers transmitted through inward and outward FDI in the case of Sweden. The choice of Sweden is guided by the fact that it is one of the very few countries for which firm-level data on multinational activity are available. We apply the analysis to two different data-sets. The first consists of a panel of Swedish MNEs and thus constitutes a firm-level sample. The second is a panel of industry-distributed data for the Swedish manufacturing sector as a whole. The fact that we use two different data-sets enables us to examine separately

[1] There is also an extensive literature focusing on technology spillovers between developed and developing countries, of which Blomström and Kokko (1998) provide a comprehensive overview.

[2] For instance, investments financed by locally borrowed funds will not be included in measures based on FDI data. For a discussion of the drawbacks of using FDI data to measure foreign operations of MNEs, see Ekholm (1995, p. 50).

the effect of R&D spillovers at the firm level, and at the national industry level. Furthermore, because the data base on Swedish MNEs incorporates data on the affiliates' activity levels, our measure of multinational activity is superior to measures based on direct investment data.

Another advantage of our data is that they allow us to examine whether the *kind of activity* undertaken by a foreign affiliate matters for the extent to which spillovers are transmitted. An MNE might benefit from a higher degree of technology acquisition, if its foreign affiliates have their own R&D departments, as compared to the case where they only have assembly plants.[3] Hence, we examine whether the extent of R&D activities conducted abroad facilitates the transmission of international R&D spillovers.

The rest of this paper is organized as follows. In section 2, we survey the literature on potential channels for international R&D spillovers. Section 3 specifies the empirical model used in the analysis and section 4 presents the estimation results. Finally, in section 5 we offer some concluding remarks.

2 International R&D spillovers

2.1 Inward FDI and R&D Spillovers

It is rather straightforward to see that inward FDI may work as a channel for R&D spillovers and technology diffusion. The existence of MNEs is usually taken to be the consequence of (a) the firm's possession of unique and superior technology, and (b) incentives to utilize this technology abroad in foreign affiliates.[4] Thus, transferring technology between different locations is an important task of MNEs. The benefit of technology transfer through inward FDI for the host country is two-fold. First, the MNE may introduce new technology in the host country. Second, through the MNE's use of this technology in the host country, it may become more accessible to domestically owned firms as diffusion costs associated with geographic distance decline.[5]

[3] Studies by Cantwell and Hodson (1991) and Fors (1998) find evidence that R&D in foreign affiliates is partly motivated by technology sourcing, i.e. R&D is located abroad in order to get access to knowledge in foreign "centres of excellence".

[4] This idea underlies the so-called knowledge-capital model recently developed by Markusen and Venables (1998); a model which is partially a formalization of the OLI framework advanced by John Dunning (Dunning, 1977).

[5] It should be noted that the MNE has strong incentives to try to conceal its technology from competitors as it may be the rationale for their existence. These efforts will of course

Hence, inward FDI may affect productivity growth positively by increasing international R&D spillovers (Baldwin *et al.* 1999).[6]

However, the efficiency of FDI as a transferor of technology across countries depends on a number of factors; firm-related as well as market-related. The most fundamental firm-related factor is probably the mode of entry into the foreign market. If a firm enters through a merger or acquisition, the potential for spillovers may be relatively small as new technology will be introduced in the host country only gradually. But if FDI takes place through greenfield investment, the MNE introduces new technology instantly. Consequently, the potential for R&D spillovers is likely to be larger.[7]

The specific type of technology that the MNE chooses to install in a foreign affiliate may also affect the potential for spillovers from R&D. As Teece (1977) shows, transfer costs decrease with the age of the transferred technology and the experience of the transferee. Similarly, Abramovitz (1986) argues that social capabilities are important for absorbing new technologies. If this is the case, there may be a tendency for newer vintages of technology to be installed in more advanced countries and thus for FDI to have a larger effect on productivity in such countries. At the same time, however, more advanced countries are likely to experience a smaller technology-gap to the technological leader and may therefore benefit relatively less from FDI transmitted R&D spillovers. Similarly, because of the pro-competitive nature of international trade, firms in countries with a history of openness to international trade are likely to have a higher average productivity.[8] Again, this works in the direction of reducing the potential for productivity effects of FDI transmitted spillovers.

Another important factor determining the potential for FDI transmitted R&D spillovers is the degree to which the MNE interacts with other agents in the host country. If the affiliates form an enclave within the host country with little contact with domestic firms, there will be few spillovers and the

tend to diminish any spillover effects.

[6] It should, however, be noted that our ability to measure productivity effects from inward FDI hinges on the assumption that pricing decisions are not affected by FDI. If prices do change, for example due to more or less competition in the local market, then the measured productivity effects of FDI will be affected.

[7] Blonigen & Slaugther (1999) find that Japanese greenfield investment is the only type of FDI into the US that affects relative factor demand.

[8] See Edwards (1997) on evidence on the linkage between openess and growth and productivity.

increase in productivity will mainly accrue to the MNE itself. Consequently, the more diversified the firms are in the host country and the more integrated the foreign-owned firms are in the host economy, the larger the spillovers are likely to be. In particular, the establishment of networks with local suppliers in the host country on the part of the MNE is likely to be important for increasing technology diffusion (Lall, 1980). Also, a high degree of labor mobility between the foreign affiliates of the MNE and domestic firms is likely to have an effect in the same direction, as the workers bring with them the knowledge of new techniques when they move from one employer to another (Fosfuri *et al.*, 1999).

Looking for evidence of R&D spillovers transmitted by inward FDI, it is important to establish at what level we should expect to observe any effects. For a foreign affiliate, R&D conducted by the parent firm is likely to affect productivity. However, this is, per definition, not a spillover effect. The natural unit of observation is rather the industry in the host country, excluding the foreign affiliate, or individual local firms. However, industry-level data do not allow such a separation. Hence, empirically, studies using industry-level data are not able to distinguish between the within-MNE productivity effect and the spillover effect. By examining firm-level data, it is possible to test for the impact of inward FDI on the productivity of domestic firms, thereby focusing directly on the spillover effect. This has been done for different developing countries, see e.g. Aitken and Harrison (1999), and Blomström and Kokko (1998) for a survey. The empirical evidence appears to be mixed: inward FDI is found to have a significant positive impact on productivity in some countries, while Aitken and Harrison (1999) find a negative impact of inward FDI on local firms' productivity.

