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Technology Spillovers and Innovation: The Importance of Domestic and Foreign Sources

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Abstract

This paper asks whether there is evidence of higher innovation output from firms where there are more foreign activity in terms of foreign direct investments (FDI), trade, collaboration on innovation, or if geographic proximity between innovators is more important. The conclusions are that 1) there is robust evidence that FDI, observed as foreign-owned firms is neutral with respect to innovation output; 2) import correlates highly significantly with innovation product sales among multinational firms (MNEs) as well as non-MNEs; 3) the evidence for spillover from R&D collaboration with domestic innovation partners is weak when bilateral arrangements are considered. Only non-MNEs collaborating with local, regional or national suppliers and customers are benefiting from the collaboration; 4) when multilateral R&D arrangements are taken into account it is shown that R&D-collaborators have higher innovation inputs than non-collaborators. In particular, when the network includes a foreign subunit and a scientific partner, the likelihood of successful technology transfer increases considerably.

Keywords: Innovation, knowledge spillover, R&D-collaboration, trade, FDI
JEL codes: D21, F23, L21, L22, O31, O32

1. Introduction

Recent data on corporate spending indicates an overall altered research and development (R&D) strategy of multinational enterprises (MNEs) implying both an increase in the total R&D-intensity and a more dispersed R&D engagements across borders.

According to the Boston Consulting Group's annual management survey of 2006, innovation is ranked among the top three strategic imperatives by over 70 percent of 1,070 executives in the world's largest corporations. Moreover, about 41 percent reported that the expenditures on research and development will increase between 2005 and 2006 (McGregor, 2006).

Statistics from UNCTAD (2005) and other data sources show that MNEs are increasingly investing in R&D activities in their foreign subsidiaries. For instance, the share of R&D by the 20 largest Swedish MNEs that was accounted for by subsidiaries abroad increased from 22 percent in 1995 to 43 percent in 2003 (ITPS, 2003).

Since the major part of global R&D is invested within the giant MNE:s, the increased geographical dispersion of their technological knowledge (and production capacity as well) has brought about a surge in interest for R&D-spillovers within different branches of the literature with focus on issues such as (i) the geographical scope of technological progress, (ii) transmission of technology through trade, (iii) spillovers from foreign direct investment, FDI, (iv) R&D-collaboration and technology diffusion, (v) strategic alliances and inter-firm knowledge transfer and (vi) the importance of national, regional and local innovation systems.

To summarize the main findings on spillovers from these and similar studies three distinct features can be distinguished. There is robust evidence for strong influence of global sources at the aggregate level. The global influence becomes weaker at the industry level and the findings on spillover using firm-level data are mixed.

Not all, but much, of the spillover literature estimates the importance of external knowledge on productivity. But technological innovations in terms of new or significant products and processes are the direct results of R&D-activities. In this paper we take the innovation approach and motivated by the inclusive findings on spillovers at the micro-level the following three hypotheses are tested

- H1**:** FDI and import affect innovation performance at the firm level in a similar way as suggested by productivity studies at the aggregate and industry level.
- H2**:** Local R&D collaboration as a R&D activity additional to internal R&D investments results in knowledge spillovers that increases the firms' innovation output.
- H3**:** Global R&D collaboration R&D activity additional to internal R&D investments results in knowledge spillovers that increases the firms' innovation output.

With a sample of approximately two-thirds of Swedish MNEs as well as non-MNEs with at least 10 employees we find that innovation output is an increasing function of the import value. The presence of FDI, however, expressed as foreign-owned firms is neutral with respect to innovation output. Among a subsample consisting only of multinational firms there is support for knowledge transfer to the local multinational firms from international collaboration networks that include foreign scientific partners and foreign subunits. We only find some weak association between geographical proximity to local partners and innovation.

The outline of our study is as follows: Section 2 presents a theoretical framework and elaborates on findings in previous studies. The discussion is focused on access to embodied foreign technology in the form of intermediate goods and disembodied technology diffusion in the form of direct communication through FDI and collaboration. Section 3 introduces the methodological approach. The data is described in Section 4. Section 5 presents an assessment of econometric results. Section 6 concludes.

2. Theoretical foundations and empirical evidence

In discussing the theoretical framework for the paper we begin by some basic definitions. First, what do we mean by *technological knowledge*? Antonelli (2007) suggests that it "consists of a complex system of machines, skills and workers all characterized by distinctive elements of complementarity, interoperability and necessary compatibility." Similarly to scientific knowledge, technological knowledge is characterized by strong elements of non-excludability and limited appropriability. The application of this complex knowledge requires dedicated competence and resources, which have a strong idiosyncratic character. (Antonelli)

Second, what do we mean by *spillovers*? Grossman and Helpman (1992) define technological spillovers (or R&D spillovers) as externalities such that that firms can acquire knowledge created by others without paying for it. Other authors, for instance Griliches (1992) and Steurs (1994) make a broader interpretation including both involuntary leakages as well as voluntary exchange of useful technological information. Some works suggest that that voluntary spillovers are more considerable than involuntary knowledge (Griliches 1992, Llerena and Matt, 1999).

Third, how do we define and distinguish *transmission* and *diffusion*? Assume that the process from new idea to absorbed know technology can be described in three steps. In the first step the new technological knowledge is generated. In step two the knowledge is transferred by complex system, moving individuals or a cod. The transfer process can be in the form of diffusion or in the form of transmission. The concept diffusion is associated externalities (Grossman and Helpman spillovers), while transmission is an intentional activity that can be commercial at the market (buying licenses, buying advanced intermediate technologies) or non-informal within multination corporations. Strategic decisions as R&D-alliances, mergers and acquisitions, and R&D-collaborations are measures in order to reduce the cost or increase the efficiency of transmission. In step three, the absorptive capacity of firms decides the ability to access and convert transmitted and diffused knowledge into product and process innovations.

2.1 Theoretical spillover literature

The new growth theory builds upon the distinguished role of knowledge in the production process, the distinction between tacit and generic knowledge and the fundamental importance of technological externalities and spillovers (and temporary monopoly). The most important source of knowledge, in the long run, is generic knowledge which flows in the air (Romer 1994).

The economic importance of generic knowledge and its context was recognized already by the pioneering works by Adam Smith (1776), Alfred Marshall (1890), and by Kenneth Arrow (1962). In Adam Smith's analysis technological knowledge is the eventual result of at least three processes: learning by doing and learning by using, the specialized activity of scientists and the interactions with suppliers of machinery and intermediary inputs. Marshall (1890) identified not only the collective character of technological knowledge suggested by Smith, but also the co localization within industrial districts of a variety of agents with complementarity bits of knowledge. Arrow (1962) separated knowledge as an economic good from knowledge embedded in capital products and organization while Pakes and Griliches (1980) empirically showed how this separated knowledge good as a distinct input factor can be used in a knowledge production function in order to produce more valuable knowledge.

A simplified and general possibility of generic knowledge flowing in the air is that all research outcomes enter a common international pool which individual firms with a certain degree of absorptive capacity (discussed in Mansfield, Schwartz and Wagner 1981 and formally expressed by Cohen and Levinthal 1990) can tap.

Rediscovering Marshall and making a distinction between knowledge that can be codified into transmittable information and knowledge that is difficult or even impossible to codify, regional economics has contributed to the understanding of localization of knowledge and technological spillovers by integrating the role of spatial proximity in the analysis (Jaffe 1986, Feldman and Audretsch 1999).

Knowledge that is difficult to codify has been termed complex by Beckmann (1994), tacit by Polanyi (1966) and sticky by von Hippel (1994). While "complex" in a direct way refers to non-codified knowledge, "sticky" refers to knowledge that is strongly attached to given persons or groups of individuals. As argued by Antonelli, Marchionatti and Usai (2003), this may imply that knowledge can be shared by firms in a local environment with little risk that the knowledge is spread outside the local context. A general assumption is that face-to-face contacts facilitate communication and transfer of complex knowledge.

