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**Multinational Enterprises and Innovation:  
Firm level evidence on spillover via R&D collaboration**

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**Abstract**

This paper estimates the knowledge spillovers to multinational firms (MNEs) in Sweden via domestic and foreign R&D collaboration. Applying an augmented GMM-estimator that accounts for both selectivity and simultaneity bias on data from 1,249 MNEs, our research has resulted in five distinct conclusions. First, we find that the knowledge spillovers via R&D collaboration typically take place as a network phenomenon rather than a process between the local firm and a single innovation partner. Second, successful collaboration is conditional on foreign innovation partners in the network. Third, output is found to be an increasing function of R&D-collaboration only among non-export oriented firms. Fourth, foreign MNEs selling mainly to local and regional markets in Sweden benefit more from R&D collaboration than other firms. Overall, the results show that demand driven motives that require entrepreneurial knowledge to adapt products to local consumers and markets are more important for successful R&D-collaboration than supply driven motives.

**Keywords:** Innovation, multinational enterprises, R&D collaboration, spillovers.

**JEL codes:** D21, F23, L21, L22, O31, O32

## 1. Introduction

A rather extensive body of literature has already looked at how innovation is affected by domestic and international transmission of technology by examining different channels such as FDI, trade, licensing, cross-patenting activities, input-output relations, labour mobility, strategic alliances, and regional and international R&D collaboration.

The aim of this paper is to better understand some of the empirical results that have been shown in recent research on knowledge spillover<sup>2</sup> and innovation. Knowledge transfer provides a potential to increase the revenues from firms' investment in research and development through access to technological assets of other firms.

Although it has been suggested that multinational enterprises, MNEs, are in a special position to handle knowledge transfer, recent research in this area has identified difficulties in transferring knowledge across networks consisting of subunits and innovation partners (see, for instance, Gupta and Govindarajan 2000). Surveying the literature based on micro-data, Carkovic and Levine (2002) conclude that firm level studies of particular countries often do not find positive spillovers from foreign-owned to domestic firms. By investigating a sample of MNEs with sub-units in Sweden, Persson (2006) has shown that only 43 % of potential receivers of knowledge for innovation within MNE organizations were using this knowledge.

Recent studies on MNEs and spillovers have shifted the focus from hierarchical links between headquarters and subunits to formal and non-formal arrangements with various partners linked together by complex operating across regions and nations. Based on evidence from Belgian CIS-survey data, Veugelers and Cassiman (2004) suggest that foreign subsidiaries are not necessarily interesting R&D partners for knowledge spillover. What seems to be more important for a local firm is to have an international network of collaborators that provides access to international technology. World Investment Report (2005) argues that the drivers of R&D internationalization are changing. The process is no longer only driven by the need for local adaptation or tapping into established knowledge centers. Instead the MNEs, must use different R&D strategies simultaneously in order to enhance their competitiveness by speeding up the process of technological development and by making better use of the investment in R&D.

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<sup>2</sup> This paper uses knowledge spillovers as a synonym to technology transfer. However, the idea of spillovers is that there is an input that is employed without paying the full price for it. In the present analysis we have no information about how the various arrangements on R&D collaboration are financed.

The research strategy of this paper is to examine how markets orientation of MNEs and corporate ownership structure influence the correlation between innovation output and R&D collaboration within and across the border of individual firms. In order to do so, we classify a Swedish sample of 1,249 MNEs on the basis of whether their main market is international or regional (Sweden), and whether they are foreign or domestically owned.

Our hypothesis is that the outcome of estimations is related to the nature of technological activities within the local MNE, by the type of required knowledge in the firms' innovation process and by technological objectivities decided in some primary market or close to the headquarters . With this in mind, we investigate whether the link between innovation performance of MNEs is associated with (i) the location, number and category of R&D collaborators and (ii) ownership and market orientation of the observed MNE. The data used in this paper is a subset of data on multinational enterprises (MNEs) from the Community Innovation Survey (CIS) IV for Sweden. The CIS information has been supplemented with register data.

Incorporation of markets in our analysis of R&D collaboration is motivated by findings about the link between innovation and growth in the literature on trade and international transfer of technological knowledge (Coe and Helpman 1995, Olley and Pakes 1996, Keller 2001, Halpern *et al* 2006) and by a first inspection of the data as well, which reveals a distinct difference in R&D intensity, knowledge intensity in production and innovation sales related to the market orientation of the observed firm.

The justification for corporate ownership structure can be traced back to the literature on globalization of R&D, which identifies different behaviors of MNE innovative activities depending on the nature of the technological activities and technological objectivities of the parent company. If knowledge spillover are related to a particular R&D strategy of the MNE, one may expect that the association between R&D collaboration and innovation tends to differ.