2.2 Outward FDI and R&D Spillovers

The standard theory of the MNE builds on the idea that the firm possesses some unique asset which may be exploited abroad through the establishment of foreign affiliates.[9] However, a further explanation may be the firm's desire to acquire new technology either by purchasing foreign firms or establishing

[9] The firm's incentives to produce abroad may stem from the existence of trade costs which make exporting a less advantageous strategy (see Markusen & Venables, 1998), or from low production costs abroad (see Helpman 1984, 1985, Markusen *et al.*, 1998).

R&D facilities in so-called 'centers of excellence' abroad.[10] Through this kind of technology sourcing, the firm may gain access to technological knowledge stemming from the host country. Thus, there may be reversed technology flows where technology is transferred from a particular host country to units in the home country, or to affiliates in other host countries. Consequently, a country may enjoy R&D spillovers through outward FDI.

The extent of R&D spillovers transmitted through outward FDI depends on a number of factors. First, there must be a pool of knowledge in the host country from which the MNE can extract new technologies. Therefore, the level of technological proficiency of domestic firms relative to the MNE is likely to affect the potential for R&D spillovers (e.g. Kogut & Chang, 1991). Second, the level of interaction between the MNE's affiliates and other agents in the host economies is a very important factor. Especially the interaction between scientists and technicians engaged in R&D is likely to promote the spreading of technological knowledge. Hence, it seems reasonable to expect that the extent of R&D undertaken in affiliates in a host country will affect the MNE's ability to absorb new technologies from that country. However, there are cases where foreign R&D operations may have little to do with technology sourcing; for instance in the case where R&D is undertaken solely in order to adapt the MNE's technology to local conditions. Finally, just as in the case of inward FDI, the mode of entry, the degree of labor mobility, and the extent of supply linkages are likely to be important for the amount of R&D spillovers that will be transmitted through outward FDI.

In analyzing R&D spillovers transmitted through outward FDI, it is important to make a distinction between productivity effects on the MNE as a whole, on the home parts of the MNE, and on the home economy of the MNE. If R&D spillovers are transmitted through outward FDI, we should primarily expect productivity increases at the level of the whole MNE. The firm absorbs new technologies, and this should lead to a higher level of productivity at the level of the firm. From a policy perspective, however, the more relevant issue is whether this also leads to a productivity increase in the parts of the firm that are located in the home country and in purely domestic firms. Obviously, this does not have to be the case, since any productivity

[10] The importance of technology sourcing as motive for investing abroad is underscored by the findings of Kogut and Chang (1991), and Neven and Siotis (1996), who report that R&D intensity in the host country has a positive impact on outward FDI. This was found to apply for Japanese investment in the US, as well as for US and Japanese investment in Europe.

increase may be confined to foreign affiliates. However, the total effect on the home economy is potentially larger than the effect on the home part of the MNE, since the knowledge of foreign technologies may diffuse even further as the MNE interacts with other agents in the home economy.

3 The Empirical Model

In this section we specify the model used in the empirical analysis. We assume the following Cobb-Douglas specification of the production function of firm i:

$$Y_i = A_i L_i^{\alpha_i} K_i^{(1-\alpha_i)} \tag{1}$$

where Y is output (value added), A is a technology parameter capturing total factor productivity (TFP) and L and K are labor and capital inputs, respectively. The technology is assumed to be constant returns to scale in capital and labor. Given the specification of the production function, TFP (A_i) can be computed as:

$$A_i = \frac{Y_i}{L_i^{\alpha_i} K_i^{(1-\alpha_i)}} \tag{2}$$

where α is labor's share of value-added. For firm-level data, we have no reliable data on capital stocks, and are therefore reluctant to construct measures of TFP. Instead, we measure productivity in terms of labor productivity ($\frac{Y_i}{L_i}$). From (1) it follows that

$$\frac{Y_i}{L_i} = A_i \left(\frac{K_i}{L_i}\right)^{1-\alpha_i} \tag{3}$$

We assume that TFP depends on the firm's own R&D capital and, due to R&D spillovers, also on R&D capital stemming from other firms. More specifically, we assume the following relationship to hold for a firm i that belongs to industry k:

$$\begin{aligned} \ln A_i &= \beta_{0i} + \beta_{1i} \ln S_i + \beta_{2i} \ln S_k^D + \beta_{3i} \ln S_k^F + \beta_{4i} \ln OFDI_i \\ &\quad + \beta_{5i} \ln IFDI_i \end{aligned} \tag{4}$$

where S_i is the firm's own R&D capital stock, S_k^D is the total domestic R&D stock in sector k and S_k^F is the stock of foreign R&D in sector k available to i

through other channels than FDI. Possible channels for R&D spillovers captured by S_k^F are international trade, migration, industrial espionage, scientific writing etc. $OFDI_i$ and $IFDI_i$ measure R&D spillovers through outward and inward FDI.

In order to model R&D spillovers through FDI we have to define the potential for R&D spillovers and model the mechanism of transmission. We follow the previous literature in defining the potential source of R&D spillovers from a certain country as the R&D stock of that country.[11] However, we assume that the technological knowledge which is potentially relevant for a firm, is the one which belongs to firms that are 'similar' to the firm at hand. More specifically, in our firm-level analysis, we define the potential for foreign R&D spillovers as the foreign country's R&D stock in the industry (k) in which the MNE is active. Hence, we restrict our analysis to intra-industry spillovers. The fact that we use a fairly high level of aggregation regarding industry classification increases the potential for intra-industry spillovers relative to inter-industry spillovers. Moreover, because we use fixed effect estimators and time dummies we will control for inter-industry spillovers as long as they are stable across firms and industries over time.

In order to model the transmission mechanism through FDI, we would have liked to take a number of factors into account, such as the mode of entry and local market conditions. However, the lack of data, as well as tractability, forces us to use a cruder approach.

Starting with outward FDI, the first question is how to measure the firm's ability to absorb foreign technology. We define the transmission potential as the MNE's share of total host country activity in the industry to which the MNE belongs. This means that our measure of R&D spillovers from a particular host country is the MNE's share of activity in industry k multiplied by the host country's R&D stock in the same industry. A similar weighting scheme is employed by Lichtenberg and van Pottelsberghe de la Potterie (1996).

More specifically, our primary measure of R&D spillovers through out-

[11] See e.g. Coe & Helpman (1995) and Grilliches (1979, 1994). Note, however, that ideally we would have liked to measure the output of the R&D process (new technologies) rather than inputs. See Grilliches (1979) on the relationship betweeen input and output in R&D activity.

ward FDI ($OFDI$) is defined in the following way:

$$OFDI_i \equiv \sum_j \frac{L_{ijk}}{L_{kj}} S_{kj} \qquad (5)$$

where L_{ijk} is a measure of the activity level of MNE i that is active in sector k in country j, L_{kj} is a measure of the activity level in industry k in country j, and S_{kj} is the R&D stock in industry k in country j.[12]

In the empirical analysis we use employment as our primary measure of activity levels. However, in an attempt to tie the analysis closer to the literature on technology sourcing, we also use R&D activities in foreign affiliates in order to define the transmission potential. In the latter case, R&D spillovers through outward FDI are defined as the MNE's share of the host country's total R&D activities in industry k multiplied by the host country's R&D stock in k (see Appendix A).