How is the not-in-the-air knowledge transferred across space and borders? It has been suggested that FDI is an important channel. Traditional FDI-models (Vernon, 1966) assume that firm advantages can be derived from favourable regional milieus and home country institutional conditions (such as the national system of innovations). These technological and managerial advantages of a firm are subsequently transferred to foreign subunits where they are exploited. Importing technologically advanced intermediate goods is another channel for a country to get access to foreign knowledge. However, despite that multinational enterprises are identified as a superior institutional form to market forces for international transfer of knowledge (Kogut and Zander 1993), difficulties in achieving knowledge transfer within multinationals have been recognized not only within the academic community (see for instance Gupta and Govindarjan, 2000), but also the business community. In a recent survey by Ernst & Young, it was found that only 13 percent of 471 corporate executives indicated that their organization was adept at transferring knowledge (Persson, 2006).

International trade is supposed to be another major circuit for spillovers. Economic research on international knowledge diffusion was spurred by a Coe and Helpman (1995), who found large spillover effects from foreign R&D capital stocks to domestic total factor productivity (TFP). However, re-estimating the data Keller (1999) obtained results similar to Coe and Helpman after replacing trade weights with randomly chosen numbers. Keller (2001) also finds that technology diffusion is severely limited by distance.

To conclude this section, a strong economic role for spillovers of generic knowledge can be found in the new growth literature while the regional economics literature proposes that diffusion of tacit and/or complex knowledge are spatial limited. Issues such as of complementarity, divisibility, path dependency and technological interdependence influence the degree of degree exert an influence on whether technological knowledge can be classified as generic or not.

Now we will briefly review the findings in the literature regrading the question whether technological knowledge spillovers are mainly global (in the air) or local (complex/sticky/tacit).

2.2 Empirical findings

A number of stylized facts on spillovers can be crystallized based on the empirical literature. First, variation in cross-country productivity is at least as much due to foreign as to domestic technology (Keller and Yeaple, 2003, Eaton and Kortum 1999, Keller 2002). Second, there is a broad agreement that trade as well as FDI is affected by spatial factors (Leamer and Levinsohn 1995, Caves 1996). Third, geographical proximity afforded by locating in large urban regions creates an advantage for firms by facilitating information and knowledge flows for innovation activities (Antonelli 2003). Forth, there is robust evidence for strong influence of global sources of at the aggregate level. The global influence becomes weaker at the industry level and the findings on spillover using firm-level data are mixed.

Generic versus tacit (or complex/sticky) separate knowledge in an economically important dimension. The distinction between embodied in form of advanced intermediate goods and disembodied in form of direct communication provides a complementary dimension which is useful for empirical analysis. Embodied spillovers are generally measured through international trade or input-output tables based on national statistics, while the stock or flow of FDI, patent, patent citations, R&D-alliances, and R&D collaboration are used in order to capture disembodied spillover. Below we summarize the main findings from some recent estimates on the measures of embodied and disembodied spillover that are of primary interest in this paper.

Embodied spillovers

Import

- (+) Acharya and Keller (2007) study technology transfer through imports for a sample of twenty-two manufacturing industries in seventeen industrial countries in four continents over the period 1973-2002. They find significant contribution of international technology transfer on total factor productivity and that this contribution often far exceeds the effect of domes tic R&D on productivity.
- (+) Examining aggregate productivity growth since World War II in five leading research economies (West Germany, France, the UK, Japan and the US) and assuming the presence of a global stock of knowledge, Eaton and Kortum (1995) find that growth is primarily the result of research performed abroad channelled across borders through trade for four of these countries. In the U.S. 40 percent of the growth is accounted for foreign sources.
- (+) Studying technology in form of product design that is transmitted to other industries, both internationally and domestically through trade in differentied intermediate goods, and based on industry level data that covers more than 65 percent of the world's manufacturing output and most of the world's R&D expenditures between 1970 and 1991, Keller (2001a) estimates that domestic R&D in the industry contribute to 50 percent of the industry's productivity growth. 30 percent of the growth is due to R&D spillovers from other domestic industries. Foreign sources accounts for the remaining 20 percent.

Disembodied spillovers

FDI

- (+-) Using a panel of country data Pottelsberghe de la Potterie and Lichtenberg (2001) suggest FDI transfer in only one direction. While inward FDI does not have an impact on the productivity of the host country outward FDI into R&D-intensive countries is a significant source of technology spillovers.

- (-+) Re-examining FDI as a potential for knowledge diffusion based on industry data from seventeen OECD countries during the period 1973-2000 and FDI capital stocks, Bitzer and Kerekes (2005) come to the opposite conclusion as Pottelsberghe de la Potterie and Lichtenberg (2001). They find that FDI receiving countries benefit strongly from FDI-related spillovers while outward FDI affect productivity negatively.
- (+) Keller and Yeaple (2003) estimate technological spillovers to U.S. manufacturing firms via FDI between 1987 and report that the size of FDI spillovers is accounting for about 14 percent of productivity growth for that period.
- (+) Using USPTO patent citations, Branstetter (2006) test the hypothesis that FDI is a channel of knowledge spillover for Japanese MNEs undertaking foreign direct investment in the United States. In conformity with Keller and Yeaple (2003), he finds that FDI is a significant channel of knowledge spillover both from investing firms to indigenous firms and from indigenous firms to investing firms.
- (-) Aitken and Harrison (1999) use annual census data on over 4.000 Venezuelan firms to measurer how the productivity effects foreign ownership. Identifying that the domestic firms in sectors with high foreign presence were significantly less productive than those in sectors with low foreign presence they claim negative spillovers from FDI.
- (Neutral) Ebersberger and Lööf (2005) estimate Community Innovation Survey data for about 5. 000 firms in the five Nordic countries Denmark, Finland, Iceland, Norway and Sweden find no distinct difference in labor productivity between foreign owned firms and domestically owned firm when controlling for industry classification, size and R&D-intensity.

R&D collaboration

- (Non-significant) Estimating Finnish Community Innovation Survey data, Paananen and Kleinknecht (2007) estimate that R&D collaboration has a non-significant effect on firm's innovation (sales of new products). This confirms previous findings by Brouwer and Kleinknecht (1996).
- (Non-significant) Fritsch and Franke (2004) investigate the impact of knowledge spillovers from R&D collaboration in innovation activities in three German regions and show that R&D cooperation is only of relatively minor importance as a medium for knowledge spillovers.
- (+) Focusing on collaborative R&D in robot technology by using patent data applied in Japan between 1991 and 2004, Lechevalier, Ikeda and Nishimura (2006) find that R&D collaboration has a positive impact on the quality of patents.

Spatial proximity

- (+) Jaffe and Trajtenberg (1998) find that patents whose inventors reside in the same country are typically 30 to 80 percent more likely to cite each other than inventors from other countries and that these citations are made sooner than citations in other countries.
- (+) Investigating U.S. patent citation data, Sonn and Stolper (2003) find that investors increasingly use domestic knowledge more than foreign knowledge, in-state knowledge more than out-of state knowledge and knowledge from the same metropolitan area more than knowledge from outside
- (+) Estimating the importance of geographical distance for technology diffusion using data for two- and three digit manufacturing industries in Canada, France, Germany, Italy, Japan, the U.K. and the U.S., Keller (2001b) finds that the scope of technology diffusion is severely limited by distance. The distance at which half of the technology has disappeared is estimated to be only 1,200 kilometers.

The tentative conclusion of the selected papers above is that both global knowledge embodied knowledge in form of imported intermediate goods and localized knowledge captured as spatial proximity has a positive influence on firms' performance while the effects of spillovers through FDI and R&D collaboration are ambiguous.

3 Models and Estimation Framework

The theoretical framework for our study is a production function explaining variation in innovation performance by different categories of knowledge sources and a number of control variables that can be represented schematically by the following equation,

(1) $$y_i = \beta_0 + \beta_x x_i + \beta_k k_i + u_i$$

where *i* denotes log of variables expressed in per employee terms, the left-hand variable y is the innovation sales in firm *i*, x is a vector of standard control variables such as R&D, size as physical capital, employment and industry dummies, and k is the various sources of knowledge or technology spillovers that might influence innovation. β_x is the elasticity of output with respect to changes in the control variables, β_k is the elasticity of output with respect to knowledge and technology spillovers, and u is the random error term representing all disturbances that prevent (1) from holding exactly.

Let us first consider the OLS linear model:

(2) $$y = X\beta + u$$

where, in matrix form, y is innovation sales, X is a matrix of different categories of possible influences on firm performance: (i) knowledge sources within the firm, (ii) knowledge sources within the local/national systems of innovation, (iii) global knowledge sources within the group, scientific, vertical and horizontal partners, (iv) international knowledge spillovers via imports and FDI and (v) other firm and industry characteristics.

The key assumption in regression model (2) is that the unobserved factors involved in the production function are not related systematically to the observed factors *X*, i.e. that the *u* processes have a zero-conditional mean. However, if we consider a non-random sample of firms with observed innovation output as well as simultaneous determination of some exogenous variables and the endogenous innovation output, the basic statistical assumptions do not hold and we have to make a departure from the linear model.

3.1 Sample-selection regressions

A regression estimated from the subpopulation of innovative firms, that is, firms with positive R&D and innovation sales will yield coefficients that are biased without correction for non-random selection from the population at large. In this paper, we will employ Heckman's two-step estimator of the Heckman selection model (Heckman 1979) in order to make such correction by estimating an omitted regressor $\lambda(x_1^{'}\beta_1)$, labelled the inverse Mills ratio (IMR). Formally, this can be described as follows[2]:

Let y_1^* denote a latent variable and the outcome y_2^* is observed if $y_2^* > 0$, that is, if the observed firm is classified as innovative. For example, y_1^* determines whether or not the firm is classified as innovative, and y_2^* determines the firm's innovation performance. The variable y_1^* is different from y_2^* since firm size or corporate structure, for instance, are more important in determining engagement in innovation activities than the size of innovation sales per employee. The sample selection model then comprises the following participating or selection equation and resulting outcome equation:

[2] Here we are partly following Baum (2006) and Cameron and Trivedi (2005)

$$(3) \quad y1 = \begin{cases} 1 \quad if \ y_1^* > 0, \\ 0 \quad if \ y_1^* \leq 0 \end{cases}$$

$$(4) \quad y2 = \begin{cases} y_2^* \quad if \ y_1^* > 0, \\ - \quad if \ y_1^* \leq 0 \end{cases}$$

The standard model specifies a linear model with additive errors for the latent variables:

$$(5) \qquad \begin{aligned} y_1^* &= x_1^{'}\beta_1 + \varepsilon_1 \\ y_2^* &= x_2^{'}\beta_2 + \varepsilon_2 \end{aligned}$$

Where β_2 is our primary interest but a problem will arise estimating β_2 if ε_1 and ε_2 are correlated. Is this case OLS regression of y_2 on x_2 using only the observed positive variables on y_2 results in inconsistent estimates.

By including an estimate of IMR, the Heckman's two-step procedure can be written as:

$$(6) \quad y_{2i} = x_{2i}^{'}\beta_2 + \sigma_{12}\lambda(x_{1i}^{'}\hat{\beta}_1) + \upsilon_i$$

Where ν is an error term, $\hat{\beta}_1$ is obtained by first-step probit regression of y_1 on x_1.

The Heckman model performs a test of whether or not the error terms ε_1 and ε_2 in equation (5) are correlated and whether the sample selection correlation is needed.

In addition to the selection model, we will exploit the predicted IMR in the model dealing with the issue of simultaneity bias, which is presented below.

3.2 Generalized method of moments

Consider linear regression model (2), where each component of *x* is acting as an exogenous regressor if it is uncorrelated with the error in the model and a variable x is endogenous if it is correlated with the disturbance. In the first case, the OLS estimators can be used; otherwise, the OLS estimators are inconsistent for estimating β .

In order to derive consistent estimates of equation (2) in the presence of endogeneity among the regressors, we must find variables that satisfy two properties: they must be uncorrelated with u but must be as highly correlated with x as possible. A variable that meets those two conditions can serve as an instrument for the correlation of the regressor and the error term.

In the case of simultaneous determination of response variables and regressors, or endogeneity, there are several instrumental-variable options; the IV and two-stage least-squares (2SLS) as well as the generalization to generalized method-of moments (GMM) estimators. In this paper, we will employ the GMM estimator.

3.3 Model specifications

Consider first the selection equation of the Heckman two-step model. The empirical challenge here is to find a single or a set of variables that strongly affects the probability of being an innovative firm but not necessarily the size of innovation output. The determinants in the first step of the model (selection equation) are firm size, physical capital, capital structure and market (a dummy variable indicating whether the firm is mainly focused on the global market). Ten industry dummies are also included.

Our primary interest variables in the outcome equation are R&D collaboration, FDI and imports. The dependent variable innovation output is measured as sales income from new products per employee. The control variables in the outcome equation are R&D, skill (approximated by wage sum per employee), the firm’s size measured by employment, investment in machinery and equipment, capital structure and industry indicators.

All variables are expressed as logarithms and are in per employee terms, except capital structure, human capital, market and the indicator variables for collaboration on innovation, which are given as percentages.

The GMM estimation is split into two parts. First, we consider a vector of determinants that is almost the Heckman set of variables, with the exception that we have included and instrumented for export. The instruments are (in logs and intensity) gross investment, export value/export weight and import value/import weight and the dummy variable that indicates whether the firm exports more than 50 percent of its production. Second, we extend the analysis of collaboration on innovation by considering 50 different combinations of cooperation arrangements, reflecting complementarities between various innovation partners.

4. Data

The empirical analyses in this study are based on data from the Community Innovation Survey (CIS) IV for Sweden. The survey was conducted in 2005 and covers the period 2002-2004. The rate of response was close to 70 percent. It covers both manufacturing and business service sectors. The original sample contains 3,094 firms. The information on innovation activities from the survey has been supplemented with register data on sales, value added, wages, physical capital, human capital, employment, export, import and corporate structure from Statistics Sweden for the firms in question.

In order to ensure that the data are suitable for our estimation purposes, we have imposed restrictions on the sample. First, we removed all observations which the total sales in both the survey data and in the register data remained zero even after the data treatment (see below). A second restriction was the elimination of all observations for which the value added and wage cost were zero. In total the restrictions applied to 10 observations. A third restriction was the removal of 113 public utility firms (Nace 40 and 41) and 6 financial intermediates (Nace 66-69).

In the present analysis, these industries are not considered ‘innovative industries’. The result was 2,962 complete observations of firms with more than 10 employees.

4.1 Definition of innovative firms

Aiming to distinguish firms by their innovative nature we selected a sample consisting of only innovative firms. There is, however, no general agreement in the literature on how to classify a firm as “innovative” or what distinguishes innovation from technical changes. Schmookler (1966) suggests that when an enterprise produces new goods or services or uses a method that is new to it, it is introducing technical changes.

The enterprise that is first to make a given technical change is an innovator. However, Hall (1994) noticed that the distinction between an innovator and its followers – the imitator firms – often is unclear. In their attempts to imitate, firms often do things differently (unintentionally or by design) from the way they were done by the first firm and thus become innovators in their own right. The Oslo Manual (OECD, 2005), which sets out the guidelines for collecting and interpreting innovation data of the CIS surveys defines an innovation as products, services and methods new or significantly improved in respect to the market.