For inward FDI, we use industry-level data. We define the transmission mechanism in a similar way as for R&D spillovers through outward FDI. Thus, the potential for R&D spillovers through inward FDI is measured as the ratio between Swedish employment in affiliates of MNEs originating in country j and total employment in industry k in country j, multiplied by the home country's R&D stock in industry k. More specifically, we use the following definition:[13]

$$IFDI_i \equiv \sum_j \frac{L_{kSj}}{L_{kj}} S_{kj} \qquad (6)$$

where L_{kSj} is the number of employees in Sweden in industry k that work in affiliates of MNEs from country j.

To check the robustness of our results, we have also defined a number of variables capturing FDI-related R&D spillovers using other weighting schemes. A complete list of weighting schemes is found in Appendix A. As the results of the empirical analysis turn out to be qualitatively unaffected by the choice of weighting scheme, we shall only present results based on (5) and (6).

[12] In the analysis based on industry-level data, the corresponding variable is defined as: $OFDI_k \equiv \sum_j \frac{\sum_i L_{ijk}}{L_{kj}} S_{kj}$

[13] The weighting scheme used is again analoguous to that used by Lichtenberg and van Pottelsberghe de la Potterie (1996).

As for the variable S_k^F, i.e. the variable capturing R&D spillovers transmitted through other channels than FDI, this is simply measured as the sum of foreign R&D stocks in industry k:

$$S_k^F \equiv \sum_j S_{kj} \tag{7}$$

4 Empirical Results for Swedish Manufacturing

The empirical analysis is conducted on two data sets: one consisting of a panel of Swedish multinational firms and one consisting of industry-distributed data for Sweden. The firm-specific data are taken from the Research Institute of Industrial Economics (IUI) database on Swedish MNEs.[14] These data are collected every four years since 1970, with the exception of 1982, and we use observations for 1978, 1986, 1990 and 1994. Data on value added, employment in the Swedish parts of the MNEs as well as in affiliates in foreign countries (outward FDI), book value of capital stocks and R&D spending within the firm are from this database, while employment data for each industry in each country are from STAN (OECD). Data on domestic (Swedish) industry-level R&D and foreign industry-level R&D are from the OECD database ANBERD. Data on foreign multinational activity in Sweden (inward FDI) are from Statistics Sweden. All variables have been converted into 1990 USD by using the Swedish GDP deflator and the PPP exchange rates from STAN (OECD). As for the industry-level analysis, the data sources are the same as in the firm-level analysis, except for data on employment and value added which are from STAN (OECD) and capital stocks from Statistics Sweden.[15]

4.1 Firm-Level Analysis

In the econometric analysis of the firm-level data, firms are only included if we have at least two observations during the period 1978 to 1994. Altogether,

[14] See Braunerhjelm & Ekholm (1998) for a description of the dataset.

[15] In the industry-level analysis, our time series for productivity levels start 1980. We have used data on foreign operations by Swedish multinationals in 1978 to construct our measure of R&D spillovers through outward FDI for 1980.

this leaves us with an unbalanced sample of 84 firms and 217 observations.[16] We use the (log of) labor productivity, computed as value added per employee at firm level, as the dependent variable. However, to examine whether R&D spillovers benefit the home country of the MNEs, we have also used labor productivity of the *Swedish* part of the firms as regressand.

In our base specification the (log of) labor productivity in firm i takes the form:

$$\begin{aligned} \ln LP_{it} &= \beta_0 + \beta_1 \ln R_{it} + \beta_2 \ln S^D_{kt} + \beta_3 \ln S^F_{kt} + \beta_4 \ln OFDI_{it} + \\ &\quad + \beta_5 \ln IFDI_{kt} + \beta_6 \ln \left(\frac{K_{it}}{L_{it}} \right) + \sum_{\substack{y=1978,1986, \\ 1990}} \delta_y D_y \end{aligned} \quad (8)$$

where R_i is total R&D spending of firm i (as a proxy for the firm's R&D stock), S^D_k is the Swedish R&D stock in the industry in which firm i is active, S^F_k is the unweighted foreign R&D stock, $OFDI_i$ is the measure of R&D spillovers through outward FDI and $IFDI_k$ the measure of R&D spillovers through inward FDI. Finally, $(\frac{K_i}{L_i})$ is the capital intensity of firm i while D_y represents a time dummy for each year included in the analysis, except 1994.[17]

In Table 1, we present some preliminary statistics for the four years of observation. We see that labor productivity and the capital-labor ratio have increased over the period of observation, with mild decreases between 1986 and 1990 and sharp increases taking place between 1990 and 1994. Average real R&D spending in Swedish MNEs more than doubled during the period. $FDIIN$ denotes degree of penetration of inward FDI in Sweden, measured as the share of Swedish manufacturing employment that can be attributed to foreign-owned firms. Similarly, $FDIOUT$ is degree of penetration of outward FDI, measured as the foreign share of the Swedish MNEs' total employment. Table 1 shows that the unweighted average of $FDIIN$ has risen from 6 to 12 percent, while the unweighted average of $FDIOUT$ has increased from 21 to 29 percent between 1978 and 1994.

{Table 1 about here}

Table 2 shows the correlation between the different variables included in the econometric analysis. The (log of) labor productivity is fairly highly

[16] These firms cover somewhat less than half the total sample of Swedish multinationals.

[17] For a detailed account of the construction of the variables in (8), see appendix A.

correlated with the firms' own R&D spending, R&D spending within the industry in Sweden and the capital-labor ratio, while the correlation with all the other independent variables is low.

{Table 2 about here}

To begin with, we estimate equation (8) with OLS, a fixed-effects (FE) model and a random-effects (RE) model. The results are presented in the first three columns of Table 3. All three methods yield similar results. Regardless of estimation technique, the capital-intensity and firm's own R&D spending have positive and significant effects on labor productivity and the estimated coefficients are very similar.[18] However, there is no evidence of R&D spillovers transmitted through inward or outward FDI – regardless of whether we analyze total variation across firms and over time (OLS), or whether we focus on the variation when time-invariant firm-specific effects have been removed (FE).