The CIS survey also opens up for a softer definition of innovation by questions on products that are new or significantly improved with respect to the market as well as the firm only. Together these two aspects will probably capture the findings of Geroski et al. (1993) who indicate that the importance of innovation is not only innovation in itself, but also the learning process associated with the innovation. These CIS classifications of innovation can either be analyzed jointly or separately. In this paper we will choose to consider the former.

We then define an innovative firm according to the following criteria: a firm is innovative if its total sum of research and development expenditures on (i) intramural R&D, (ii) extramural

R&D, (iii) acquisition of machinery, (iv) other external knowledge is positive, and if it also has positive sales of goods and services according to the joint classification of innovation.

The CIS survey also allows us to separate between products (i) mainly developed by the firm, (ii) by firms in collaboration with others and (iii) mainly by others. Interestingly, all three categories are associated with about the same average innovation expenditures as a fraction of sales (7-9%). Moreover innovation sales as a fraction of sales are on average biggest among firms that reported that their innovative products were mainly developed by others (24% versus 19% and 17% respectively for the two other categories of firms). Based on this information we consider a firm as innovative irrespective of whether it mainly developed the new product itself or not. We end up with a sub sample of 1,091 (36.8%) innovative firms.

4.2 Cleaning data

Finally, we have defined a ”clean” data set according to the following criteria. First, we censored any observation for which R&D was more than two times larger than sales. This means that for 21 observations with R&D expenditures reported to be more than 200% bigger than sales the R&D expenditures are replaced by observations equal to sales times two. Second, if the reported sales were zero or missing in the survey data, these have been replaced by the figures from the register data and vise verse. There are 33 such observations and all concern non-innovative firms. Third, we censored value added to be identical to sales if value added was larger than sales. This resulted in 21 changes, all concerning non-innovative firms. Finally, for all observations for which the employment was zero or missing in the register data, we replaced these with the information from the survey data (16 observations of non-innovative firms and 5 of innovative firms). In total, the “cleaning process” resulted in 150 changes for non-innovative firms and 7 for firms belonging to the innovative sample. The censoring eliminates the influence of extreme observations and yet allows us to retain the observations in the estimation procedure.

The non-innovative firms, according to our definition, consist of firms with neither positive R&D nor positive innovation sales, firms with positive R&D but no positive innovation sales, and firms with positive innovation sales but no R&D. The non-innovative firms are retained in the total sample and are used in the selection equation for estimating a correcting variable which Heckman (1979) refers to as the inverse of Mills' ratio (IRM). We will also employ the IRM in the GMM estimations predicted from the Heckman model.

4.3 Variables

INSERT TABLE 1 HERE

Innovative product sales. The Schumpeterian branch of economic literature, a branch characterized as explicitly focusing on innovation as a distinct economic activity with distinct economic causes and effects, has shown that R&D is a main determinant to productivity. A serious limitation of many studies on R&D and productivity is that they only investigates the relationship between R&D coefficients that are biased, and other input factors on the one hand side, and productivity on the other. The neglected link is what Pakes and Griliches (1984) labelled "the knowledge production function", a production of commercially valuable knowledge or innovation output. The explanation for this "ignorance" is the lack of data on this commercially valuable knowledge. Although not perfect the CIS-surveys, which now have been introduced in the major part of the OECD-countries offer an observation on the firm's assessment of their annual income from new products introduced to the market during the recent three-year period. coefficients that are biased Our analysis will use this variable as the left-hand side variable and it is measured as the logarithm of innovative product sales per employee

Our set of explanatory variables consists both of those that have commonly been documented as affecting innovation performance in the Schumpeterian literature (our controls) and those that are suppose to capture the importance of positive externalities. The following variables are included in the analysis:

R&D. Since the objective of the paper is to investigate the importance of external knowledge on firm's innovation performance we need to control for variation in (log) R&D-intensity.

Skill. In the specifications of the econometric models we have to account for factors that can cause problems in the estimation procedure. Along with the two main problems discussed in Section 3, multi-collinearity among the explanatory variables and difficulties in identifying their effect is another issue. Two simple ways of checking for the presence of multi-collinearity are to look at the correlation coefficients among the explanatory variables and the R2 from regression of each explanatory variable on the remaining explanatory variables. Table A1 in the Appendix reveals a strong association between log R&D per employee and human capital, partly due to the fact that R&D personnel are a fraction of human capital. Since our data not distinguish between R&D personnel and other kind of human capital, we will exploit wage sum per employee as a proxy for human capital in order to avoid double-counting of R&D. The assumption is that the wage sum includes a skill premium. We therefore label this variable as "skill.''

Firm size and physical capital. The Schumpeterian literature has suggested the importance of controlling for variation in firm size and physical capital investment, which might be associated with innovation activities. Firm size is measured as log of employment. For physical capital we are employing two different measures - gross investment and investment in machinery and equipment. The former is employed in the first step of the Heckman equation and the latter as an instrument in the GMM estimation.

Market. In order to better isolate the importance of spillover effects, we include a variable that might pick up the importance of global export markets. It is a dummy variable indicating if the firm is selling more than 50% of its production outside Sweden.

Capital structure. Since the seminal paper by Modigliani and Miller (1958), several theories have been proposed to explain the variation in debt ratios across firms. There is, however, a broad agreement in the corporate finance literature that firms prefer to draw on internal financing from retained profits and seek external financing by issuing shares or corporate bonds when there are insufficient funds for internal financing. Recent literature suggests that small firms and R&D firms are financially constrained. See also Tiwari, Mohnen, Palm and Schim van der Loeff in [**chapter X**.] While there is an extensive literature investigating how financial constraints affect a firm's R&D intensity, the issue of how the firm's capacity to leverage (increase the ratio between debt and equity) affect its innovation performance has been far less scrutinized. Assuming that the firm's innovation output signal growth opportunities, Harris and Raviv (1991) report that there is consensus in the literature the leverage should increase. If the innovation performance is related to profitability the evidence from the literature is mixed. Discussing the effect of profitability on leverage Jensen (1986) predicts a positive correlation if the market for corporate control is effective and negative otherwise. The negative relationship is explained by the management's preference for internal financing while efficient corporate control forces the firm to pay out cash by levering up. Including information asymmetry among market imperfections in the analysis of Razin, Sadka and Yuen (2001) suggest that debt financing is preferred to equity since the choice of equity finance signals that the firm's shares are overvalued.

Knowledge transfer via collaboration on innovation. Eight different indicators are used for measuring the importance of transmission of technology and knowledge via collaboration on innovation. We are focusing on collaboration within the group, with scientific partners (universities and research institutes), with vertical partners (suppliers and customers) and with horizontal partners (competitors and consultants). Since the data on collaboration contains information on national as well as global collaboration we hope to identify both local and global spillovers. In total 50 different network combinations of R&D collaborations are investigated.

Knowledge transfer via FDI and trade. Following Veugelers & Cassiman (2004) and others we use the presence of foreign owned MNEs in the host country (Sweden) as an indicator of international knowledge spillovers. We are interested to know whether foreign-owned firms ceteris paribus have superior innovation performance in comparison to local firms. International trade is another common method of measuring knowledge diffusion across borders and among two different alternatives – the ratio of import value to import weight. Only the import value we use the latter in the equations and the former as an instrument in the GMM estimation. There is also a possibility that the firm's export can be associated with knowledge transfer to the customers. However, in the paper we include export among the control variables. A problem with this variable is that it can be assumed to be determined together with the endogenous variable, i.e. innovation sales, and a possible result is that the estimation suffers from simultaneity bias. Therefore, in equation (4) we instrument for the export variable (export value) and exploit the ratio of export value to export weight as an instrument in the GMM regressions.

TABLE 2 INSERTED HERE

Industry classifications: In order to control for any industry-specific effects that may not be captured by the variables above, we also include ten industry dummies. Table 2 provides mean values for some key variables distributed over the ten industry classes. There are large differences across industries. For instance, there are four industries for which the fraction of innovative industries is about 50% or more (Electrical and optical equipment 48%, Machinery and equipment 50%, Transport equipment 51% and Pharmaceutical, plastics and other 55%). In contrast Transport and communication has only 16% innovative firms.

The average ratio of R&D to sales is 5.2 % in our sample, with a variation from 1.9% (Food, textile and leather) to 11.9% (Business activities). The firms in Business activities have the biggest average innovation output when innovation sales is measured as a fraction of sales (12%), while another service industry, Transport and communication, has a fraction of only 4%.

The most human capital intensive industry is Business services. The average share of university educated employees is 55%. The corresponding figure for food, textile and leather is only 4%. There is a substantial presence of foreign ownership in the Swedish economy. One out of five firms in the sample are foreign-owned. The fraction of foreign ownership is highest in Wholesale and retail (40%) and Pharmaceutical, plastic and rubber (31%). Finally, Table 1 shows that for 11% of the firms in the sample, exports constitute more than half of their total sales. The most export-oriented industries are Machinery and equipment (25%), Pharmaceutical, plastics, rubber and petroleum (22%), and Electrical and optical equipment (19%). Not unexpectedly, we see that the service industries in the sample are highly focused on the home market.

INSERT TABLE 3 HERE

Table 3 gives summary statistics for all the variables used in the analysis. We make a special distinction between multinational firms and non-multinational firms. The descriptive statistics are restricted to the innovative sample and we have transformed all observations into logarithms of intensity terms (per employee) or percentages. The monetary variables are measured in thousands of Swedish crowns. Column 1 shows statistics for the full sample, while Columns 2 and 3 give statistics for only MNEs and non-MNEs respectively. The most interesting findings are the large differences between the average MNE and non-MNE in almost all variables. Looking first at collaboration on innovation, not surprisingly it is shown that the typical MNE has a fairly broad network of national and global partners within and outside the group. The most important collaboration partners for non-MNEs are customers and suppliers both in Sweden and abroad and domestic universities. We then see that close to one out of two MNEs in Sweden is foreign-owned and, not surprisingly, that only MNEs have extensive trade. Among the controls, the most striking differences concern firm size. The average employment is almost ten times higher among MNEs (about 440) compared to non-MNEs (about 50). The large difference between these two categories of firms motivates our split of the sample into two groups and the choice to focus on the MNE group in our final analysis.

5. Empirical Analysis

In the study, we investigate three main categories of external knowledge transfer: (i) through collaboration on innovation, (ii) through the presence of foreign affiliates and (iii) through imports. The firms' collaboration on innovation is local/national as well as global. Tables 4 and 5 present results for the importance of eight different collaboration partners separately while Table 6 reports estimates for collaboration within various networks. Only the significant estimates are displayed. Table A3 of the Appendix presents all the 50 different combinations of collaboration arrangements analyzed.

We have tried two estimators that differ in correction for selectivity and simultaneity bias. Table 4 gives the results from the Heckman two-step selection model. Tables 5 and 6 display results from the GMM-model including the inverse Mills ratio (IMR), which implies that we attempt to control for both selectivity and simultaneity bias. Tables 4 and 5 show coefficient estimates for the full sample of innovative firms, innovative MNE firms and innovative non-MNE firms respectively. In Table 6 we report coefficient estimates for only FDI, imports and network of R&D collaborators.

From the economic theory, we would expect that the propensity to be innovative is an increasing function of firm size, gross investment and export market. Yet firms who are highly dependent on bank loans are less likely to be engaged in innovation activities compared to firms that finance their R&D investments through retained profit or the stock markets. Given that the firms are classified as innovative, our priori assumption is that the influence on innovation output exerted by R&D, skill and coefficients that are biased, physical capital the capacity to leverage is positive. Regarding our key variables Ebersberger and Lööf (2005) suggest that FDI is neutral with respect to innovation output when the observed firms are MNEs and positive when compared to non-MNEs. The importance of import on innovation output has been overlooked in the empirical innovation literature analyzing firm level data, but based on work studying the correlation between import and productivity a positive effect can be expected. The literature provide mixed results on the importance of R&D collaboration on innovation output.

INSERT TABLE 4 HERE

Consider first the selection equation results reported in Table 4. The benefit of using a selection model is to correct for a non-representative sample. In order to reduce possible endogeneity problems we have excluded the export variable from this equation but it will be used in the GMM-equation. The columns correspond to different samples. The first column corresponds to the full sample, where we include all observations in the selection equation and only innovative firms in the outcome equation. The second column reports results only for MNEs. In the third column we report estimates for firms with no affiliates abroad, that is, non-MNEs. There is data for 2,962 firms in the full sample, of which 1,091 are uncensored. The corresponding figures for the MNE-sample and the non-MNE sample are 1,249 (611) and 1,733 (480) respectively.

Recent research has addressed the involvement of foreign companies in domestic economies; the relative engagement of foreign-owned companies in R&D activities and embeddedness in various national innovation systems and the relative output performance from R&D in terms of innovation and productivity with some mixed findings (Pavitt and Patel, 1999, Pfaffermayr and Bellak 2002, Dachs *et al* 2007). As displayed in columns (1) and (2) we find that the presence of inward FDI *per se* is neutral with respect to innovation output, that is, we find no difference between foreign and domestic MNEs with respect to innovation sales. When considering the coefficients on imports, a pattern emerges in these coefficients showing that spillovers from imports contribute significantly to innovation productivity. Note also that the estimated impact is highly significant for MNEs as well as for non-MNEs.

The point elasticities for knowledge transfer through collaboration on innovation are estimated to be non-significant for the full sample and MNEs only - columns (1) and (2). When looking at non-MNEs in column (3) it shows that the estimate for global scientific collaboration is highly significant and negative. However, as reported in the summary statistics (Table 2), only a small percentage of these firms have global scientific collaboration arrangements. The typical innovative non-MNE is considerably less oriented towards the global market than its MNE counterpart. More interesting is the positive and significant correlation between innovation sales and customers and suppliers. Our interpretation is that these firms, which are smaller and are less knowledge intensive in terms of human capital and R&D than the MNEs, are more dependent on external knowledge received through market transactions.

The weak association between R&D collaboration and innovation output is fully consistent with the findings by Brouwer and Kleinknecht (1996). It is surprising that R&D collaborators do not have higher innovation output than non-collaborators. This motivates for further analysis, which we will come back to in the subsequent discussion.

We now consider the control variables. The coefficients for R&D and physical capital are statistically significant and show a close association with innovation sales. The results are also consistent with the literature. Due to the strong correlation between innovation sales and human capital, we are using wage per employee as a proxy for human capital. The coefficient estimate is highly significant and the order of magnitude is close to 0.6. The capital structure variable controls for the firm's access to external financial resources. The estimate is significant and quite sizable indicating the importance of the link between debt funding and innovation performance.

The selection equation confirms previous findings that the propensity to be engaged in innovation activities is an increasing function of firm size for our both categories of firms. However, the results for the other three variables are somewhat mixed. As expected, the firms focusing on the export market have a large likelihood of being an innovative (only MNEs). In accordance with our a priori assumption, debt financing is negatively correlated to the likelihood of being an innovative firm (only MNEs). The coefficient estimate for investment intensity is positive and significant (full sample and MNEs). Finally, it is shown that the inverse Mills ratio (IRM) is significant.