{Table 3 about here}

From Table 2 we see that $OFDI$, $IFDI$ and S^F are highly correlated with each other. This leads us to believe that we may have a problem with multicollinearity regarding these variables. In column 4 we therefore present the results from an FE estimation where we have excluded the unweighted foreign R&D stock (S^F). However, this is not found to have an impact on the significance of the remaining variables.[19]

The sample of MNEs constitutes a very particular sub-sample of firms which is not necessarily representative for local Swedish firms, and possibly less affected by inward FDI than the average local firm. Hence, in column 5 of Table 3 we report the results from an estimation where both $IFDI$ and S^F are excluded. The results for the other variables included in the specification, still do not change.

As argued earlier, R&D spending in foreign affiliates may be a better indicator of the MNE's capacity to absorb foreign R&D results than employment. Consequently, in column 6 of Table 3 we use the R&D-weighted foreign R&D stocks instead of the employment-weighted ones. Compared to the employment data there are fewer observations on R&D conducted in foreign affiliates, which leaves us with a panel of only 66 firms. We may

[18] Time dummies are not reported.

[19] In the following we only use the FE model, as the hypothesis of no fixed-effects is rejected and it seems likely that (unobserved) determinants of productivity differences are better captured by an FE model than an RE model. The test statistic for H_0: No fixed effects is $F(37,74) = 2.92^*$.

also encounter selection-bias problems when using R&D spending instead of employment, as R&D data are mainly missing for the smaller firms in the sample.[20] Still, with these caveats in mind, we conclude that the results give no support for the hypothesis that R&D in foreign affiliates increase the firms' ability to absorb foreign R&D results.[21]

As argued in section 2, productivity in the home parts of the MNE is the relevant variable for domestic welfare considerations. Moreover, when estimating the impact of R&D spillovers transmitted through inward FDI at the firm level, it is probably more relevant to confine the analysis to the productivity of the Swedish parts of the firms (bearing in mind that our sample lacks representativeness). Therefore, we also present the results from an estimation of equation (8) where the dependent variable is taken to be the labor productivity in the Swedish parts of the firms. Since physical capital is a rival (location-specific) input whereas R&D is a non-rival (firm-specific) input, we use the capital intensity of the Swedish part of the MNE, while retaining *total* firm-level R&D spending, in this estimation. The results from this estimation are presented in column 7 of Table 3. As can be seen, there are no significant effects from R&D spillovers transmitted through either outward or inward FDI. Nor do we find any significant effects from the firms' own R&D spending in this estimation. This suggests that the firms' R&D investments, which are mainly undertaken in Sweden, may do more to raise productivity in foreign affiliates than in the parent firms in Sweden. However, this result could also be due to the fact that most of the costs of conducting R&D are allocated to the Swedish parts of the MNEs while the benefits (in terms of higher productivity) are shared across all units.

We conclude that neither inward nor outward FDI seems to be essential for the transmission of R&D spillovers affecting labor productivity in Swedish MNEs. The only variables that consistently seem to affect labor productivity are the firms' own R&D spending and their capital-labor ratios.[22]

[20] A further problem is that for a large number of observations, reported R&D spending in foreign locations is zero, which means that we cannot take the logs of these observations. We therefore set R&D spendings in these cases to one.

[21] It should be noted that, qualitatively, the reported results also hold for the inclusion of the variables $IFDI$ and S^F and an RE specification of the model.

[22] We also divided the sample into high and low-tech industries – according to R&D intensity – to see whether the effects differed between the two samples. As we found no significant effects for $OFDI$ and $IFDI$ in any of the samples, these regressions are not presented.

Finally, it may be instructive to see whether inward and outward FDI *per se* affect labor productivity in the Swedish MNEs. In the last column of Table 3, we present results from estimations where we have replaced the FDI-weighted R&D stocks with the two measures of the degree of FDI penetration, $FDIIN$ and $FDIOUT$, measured at the industry and firm level, respectively. The results indicate that none of the penetration variables affect labor productivity. Thus, the extent to which an industry is characterized by inward FDI activity does not appear to be related to the productivity in Swedish MNEs. Nor does the MNEs' degree of outward FDI seem to be correlated with labor productivity within the firm.

4.2 Industry-Level Analysis

Next we turn to the analysis of spillovers at the industry level. Given that we did not find any strong evidence of R&D spillovers transmitted through outward FDI at the firm level, it seems unlikely that we should find evidence of such spillovers at the industry level. However, potential effects on productivity stemming from inward FDI are more likely to be picked up when we focus on productivity in aggregates, including both the foreign-owned firms themselves as well as pure domestic firms.

For the industry level, the following base equation is estimated:

$$\begin{aligned} \ln TFP_{kt} &= \alpha_0 + \alpha_1 \ln S_{kt}^D + \alpha_2 \ln S_{kt}^F + \alpha_3 \ln IFDI_{kt} \\ &\quad + \alpha_4 \ln OFDI_{kt} + \sum_{\substack{y=1980,1986,\\1990}} \delta_y D_y \end{aligned} \tag{9}$$

where TFP_{kt} is an index measuring total factor productivity in industry k and D_y again is a time dummy controlling for fixed time effects.

Table 4 shows summary statistics for the variables included in the industry-level analysis. As can be seen, the TFP index increases by 68 percent in the period 1980-1994. A particularly sharp increase in TFP is found between 1990 and 1994. This is probably due to the increase in productivity that occurred after Sweden went into a deep recession in the early 1990's. During the first years of the 1990's, there was a very sharp decline in industrial activity, and the closure of many plants increased the average productivity in Swedish manufacturing. The average domestic R&D stock has also increased substantially during the time period studied. It more than doubled between 1980 and 1994.

{Table 4 about here}

Table 5 shows the simple correlation matrix for the index of TFP and the different independent variables. TFP is weakly correlated with all potential regressors except inward FDI-penetration. The degree of correlation between the R&D variables is now even higher than in the firm level analysis.

{Table 5 about here}

The fact that the four R&D variables are highly correlated with each other indicates that we may have a serious multicollinearity problem. Regardless of whether we weigh the R&D stocks by inward or outward FDI, or whether we weigh them at all, domestic and foreign R&D stocks seem to follow the same trends. Thus, changes in R&D stocks and the magnitude of such changes seem to be industry rather than country specific. To separate the effects of foreign and domestic R&D on productivity from each other, as well as to establish the importance of outward and inward FDI as channels of technology diffusion may thus be a difficult task.