INSERT TABLE 5 HERE

Table 5 reports the innovation elasticities using the GMM estimator and an IMR variable predicted from the Heckman equation. The estimation results are supposed to have been corrected for both simultaneity bias and selection bias. The J statistics (over- identification) and the identification statistics are satisfactory for the two sub-samples, whereas the statistics for the four instruments are not entirely satisfactory when the full sample is considered. Table 5 includes instrumented export intensity among the regressors, but it is found to have weak influence on innovativeness. Comparing the results presented in Table 4 and 5 we find only marginal differences in the coefficient estimates. The summary finding is that import is the main channel of technology diffusion when MNEs are considered whereas import and vertical collaboration with domestic partners is important in the case of non-MNEs.

We will now consider the effect of R&D collaboration in some detail and investigate 50 possible network arrangements between the local firm and various innovation partners. There are 30 possible arrangements between the local firms and networks including both foreign and domestic partners and 10 collaboration networks with only domestic innovation partners. In order to properly include foreign subunits in the analysis we will limit the discussion to only MNEs.

INSERT TABLE 6 HERE

The results presented in Table 6 show the correlation between innovative product sales and our three categories of knowledge transfer using the same controls and industry dummies as those displayed in Table 5. The analysis is limited to the subsample of MNEs and we will only report the estimates for the key variables. The estimator is GMM augmented with an inverse mills ratio among the explanatory variables.

Three overall findings emerge from the analysis displayed in Table 6 and Table A3 in the Appendix. First, the results for the FDI-variable and the import variable are almost identical to those reported in Table 4 and Table 5. We can therefore concentrate our discussion on the effects of network collaboration. Foreign-owned firms do not have a different innovation performance than domestically-owned MNEs and innovative product sales is an increasing function of the import intensity. Second, when the aspect of network collaboration is taken into account it is shown that R&D-collaborators have higher innovation output than non-collaborators for about one out of five collaboration combinations (9 out of 50 investigated networks).

Interestingly, there is a fairly robust pattern of collaboration arrangements that affects innovation performance. When the network is restricted to local (domestic) partners, no spillover effect can be established. When the network includes a foreign subunit and a scientific partner, the likelihood of successful technology transfer increases considerably. In fact, all six networks, that include the local multinational firms, a foreign subsidiary and a foreign scientific partner, correlate positively with innovation performance. It is also shown that the benefit of collaborating with local scientific, vertical and horizontal partners increases considerably when a foreign subunit and a foreign university are included in the arrangement. Finally, the possibility of spillover from foreign customers, suppliers, competitors and consultants is entirely dependent on assistance of a foreign firm within the group.

Concluding the results from this section, we show that multinational enterprises are in a special position to handle knowledge transfer. However, recent research in this area has identified difficulties in transferring knowledge across networks consisting of subunits and innovation partners. Our results indicate that what seems to be important for the local MNE is to involve its foreign subunits when collaborating on R&D internationally. Hence, it looks like the technology transfer not necessarily is a flow from one subunit to another, but rather from different R&D-collaborators to the local firm via the foreign subunit. In this collaboration arrangement foreign scientific partners also play a crucial role. In a growing number of recent studies research universities have been identified as location factors of growing importance (Henderson, Jaffe and Trajtenberg 1998; Zucker Darby and Brewer 1998; Adams 2002; Hall, Link and Scott 2003; Brennenraedts, Bekkers and Verspagen, 2006). It has been suggested that regions with strong research universities have better opportunities to attract and support innovative industries than other regions. Our study suggests that such universities contribute not only to regional spillover but also to spillover across borders.

6. Conclusions

We investigate the importance of domestic and foreign sources for local firms innovation performance. Several main points emerge:

1. There is robust evidence that FDI, observed as foreign-owned firms, is neutral with respect to innovation output. No difference can be found in innovation output between foreign-owned MNEs and domestically owned MNEs.
2. Technology transfer through import correlates highly significantly with innovation product sales among MNEs as well as non-MNEs.
3. The evidence for spillover from R&D collaboration with domestic innovation partners is weak when bilateral arrangements are considered. Only non-MNEs collaborating with local, regional or national suppliers and customers are benefiting from the collaboration.

4. When multilateral R&D arrangements are taken into account it is shown that R&D-collaborators have higher innovation inputs than non-collaborators.

5. When the network includes a foreign subunit and a scientific partner, the likelihood of successful technology transfer increases considerably.

We believe that our work suggest several lines for future research on domestic and foreign sources of knowledge for innovation. First, a deeper understanding is necessary of why a network, including both foreign units within the group and a foreign scientific partner is superior to other combinations of collaboration arrangements. Second, much remains to be done in order to better understand how both import and export influence the local firms' innovation performance. In particular, information on the geographical destination of export and the geographical origin of import together with the technology classification of traded goods and a distinction between intra-firm trade and other trade would improve the quality of the analysis considerably. Third, in order to assess the importance of FDI, it is desirable to investigate how the local firms' are related to the foreign-owned firms in terms of suppliers, customers or collaborators. Fourth, the CIS-data on R&D collaboration is limited. We are only informed whether collaboration exists or not. A proper analysis requires information on the scope of the collaboration in terms of expenditures, time period and characteristics about the innovation projects. Finally, one must note that there are several other sources of spillover than those considered in this paper, for example patent, and patent citations and strategic alliances.

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Table 1. Variable definition.

Variable	Definition
Innovative firms	Firms with positive R&D expenditures and positive innovative product sales.
Innovative product sales	Log sales income from innovate products per employee
FDI	Dummy variable indicating whether the firm is foreign-owned
Import value	Log import value (in monetary terms) per employee
FOR GRO	R&D collaboration, with foreign partners within the group
DOM GRO	R&D coll. with domestic partners within the group
FOR SCI	R&D coll. with foreign scientific partners (universities, research institutes)
DOM SCI	R&D coll. with domestic scientific partners
FOR VER	R&D coll. with foreign vertical partners (suppliers and customers)
DOM VER	R&D coll. with domestic vertical partners
FOR HOR	R&D coll. with foreign horizontal partners (competitors and consultants)
DOM HOR	R&D coll. with domestic horizontal partners (suppliers and customers)
Import value/weight	Log import value (in monetary terms)/import weight per employee
Market	Dummy variable indicating whether export/sales > 50 percent
Skill	Log wage sum per employee
Size	Log employment
Gross investment	Log gross investment in physical capital per employee
Machinery investment	Log investment in machinery per employee
Export value	Log export value (in monetary terms) per employee
Export value/weight	Log export value (in monetary terms)/export weight per employee
Capital structure	Total debt/(Total debt+Equity)

Notes: Table 1 displays the variables included in the Heckman selection model and in the GMM-estimation.

Table 2: Summary statistics

Key variables distributed over industry classes. Number of observations: 2,962.

Industry	Obs	Innovative[a]	R&D[b]	Innovation sales[b]	Human capital[c]	FDI[d]	Market[e]
1. Food, textile, leather	506	.312	.019	.070	.120	.144	.113
2. Pulp and paper	231	.346	.031	.075	.243	.173	.117
3.Pharmaceutical and plastics	199	.547	.071	.119	.218	.306	.215
4. Mineral and metals	317	.343	.039	.060	.123	.208	.144
5. Machinery and equipment	194	.500	.058	.120	.216	.231	.253
6. Electrical and optical equip.	251	.478	.095	.155	.293	.211	.190
7. Transport equipment	154	.512	.034	.127	.155	.233	.158
8. Wholesale and retail	197	.355	.014	.099	.269	.406	.044
9. Transport and communication	392	.155	.015	.040	.220	.178	.006
10. Business activities	521	.399	.119	.132	.548	.166	.025
Mean		.368	.052	.095	.258	.206	.107
Min		.155	.019	.040	.120	.144	.006
Max		.547	.119	.132	.548	.406	.253

Notes: Table 2 reports summary statistics for the ten industry classes included in the study.