We report the results based on equation (9) in Table 6. The first two columns show the random-effect and the fixed-effect estimators for the base equation.[23] Again, we can reject the hypothesis of no fixed-effects so we shall primarily focus on the FE specification. As can be seen from Table 6, the coefficients for S^F and $IFDI$ are the only ones that are significant and they have an unexpected negative sign. Furthermore, the coefficients for the time dummies are all negative and highly significant, which indicates a positive trend in TFP across industries. This positive trend might be explained by other sources of increased technological knowledge, such as inter-industry R&D spillovers, government spending on R&D, or by an increased skill-level among employees. To check whether the inclusion of all R&D variables creates a problem with multicollinearity, we have excluded S^F from the specification presented in column 3 and S^D from the specification presented in column 4. As can be seen, this does not affect the results for $OFDI$ and $IFDI$. However, the exclusion of S^D makes the estimated coefficient of S^F insignificant. Thus, in contrast to e.g. Grilliches (1994), our results give no support for the idea that there is an excess return to investment in R&D

[23] Note that an OLS estimation does not make sense when TFP is used as the dependent variable since the choice of units can affect the ordinal ranking of industries with respect to the measure of TFP.

within industries.[24]

{Table 6 about here}

To check whether inward or outward FDI *per se* is related to TFP, we have again run regressions with inward and outward FDI penetration as independent variables instead of the weighted R&D stocks. As can be seen from column 5 in Table 6, none of the penetration measures have any significant impact on TFP. We therefore conclude that, at the industry-level, we find no evidence that TFP is affected by either inward or outward FDI. It is especially important to note that we do not find any evidence of R&D spillovers being transmitted through inward FDI at the industry level. Given that here we should pick up any effect of a higher productivity in the foreign-owned firms themselves, this is perhaps somewhat surprising. However, almost all Swedish affiliates of foreign firms have come about through M&As; very few are the results of greenfield investments. Hence, the lack of effect of $IFDI$ on TFP could be a reflection of weak technology transfers associated with M&As.

All in all, our results do not lend any support to the hypothesis that FDI is an important channel for international technology diffusion for the Swedish manufacturing sector. This is partly in line with Lichtenberg and van Pottelsberghe de la Potterie (1996), who do not find any support for the hypothesis that R&D spillovers are transmitted across OECD countries through inward FDI (although they do find support for the idea that they are transmitted through outward FDI). The results in Braconier and Sjöholm (1999) and Baldwin et al. (1999) differ from those of Lichtenberg and van Pottelsberghe de la Potterie (1996) as well as from ours, in that both studies report positive findings of international R&D spillovers transmitted through inward FDI.

One question that should be raised here, is whether Sweden constitutes a special case. Particular features of the Swedish economy may make foreign R&D spillovers relatively less important. Swedish manufacturing is dominated by a few very large and highly internationalized corporations that undertake most of the private sector's R&D investments. These R&D investments are very high from an international perspective and reflect the fact that Sweden ranks among the top countries with respect to share of

[24] Like in the firm-level analysis, we also divided the sample into high and low-tech industries. As we found no significant effects for $OFDI$ and $IFDI$ in any of the samples, these regressions are not presented.

R&D expenditures in GDP.[25] As a consequence, in those industries where FDI is important, the technology of the Swedish firms is most probably very close to the technological leader and, hence, the scope for R&D spillovers small. We have conducted a similar industry-level analysis for the only other country for which we have activity level data on inward and outward FDI, which is the US, but found no evidence of FDI-linked R&D spillovers and nor did we find any correlation between outward and inward FDI-penetration and the level of TFP. However, the US is in many respects similar to Sweden regarding technological proficiency and R&D spending. The results for the US are not reported in the paper.[26] Other factors that may reduce the scope for R&D spillovers are the dominance of M&As in Swedish inward FDI, and the fact that the Swedish economy exhibits a relatively low degree of labor mobility.

5 Concluding remarks

In this study, we have used firm-level and industry-level data for Sweden to study whether inward and outward FDI work as channels for international R&D spillovers. We argue that industry data and, even more so, firm level data increase the probability of observing patterns of actual spillovers as opposed to spurious correlations. Especially in the case of outward FDI, if we are to take country level results seriously, spillovers should at least be observed at the firm level. In the case of inward FDI, for which we only have industry level data, one could argue that purely domestic firms should be the main beneficiaries of R&D spillovers. Hence, effects of inward FDI should primarily be expected to appear at the industry level.

A major advantage of this study compared with previous studies of FDI-transmitted R&D spillovers, is that we use activity data for MNEs rather than FDI stocks to measure the potential for R&D spillovers. Unlike previous studies which have relied on macroeconomic investment data, we are thus able to measure directly the extent of the MNEs' foreign involvement. In the analysis, we have used affiliate employment as well as affiliate R&D spending in our measures of FDI-transmitted R&D spillovers.

A further advantage of using firm or industry-level data, as opposed to

[25] In 1995, total R&D expenditures as a share of GDP was 3.59 percent, while the average for the OECD countries were 2.15 percent.

[26] The results for the US are available from the authors on request.

country-level data, is that causality problems are mitigated. At the country-level, a positive association between productivity growth and FDI may simply reflect that MNEs invest more heavily in fast-growing economies in order to supply a growing market. The strong link between productivity growth and demand growth that we can observe at the aggregate level is likely to be much weaker on the industry-level, and especially at the firm-level.

To check the robustness of our results, we have used different specifications and weighting schemes of inward and outward FDI. The main conclusions are however robust to the choice of specification: For Swedish MNEs, we do not find any evidence of FDI-transmitted R&D spillovers. We find that the only variables that consistently affect the labor productivity of these firms, are their own R&D spending and capital-labor ratio.

Turning to the industry-level analysis, we find no evidence of inward or outward FDI being important for productivity in Swedish manufacturing industries. Neither inward nor outward FDI appear to be an important channel for international R&D spillovers. Moreover, neither inward nor outward FDI penetration is correlated with total factor productivity. The only significant explanatory variables for TFP are time dummies, suggesting a positive trend in TFP over time. This trend may be caused by improvements in overall technology or increased average skills of the workforce.

The lack of evidence of FDI transmitted international spillovers is somewhat surprising, and suggests that international technological spillovers are less enjoyed by countries with high R&D expenditures, i.e. technological leaders. It should further be emphasized, that this study concentrates on spillovers from OECD countries, which all have very similar levels of technology. Consequently, it may be that the scope for technology spillovers is very limited for these countries.

References

[1] Abramovitz, M. (1986), "Catching Up, Forging Ahead, and Falling Behind", *Journal of Economic History* 66: 385-406.

[2] Aitken, B. J. and A. Harrison (1999), "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela", *American Economic Review* 89: 605-618.