1) Manufacture of food products, beverages and tobacco; Textile and textile products; Leather and leather products; Manufacturing N.E.C.
2) Manufacture of pulp, paper and paper products: Publishing and printing
3) Manufacture of pharmaceutical products; Plastic and rubber products, of coke, refined petroleum products nd man-made fibers.
4) Manufacture of other non-metallic mineral products; Basic metals and fabricated products
5) Manufacture of machinery and equipment
6) Manufacture of electrical and optical equipment
7) Manufacture of transport equipment
8) Wholesale and retail (Service industry)
9) Transport, storage and communication (Service industry)
10) Business activities (Service industry)

a) Fraction of the firms
b) Fraction of total sales
c) Employment with a university education as a fraction of total employment
d) Foreign-owned firms as a fraction of all firms in the sample
e) Fraction of firms with export more than 50 percent of sales.

Table 3: Summary statistics

	Full Sample n = 1,091				Only MNE n = 611				Only Non-MNE n=480			
	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Performance. variable												
Log innovative. products sales/emp	12.27	1.31	5.88	16.50	12.44	1.34	5.99	16.50	12.05	1.26	5.88	15.95
Knowledge transfer via collaboration												
FORGRO	0.21	0.41	0.00	1.00	0.36	0.48	0.00	1.00	0.00	0.00	0.00	1.00
DOMGRO	0.15	.366	0.00	1.00	0.23	0.42	0.00	1.00	0.08	0.26	0.00	1.00
FORSCI	0.11	0.31	0.00	1.00	0.16	0.36	0.00	1.00	0.04	0.20	0.00	1.00
DOM SCI	0.31	0.46	0.00	1.00	0.39	0.49	0.00	1.00	0.22	0.41	0.00	1.00
FORVER	0.33	0.47	0.00	1.00	0.41	0.49	0.00	1.00	0.23	0.42	0.00	1.00
DOMVER	0.45	0.50	0.00	1.00	0.49	0.50	0.00	1.00	0.39	0.49	0.00	1.00
FORHOR	0.16	0.31	0.00	1.00	0.23	0.42	0.00	1.00	0.08	0.27	0.00	1.00
DOMHOR	0.32	0.56	0.00	1.00	0.38	0.48	0.00	1.00	0.24	0.43	0.00	1.00
Knowledge transfer via FDI and import												
FDI	0.25	0.43	0.00	1.00	0.45	0.49	0.00	1.00	0.00	0.00	0.00	0.00
Log import/emp	14.39	7.50	0.10	23.54	17.13	6.09	0.10	23.28	10.91	8.32	0.10	21.68
Controls												
Log R&D/ emp	10.47	1.79	1.70	14.84	10.59	1.79	3.55	14.84	10.31	1.78	1.70	14.61
Skill[1]	5.74	0.27	5.00	7.99	5.79	0.26	5.00	7.05	5.67	0.28	5.00	7.99
Human capital	0.32	0.26	0.00	1.00	0.33	0.24	0.00	1.00	0.30	0.27	0.00	1.00
Log firms size	4.10	1.50	2.30	9.87	4.78	1.51	2.30	9.87	3.22	0.91	2.30	8.25
Log mach. inv/emp	9.38	2.87	0.00	17.12	9.63	2.70	0.00	14.09	9.07	3.05	0.00	17.12
Log gross. inv/emp	11.13	1.95	0.00	17.47	11.41	1.80	0.00	15.16	10.78	2.07	0.00	17.52
Log [import value/ import weight]/emp	5.91	3.79	0.10	14.16	6.17	3.15	0.10	14.16	5.58	4.45	0.10	13.80
Market [2]	0.19	0.33	0.00	1.00	0.27	0.37	0.00	1.00	0.08	0.24	0.00	1.00
Log export value/emp	14.53	8.06	0.00	23.28	17.41	6.09	0.00	14.09	10.88	8.76	0.00	22.49
Log [export value/ export weight]/emp	5.89	3.91	0.00	15.06	6.28	3.28	0.00	13.66	5.39	4.46	0.00	15.06
Capital structure	0.68	0.23	0.01	1.00	0.66	0.23	0.01	1.00	0.70	0.22	0.02	1.00
Industry dummies	Yes				Yes				Yes			

Notes. Table 3 reports summary statistics for the performance variable, the variables used for investigating knowledge transfer via R&D collaboration, FDI and import, and the control variables. The abridgements FORGRO, FORSCI, FORVER, FORHOR corresponds to foreign collaboration on innovation with partners within the group, scientific partners, vertical partners and horizontal partners. The abridgements DOMGRO, DOMSCI, DOMVER, DOMHOR corresponds to domestic collaboration on innovation with partners within the group, scientific partners, vertical partners and horizontal partners. Skill (1) is measured as log wage per employee, and the variable Market is a dummy variable indicating if Export/sales > 0.5,

Table 4. Regression results Selection equation, Heckman two-step model
Dependent variables: Outcome equation: Log innovation sales per employee (only innovative firms). Selection equation: Propensity to be engaged in product innovation

	All Firms		MNE Only		Non-MNE Only	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Outcome equation						
Knowledge transfer via FDI and import						
Inward-FDI	.124	.097	.075	.106	-	-
Log import/emp	.034***	.005	.030***	.011	.038***	.007
Knowledge transfer via collaboration						
FORGRO	.113	.118	.136	.132	-	-
DOMGRO	-.058	.111	-.148	.132	-	-
FORSCI	.057	.150	.264	.171	-.690**	.311
DOMSCI	-.045	.106	-.148	.138	.105	.160
FORVER	.199	.105	-.030	.141	.474***	152
DOMVER	.079	.099	.111	.141	.070	.131
FORHOR	-.201	.132	-.105	.158	-.385*	.231
DOMHOR	-.111	.104	.004	.137	-.238	.156
Controls						
Log R&D/emp	.157***	.022	.168***	.030	.143***	.032
Skill [1]	.588***	.154	.586***	.213	.567**	.222
Log firms size	-.138***	.043	-.089	.051	-.237***	.074
Log gross investment/emp	.025*	.015	.046**	.021	.009	.021
Capital structure	.694***	.176	1.152***	.263	.278	.242
10 Industry dummies	Yes		Yes		Yes	
Selection equation						
Log firm size	.146***	.018	.100***	.025	.133***	.037
Market [2]	.751	.097	.617***	.120	.832	.182
Capital structure	-.110	.112	-.303*	-.303	.087	153
Log gross investment/emp	.030***	.008	.023*	.013	.037	.101
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Mills, lambda	-.713**	.285	-.989**	.453	-.470	.433
Number of obs.	2,962		1.249		1,713	
Censored obs.	1,871		638		1,233	
Uncensored obs.	1,091		611		480	

Notes: Standard error between brackets, *** p<0.01, **<.005, * p<0.10. (1) Log wage per employee, (2) Log investment in machinery per employee, (2) Export/sales > 0.5. The table reports the parameter estimates of the correlation between innovation sales (i) FDI, (ii) import, (iii) and 8 indicator variables for collaboration on innovation respectively, using the Heckman two-step estimator. In the regression 15 control variables are included. In the selection equation all observations are included, while the outcome equation contains only innovative firms.

Table 5. Regression results GMM

Dependent variables: Log innovation sales per employee.