[3] Baldwin, R., H. Braconier, and R. Forslid (1999) "Multinationals, Endogenous Growth and Technological Spillovers: Theory and Evidence ", CEPR Discussion Paper No. 2155.

[4] Blomström, M. and A. Kokko (1998), "Multinational Corporations and Spillovers", *Journal of Economic Surveys* 12.

[5] Blonigen, B. and M. Slaughter (1999), "US Inward FDI and Relative Wages", presented at the Western Economic Association International Conference (San Diego).

[6] Braconier, H and F. Sjöholm (1999), "National and International Spillovers from R&D: Comparing a Neoclassical and an Endogenous Growth Approach", *Weltwirtschaftliches Archiv 134*.

[7] Branch, B. (1974), "Research and Development Activity and Profitability: A Distributed Lag Analysis", *Journal of Political Economy* 82: 999-1011.

[8] Braunerhjelm, P. and K. Ekholm (1998), *The Geography of Multinational Firms*, Boston: Kluwer Academic Publishers.

[9] Coe, D. T. and E. Helpman (1995), "International R&D Spillovers", *European Economic Review* 39: 859-887.

[10] Dunning, J. H. (1977), "Trade, Location of Economic Activities and the MNE: A Search for an Eclectic Approach", in P.-O. Hesselborn, B. Ohlin and P.-M. Wijkman (eds.), *The International Allocation of Economic Activity*, London: MacMillan.

[11] Eaton, J. and S. Kortum (1997), "Technology and Bilateral Trade", NBER Working Paper No. 6253.

[12] Edwards, S. (1997), "Openess, Productivity and Growth: What Do We Really Know?", NBER Working Paper 5978.

[13] Ekholm, K. (1995), *Multinational Production and Trade in Technological Knowledge*, Lund Economic Studies 58.

[14] Ekholm, K. (1998), "Proximity Advantages, Scale Economies, and the Location of Production", in Braunerhjelm, P. & K. Ekholm (eds.), *The Geography of Multinational Firms*, Boston: Kluwer Academic Publishers.

[15] Fors, G. (1998), "Locating R&D Abroad: The Role of Adaptation and Knowledge-Seeking", in Braunerhjelm, P. & K. Ekholm (eds.), *The Geography of Multinational Firms*, Boston: Kluwer Academic Publishers.

[16] Fosfuri, A., M. Motta and T. Ronde (1999), "Foreign Direct Investment and Spillovers through Workers' Mobility", CEPR Discussion Paper No. 2194.

[17] Grilliches, Z. (1979), "Issues in Assessing the Contribution of Research and Development to Productivity Growth", *The Bell Journal of Economics* 10: 92-116.

[18] Grilliches, Z. (1992), "The Search for R&D Spillovers", *Scandinavian Journal of Economics* 94: 29-47.

[19] Helpman, E. (1997), "R&D and Productivity: The International Connection", NBER Working Paper No. 6101.

[20] Jaffe, A. (1989), "Real Effects of Academic Research", *American Economic Review* 79: 957-970.

[21] Keller, W. (1998), "Are International R&D Spillovers Trade-related? Analyzing Spillovers among Randomly Matched Trade Partners.", *European Economic Review* 42: 1469-1482.

[22] Kogut, B. and S. J. Chang (1991), "Technological Capabilities and Japanese Foreign Direct Investment in the United States", *The Review of Economics and Statistics* 73: 401-413.

[23] Lall, S. (1980), "Vertical Interfirm Linkages in LDCs: An Empirical Study", *Oxford Bulletin of Economics and Statistics* 42: 203-226

[24] Lichtenberg, F. and B. van Pottelsberghe de la Potterie (1996), "International R&D Spillovers: A Re-examination", NBER Working Paper No. 5668.

[25] Mansfield, E. and A. Romeo (1980), “Technology Transfers to Overseas Subsidiaries by U.S.-Based Firms”, *Quarterly Journal of Economics*, 94, 737-50.

[26] Markusen, J. R. and A. J. Venables (1998), "Multinational Firms and New Trade Theory", *Journal of International Economics* 46: 183-203.

[27] Markusen, J.R., A.J. Venables, D.E. Konan and K. Zhang (1996), "A Unified Treatment of Horizontal Direct Investment, Vertical Direct Investment, and the Pattern of Trade in Goods and Services", NBER Working Paper No. 5696.

[28] Miyagawa, K. (1991), "Scale Economies in Education and the Drain Brain Problem", *International Economic Review* 32:743-759.

[29] Nadiri, M. I. and S. Kim (1996), "International R&D Spillovers, Trade and Productivity in Major OECD Countries" NBER Working Paper No. 5801.

[30] Neven, D. and G. Siotis (1993), "Foreign Direct Investment in the European Community: Some Policy Issues", *Oxford Review of Economic Policy* 9: 72-93.

[31] Neven, D. and G. Siotis (1996), "Technology Sourcing and FDI in the EC: An Empirical Evaluation", *International Journal of Industrial Organization* 5: 543-560.

[32] OECD (1994), *The Performance of Foreign Affiliates in OECD Countries*, Paris: OECD.

[33] Rogers, E. and F. Shoemaker (1971), *Communication of Innovations: A Cross-Cultural Approach*, New York: The Free Press.

[34] Teece, D.J. (1977), "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-How", *Economic Journal* 87: 242-61.

Appendix

A FDI Weights

In the analysis, we have used different weighting schemes for the FDI-transmitted spillover variables. For outward FDI, using employment data for foreign affiliates, the following three different variables have been used:

$$OFDI1_{ikt} = \sum_j \frac{\sum_h L_{hijkt}}{L_{kjt}} S_{kjt} \tag{10}$$

$$OFDI2_{ikt} = \sum_j \frac{\sum_h L_{hijkt}}{L_{kSt}} S_{kjt} \tag{11}$$

$$OFDI3_{ikt} = \sum_j \frac{\sum_h L_{hijkt}}{\sum_j L_{ijkt}} S_{kjt} \tag{12}$$

where L is employment and S is the R&D stock. The subscript h denotes foreign affiliate, i denotes firm (MNE), k denotes sector and j denotes host country of affiliates. The subscript S denotes Sweden (e.g. L_{iS} is the employment in the Swedish part of firm i). Corresponding measures have been constructed for the industry sample, where the MNEs have been distributed over industries based on the main activity of the MNE.

For inward FDI, the following variables have been used:

$$IFDI1_{kt} = \sum_j \frac{L_{kSjt}}{L_{kjt}} S_{kjt} \tag{13}$$

$$IFDI2_{kt} = \sum_j \frac{L_{kSjt}}{L_{kSt}} S_{kjt} \tag{14}$$

$$IFDI3_{kt} = \sum_j \frac{L_{kSjt}}{\sum_j L_{kSjt}} S_{kjt} \tag{15}$$

where L_{kSj} denotes the employment in Sweden in sector k that can be attributed to firms originating in country j.

The alternative measures for outward FDI based on R&D data have been constructed as follows:

$$OUTRD1_{ikt} = \sum_j \frac{\sum_h R_{hijkt}}{R_{jkt}} S_{kjt} \tag{16}$$

$$OUTRD2_{ikt} = \sum_j \frac{\sum_h R_{hijt}}{\sum_j \sum_h R_{hijkt}} S_{kjt} \tag{17}$$

$$OUTRD3_{ikt} = \sum_j \frac{\sum_h R_{hijt}}{\left(\sum_j \sum_h R_{hijkt} + R_{ikSt}\right)} S_{kjt} \tag{18}$$

$$OUTRD4_{ikt} = \sum_j \frac{\sum_h R_{hijkt}}{R_{ikSt}} S_{kjt} \tag{19}$$

where R is R&D expenditures and the indexation is as before (i.e., R_{hijk} is R&D expenditures in affiliate h that belongs to firm i and is located in country j while R_{jk} is R&D expenditures in industry k in country j).

B Data

Both our data sets for Sweden relate to the manufacturing sector only and use the same division of industries into the following 16 sectors: Food, Beverages & Tobacco; Textiles, Apparel & Leather; Wood Products & Furniture; Paper, Paper Products & Printing; Chemicals; Petroleum Refineries & Products; Rubber & Plastic Products; Non-Metallic Mineral Products; Iron & Steel; Non-Ferrous Metals; Metal Products; Non-Electrical Machinery; Electrical Machinery; Transport Equipment; Professional Goods; Other Manufacturing. In the econometric analysis, the industries Petroleum Refineries & Products and Other Manufacturing have been excluded because of the difficulties related to construction of appropriate R&D stocks for these industries.

B.1 Productivity Growth

TFP series have been computed from data from a number of sources. Value added, employment and total labor costs have been collected from STAN (OECD, 1999) and have been expressed in 1990 prices. The shares of labor costs have also been computed from STAN. Capital stocks, on the other hand, have been supplied by Statistics Sweden for the period 1980 to 1994 (and they are expressed in 1990 prices). The cost shares of labor and capital are constructed by taking the average for the period 1980 to 1996 for each industry. The reason for taking averages, is that there is a significant variability in factor shares over the business cycle due to labor hoarding etc.

In the firm-level regressions, where we use value added per employee as productivity measure we control for the capital-intensity of the firm. The capital-labor ratio of firm i is computed as the book-value of capital (in 1990 USD) per employee.

B.2 R&D variables

We have constructed R&D stocks for each industry in Sweden (S_k^D), as well as for each industry in the other countries included in the sample (S_{kj}) and also unweighted joint stocks for each industry in the other countries ($S_k^F = \sum_j S_{kj}$). The countries are the following: Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom and the U.S. Data on R&D spending have been collected from the OECD database ANBERD (1998). ANBERD includes observations on R&D spending from 1973 for all the included countries.

To construct R&D stocks for the initial year (1973) we follow Coe and Helpman (1995) and assume that $S_0 = R_0/(g+\delta)$, where the initial stock (in 1990 USD) is a function of initial real R&D spending, growth in real R&D spending (1973 to 1995) and the rate of depreciation. We have set the rate of depreciation to 5 percent. Fast growing R&D spending combined with the fact that we do not include observations prior to 1978 in the main analysis will mitigate potential measurement problems due to this procedure.

From 1973 and onwards R&D stocks are computed with the perpetual inventory method ($S_t = (1-\delta)\,S_{t-1} + R_{t-1}$). Data on real R&D spending in USD (1990 prices) have been constructed by deflating nominal R&D spending with the GDP deflator (from *OECD Economic Outlook*) to 1990 prices in national currencies. The transformation into USD has been carried out with PPP exchange rates from STAN (OECD), with the exception of Ireland for which we have taken PPP estimates from BILAT (OECD).

In the firm-level regressions we have used a proxy for R&D stocks in the individual MNE. From the IUI database we only have data on R&D spending for the sampling years. The variation in R&D spending is substantially higher at the firm level than at the industry level and complete series on R&D spending are only available for a few firms. Due to these data problems, we have not tried to compute stocks of R&D for the individual firms, but rather use real R&D spending as a proxy for this variable.[27] This may be a fairly good proxy if the (excess) private return to R&D declines rapidly over time and converges to the industry-wide (excess) return that is captured by the R&D stock in the industry.[28]

B.3 Data on Multinational Activities

Data on foreign activities by Swedish multinational firms have been collected by the Research Institute of Industrial Economics (IUI) through comprehensive surveys about every fourth year since 1970. We have used data from the surveys made in 1978, 1986, 1990 and 1994. This data-base gives us the number of employees for each foreign affiliate of the Swedish multinationals covered by the survey (which constitute around 85-95 percent of the total number of Swedish multinationals). By aggregating on the basis of industry of the parent company and host country, we get the employment measure used to construct our FDI-weighted R&D stocks.

The country- and industry-distributed data on employment in foreign-owned firms in Sweden used to construct weights for inward FDI have been supplied by Statistics Sweden.

[27] We have also tried to use lagged real R&D spending, but the correlation with current R&D spendings is very high (0.98).

[28] Branch (1974) and Grilliches (1979) show evidence of short lags (2 to 5 years) between R&D spending and productivity and profitability at the firm level.