	Full Sample n=1,091		MNE Only n=611		Non-MNE Only n=480	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
<u>Knowledge transfer via FDI and import</u>						
Inward-FDI	.117	.100	.054	.111	-	-
Log import/emp	.028***	.008	.033**	.016	.029***	.009
<u>Knowledge transfer via collaboration</u>						
FORGRO	.119	.118	.140	.138	-	-
DOMGRO	-.029	.118	-.152	.139	-	-
FORSCI	.089	.167	.273	.181	-.635*	.348
DOMSCI	-.020	.107	-.125	.140	.070	.150
FORVER	.184*	.105	-.214	.144	.461***	.147
DOMVER	.048	.103	.100	.149	.052	.135
FORHOR	-.209	.132	-.106	.167	-.369*	.147
DOMHOR	-.105	.105	.012	.143	-242	.149
<u>Controls</u>						
Log R&D/ emp	.149***	.024	.163***	.034	.124***	.033
Skill [1]	.625***	.175	.616**	.251	.575**	.225
Log firms size	-.147***	.041	-.114**	.022	.248***	.073
Log gross investment/employee	.032**	.015	.049**	.022	.018	.020
Log export/emp	.010	.010	-.009	.017	.020*	.011
Capital structure	.718***	.172	1.030***	.232	.474**	.232
Inverse Mills Ratio, IMR	-.629**	.264	-.844**	.340	-.362	.443
10 Industry dummies	Yes		Yes		Yes	
Test statistics						
Hansen J statistics. Overidentification	7.879	.048	3.431	0.329	3.667	.299
Anderson canon. Corr. Identification	1310.118	.000	544.471	.000	693.643	.000

Notes: The table reports the parameter estimates of the correlation between innovation sales (i) FDI, (ii) import, (iii) and 8 indicator variables for collaboration on innovation respectively, using the GMM estimator. In the regression 16 control variables are included. Standard error between brackets. ***: p<0.01, **: p<.005, *: p<0.10. (1) Log (w/l). Instrumented: Log export value per employee Included instruments: All variables reported in the table above. Excluded instruments: Log gross investment per employee, Export/sales>0.5, Log export value/export weight per employee, Log import value/ import weight per employee. FDI is foreign owned firms

$ Test statistics in agreement with results reported in Table 3, column 2. The identification test (Andersson) and the overidentification test (Hansen) are both satisfactory.

Table 6. Regression results GMM. Collaboration with foreign partners

Dependent variables: Log innovation sales per employee.

Only MNEs. Number of observations: 611.

Equation	1	2	3	4	**5**	6	7	8	9
Knowledge transfer. via FDI and import.									
FDI	.087	.102	.091	.080	.102	.094	.091	.093	.080
	(.102)	(.102)	(.102)	(.101)	(.102)	(.101)	(.101)	(.101)	(.102)
Log import/emp	.033**	.034**	.033**	.032**	.033**	.033**	.033**	.033**	.032**
	(.015)	(.015)	(.015)	(.016)	(.016)	(.015)	(.015)	(.016)	(.016)
Knowledge transfer via collaboration.									
FORGRO + FORSCI	.365**								
	(.183)								
FORGRO+FORSCI+FORVER		.385**							
		(.195)							
FORGRO+FORSCI+FORHOR			.452**						
			(.208)						
FORGRO+FORVER+FORHOR				.302*					
				(.162)					
FORSCI+DOMVER					.321*				
					(.175)				
FORGRO+FORSCI+DOMSCI						.389*			
						(.199)			
FORGRO+FORSCI+DOMVER							.393**		
							(.189)		
FORGRO+FORSCI+DOMHOR								.376*	
								(.211)	
FORGRO+FORHOR+DOMVER									.287*
									(.166)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Selection equation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test statistics	$	$	$	$	$	$	$	$	$

Notes: The table reports the parameter estimates of the correlation between innovation sales (i) FDI, (ii) import, (iii) and 8 indicator variables for collaboration on innovation respectively, using the GMM estimator. In the regression 16 control variables are included. Standard error between brackets. ***: p<0.01, **: p<.005, *: p<0.10. (1) Log (w/l). Instrumented: Log export value per employee Included instruments: All variables reported in the table above. Excluded instruments: Log gross investment per employee, Export/sales>0.5, Log export value/export weight per employee, Log import value/ import weight per employee. FDI is foreign owned firms

$ Test statistics in agreement with results reported in Table 3, column 2. The identification test (Andersson) and the overidentification test (Hansen) are both satisfactory.

APPENDIX

Table A1: Regression results of explanatory variables:
Dependent variable: Log R&D per employee

Variables	Innovative sample n=1,091		
	Coeff.	S.E.	P-value
Human capital	1.862	.247	.000
Skill	.592	.224	.009
Market	.498	.169	.003
Global collaboration on innovation with scientific partners	.456	.188	.016
Domestic collaboration on innovation with scientific partners	.003	.136	.977
Global collaboration on innovation with vertical partners	.205	.137	.137
Domestic collaboration on innovation with vertical partners	.310	.129	.017
Global collaboration on innovation within the group	-.091	.149	.546
Domestic collaboration on innovation within the group	.023	.158	.883
Log import value per employee	-.001	.009	.883
Log export value per employee	.029	.009	.002
Log investment in machinery per employee	.054	.017	.002
Capital structure	-.070	.225	.754
FDI	-.378	.128	.003

Table A2: Test of appropriate instruments. Partial correlation of log export per employee with the following variables. Innovative firms. Number of observations: 1,091

Variables	Corr	Sig
Log (export value per employee/ export weight) per employee	.682	.000
Log (import value per employee/ import weight) per employee	-.126	.000
Log gross investment per employee	.303	.000
Fractions of firm with export/sales >0.5	.423	.000

Table A3: 50 different combinations on network collaborations

Foreign Collaborators		Foreign and domestic collaborators		Domestic collaborators
FORGRO + FORSCI	+	FORGRO+DOMSCI		DOMGRO+DOMSCI
FORGRO + FORVER		FORGRO+DOMVER		DOMGRO+DOMVER
FORGRO + FORHOR		FORGRO+DOMHOR		DOMGRO+DOMHOR
FORSCI + FORVER		FORSCI+DOMSCI		DOMSCI+DOMVER
FORSCI + FORHOR		FORSCI+DOMVER	+	DOMSCI+DOMHOR
FORVER + FORHOR		FORSCI+DOMHOR		DOMVER+DOMHOR
FORGRO+FORSCI+FORVER	+	FORVER+DOMSCI		DOMGRO+DOMSCI+DOMVER
FORGRO+FORSCI+FORHOR	+	FORVER+DOMVER		DOMGRO+DOMSCI+DOMHOR
FORGRO+FORVER+FORHOR	+	FORVER+DOMHOR		DOMGRO+DOMVER+DOMHOR
FORSCI+FORVER+FORHOR		FORHOR+DOMSCI		DOMSCI+DOMVER+DOMHOR
		FORHOR+DOMVER		
		FORHOR+DOMHOR		
		FORGRO+FORSCI+DOMSCI	+	
		FORGRO+FORSCI+DOMVER	+	
		FORGRO+FORSCI+DOMHOR	+	
		FORGRO+FORVER+DOMSCI		
		FORGRO+FORVER+DOMVER		
		FORGRO+FORVER+DOMHOR		
		FORGRO+FORHOR+DOMSCI		
		FORGRO+FORHOR+DOMVER	+	
		FORGRO+FORHOR+DOMHOR		
		FORSCI+FORVER+DOMSCI		
		FORSCI+FORVER+DOMVER		
		FORSCI+FORVER+DOMHOR		
		FORSCI+FORHOR+DOMSCI		
		FORSCI+FORHOR+DOMVER		
		FORSCI+FORHOR+DOMHOR		
		FORVER+FORHOR+DOMSCI		
		FORVER+FORHOR+DOMVER		
		FORVER+FORHOR+DOMHOR		

Notes: The table displays the different combinations of collaborative R&D networks investigated. The sign (+) indicates a significant correlation with innovation product sales using the GMM estimator and control variables. The sample consists of 611 innovate MNE firms.