Table 1: Unweighted averages for firm-level data (standard deviations in parenthesis) in 1990 US $ equivalents

Variable	*LP*	*K/L*	*R*	*FDIIN*	*FDIOUT*	*IFDI*	*OFDI*
1978 (n=40)	29.3E+03 (4.89E+03)	23.6E+03 (17.6E+03)	22.6E+06 (39.4E+06)	0.06 (0.04)	0.21 (0.16)	1.78E+08 (2.26E+08)	8.12E+07 (2.19E+08)
1986 (n=59)	34.1E+03 (8.16E+03)	25.3E+03 (17.0E+03)	42.0E+06 (112E+06)	0.10 (0.07)	0.23 (0.16)	2.46E+08 (2.99E+08)	1.46E+08 (5.85E+08)
1990 (n=78)	31.9E+03 (9.17E+03)	25.0E+03 (19.5E+03)	31.5E+06 (112E+06)	0.11 (0.07)	0.28 (0.17)	2.87E+08 (3.81E+08)	1.45E+08 (7.58E+08)
1994 (n=55)	43.4E+03 (12.6E+03)	33.8E+03 (34.4E+03)	49.2E+06 (183E+06)	0.12 (0.09)	0.29 (0.17)	2.97E+08 (3.91E+08)	2.12E+08 (9.33E+08)

Table 2: Correlation matrix, firm-level data

n=99	ln(*LP*)	ln(*R*)	ln(S^D)	ln(S^F)	ln(*K/L*)	ln(*OFDI*)	ln(*IFDI*)	ln(*OUTFDI*)	ln(*INFDI*)
ln(*LP*)	1.00								
ln(*R*)	0.22	1.00							
ln(S^D)	0.21	0.32	1.00						
ln(S^F)	0.12	0.36	0.83	1.00					
ln(K/L)	0.54	0.24	0.06	-0.07	1.00				
ln(*OFDI*)	0.09	0.79	0.51	0.62	0.11	1.00			
ln(*IFDI*)	0.12	0.29	0.80	0.92	-0.03	0.56	1.00		
ln(*OUTFDI*)	-0.02	-0.02	0.07	0.05	-0.06	0.35	0.12	1.00	
ln(*INFDI*)	0.16	0.04	0.43	0.58	0.01	0.30	0.78	0.25	1.00

Table 3: Determinants of Labor Productivity in Swedish Multinationals 1978-1994 (Dependent variable: log of labor productivity)

Regression Method	1 OLS	2 FE	3 RE	4 FE	5 FE	6 FE	7 FE	8 FE
ln(*R*)	0.041* (0.01)	0.050* (0.02)	0.045* (0.01)	0.052* (0.02)	0.052* (0.02)	0.048* (0.03)	0.048 (0.03)	0.054* (0.02)
ln(S^D)	0.017 (0.02)	0.093 (0.08)	0.023 (0.03)	0.044 (0.06)	0.058 (0.05)	0.034 (0.07)	0.061 (0.07)	0.034 (0.05)
ln(S^F)	0.014 (0.03)	-0.079 (0.08)	0.005 (0.04)					
ln(*K/L*)	0.186* (0.02)	0.181* (0.05)	0.183* (0.03)	0.179* (0.05)	0.183* (0.05)	0.242* (0.06)	0.172* (0.04)	0.177* (0.05)
ln(*OFDI*)	-0.039 (0.01)	-0.021 (0.02)	-0.038 (0.01)	-0.031 (0.02)	-0.030 (0.02)	0.003 (0.00)	-0.041 (0.02)	
ln(*IFDI*)	0.017 (0.02)	0.023 (0.03)	0.018 (0.02)	0.011 (0.02)			0.012 (0.03)	
ln(*FDIOUT*)								0.012 (0.03)
ln(*FDIIN*)								0.018 (0.03)
R^2(overall)	0.48	0.48	0.50	0.48	0.47	0.45	0.43	0.40
R^2(within)		0.57	0.57	0.57	0.57	0.64	0.55	0.58
No. Of obs.	217	217	217	217	217	152	205	224

Note: The asterisk (*) denotes significance at the 5 percent level.

Table 4: Unweighted averages for industry-level data (standard deviations in parenthesis)

Variable	*TFP* (1980=1)	S^D	S^F	*FDIIN*	*FDIOUT*	*IFDI*	*OFDI*
1980 (n=14)	1.00 (0.00)	1.09E+09 (1.12E+09)	1.19E+11 (1.56E+11)	0.05 (0.04)	0.12 (0.14)	1.26E+08 (2.03E+08)	2.44E+08 (5.04E+08)
1986 (n=14)	1.17 (0.15)	1.53E+09 (1.78E+09)	1.45E+11 (1.94E+11)	0.09 (0.07)	0.16 (0.26)	1.73E+08 (2.58E+08)	6.24E+08 (1.54E+09)
1990 (n=14)	1.27 (0.28)	1.89E+09 (2.32E+09)	1.68E+11 (2.26E+11)	0.11 (0.08)	0.21 (0.29)	2.33E+08 (3.31E+08)	9.44E+08 (2.13E+09)
1994 (n=14)	1.68 (0.80)	2.27E+09 (2.87E+09)	1.85E+11 (2.46E+11)	0.16 (0.13)	0.24 (0.34)	2.33E+08 (3.77E+08)	9.44E+08 (2.16E+09)

Table 5: Correlation matrix, industry-level data

n=52	ln(*TFP*)	ln(S^D)	ln(S^F)	ln(*OFDI*)	ln(*IFDI*)	ln(*FDIOUT*)	ln(*FDIIN*)
ln(*TFP*)	1.00						
ln(S^D)	-0.05	1.00					
ln(S^F)	0.06	0.87	1.00				
ln(*OFDI*)	-0.03	0.89	0.85	1.00			
ln(*IFDI*)	0.17	0.81	0.90	0.84	1.00		
ln(*FDIOUT*)	-0.05	0.63	0.55	0.87	0.63	1.00	
ln(*FDIIN*)	0.40	0.18	0.32	0.31	0.62	0.39	1.00

Table 6: Determinants of Total Factor Productivity in Swedish Manufacturing 1980-1994 (Dependent variable: log of TFP)

Regression Method	1 FE	2 RE	3 FE	4 FE	5 FE
ln(S^D)	0.251 (0.16)	-0.027 (0.10)	0.015 (0.12)		-0.073 (0.13)
ln(S^F)	-0.813* (0.37)	0.136 (0.12)		-0.418 (0.28)	
ln(*OFDI*)	-0.035 (0.03)	-0.029 (0.03)	-0.044 (0.04)	-0.032 (0.03)	
ln(*IFDI*)	-0.091* (0.04)	-0.066 (0.05)	-0.121* (0.05)	-0.097* (0.05)	
ln(*FDIOUT*)					-0.035 (0.04)
ln(*FDIIN*)					-0.110 (0.06)
D78	-0.721* (0.12)	-0.463* (0.07)	-0.548* (0.10)	-0.702* (0.12)	-0.573* (0.11)
D86	-0.427* (0.09)	-0.281* (0.07)	-0.320* (0.08)	-0.412* (0.09)	-0.352* (0.08)
D90	-0.276* (0.06)	-0.222* (0.07)	-0.234* (0.06)	-0.274* (0.07)	-0.267* (0.07)
R^2(overall)	0.00	0.17	0.03	0.00	0.07
R^2(within)	0.68	0.59	0.63	0.65	0.58
No. of obs.	53	53	53	53	53

Note: The asterisk (*) denotes significance at the 5 percent level.