The analysis has highlighted some important factors that influence the efficiency of technological transmission within and across national borders through R&D collaboration. The concluding finding is that demand driven motives that require entrepreneurial knowledge to adapt products to local consumers and markets are more important than supply driven scientific knowledge.

More specifically, while applying an augmented GMM estimator that accounts for both selectivity and simultaneity bias this research has resulted in several conclusions. We find that knowledge spillovers via R&D collaboration typically take place as a network phenomenon rather than a process between the local firm and a single innovation partner. Successful collaboration is conditional on

foreign innovation partners in the network. R&D collaboration are not found to have any significant effect on innovation by export-oriented MNEs. Innovation sales is an increasing function of R&D-collaboration among non-export oriented firms. Foreign MNEs selling mainly to local and regional markets in Sweden benefit more from R&D collaboration than other firms.

The remainder of the paper is organized in the following fashion: Section 2 presents the data and puts special emphasis on the distribution of collaboration patterns and innovation activities across firms with respect to corporate ownership structure and market orientation. In section 3, we formulate the hypothesis on the correlation between of innovation and R&D collaboration based on what is already known in the MNE literature. Section 4 discusses the empirical methodology. The result of the analysis and conclusions is presented in Section 5 and Section 6 respectively.

## 2. Data and descriptive statistics

The data used in this paper is a subset of data on multinational enterprises (MNEs) 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 %. The original sample contains 3,094 firms and covers both manufacturing and service sectors. The information on innovation activities from the survey has been supplemented with register data on firm characteristics from Statistics Sweden for the observed firms. Our data is a subset of the original sample and is restricted to MNEs.

The total number of observations on MNEs with 10 or more employees is 1,249, of which 335 export more than 50 % of their production and the remaining 914 sell the majority of their production on regional markets in Sweden. Before discussing the data, we will classify the observed firms into four different groups based on ownership and market orientation. First, we separate the 1,249 firms into two groups: those who are producing mainly for the *global* market and those who are targeting *regions* in Sweden. Second, we define a firm as *foreign* if it has its headquarters outside Sweden, otherwise it is *domestic*. We end up with four categories of firms: (i) F-EXP: Foreign-owned firms in Sweden with sales income mainly from exports to the global market, (ii) D-EXP: Domestically owned with sales income mainly from the global market, (iii) F-SWE: Foreign-owned firms with sales income mainly from regional markets in Sweden, (iv) D-SWE: Domestically owned firms producing mainly for regional markets within Sweden.

Table 1 shows that of all MNEs 49% are innovative firms. The average share is considerably higher (67 %) among firms penetrating the global market. The corresponding figure among MNEs penetrating the regional markets in Sweden is 42 %. We define “innovative” as firms reporting both

innovation input (mainly R&D) and innovation output (sales income from innovations launched on the market during the period 2002-2004) for the year 2004. Ten industry classes are used in the regression analysis. A large variation in share of innovative firms is observed, ranging from 27 % (transport, storage and communication) to 67 % (manufacture of machinery and equipment).

Table 2 reports summary statistics on the data employed in econometric model presented in section 4. We use traditional knowledge production variables suggested in the recent innovation literature (Crépon, Duguet and Mairesse 1998, Leeuwen and Klomp 2006, Lööf and Heshmati 2006), augmented by information on trade and finance. Thus, we investigate the importance of external R&D collaboration on innovation output while controlling for factors such as the firm's R&D intensity, size, skill and human capital, physical capital, export as a fraction of sales, export value and external borrowing. 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.

While Section A of Table 2 shows statistics for all firms, statistics for innovative firms only are presented in Section B. The largest fraction (63 %) of the innovative MNEs in Sweden are oriented towards local markets in Sweden. It is notable that local markets in Sweden are relatively more important for foreign owned SMEs than for domestic SMEs. The pattern of external collaboration on innovation is captured by eight dummy variables for Swedish local/regional and global collaboration (i) within the group, (ii) with academic and other scientific partners, (iii) with vertical partners, that is customers and suppliers, and (iv) with firms in the same industry and consultants (horizontal partners). The majority of the innovative MNEs participate in external R&D collaboration (62 %). The largest fraction of them has only one collaborator, while one out of four innovative firms collaborates with both foreign and domestic innovation partners. The most frequent collaboration partners are suppliers and customers within and outside Sweden.

Table 3 presents summary statistics for innovative firms after market focus and corporate ownership. Rows 2-6 displays trade statistics. Row 2 shows that firms producing for the global market sell three quarters of their production outside Sweden, while the firms producing mainly for Sweden export only slightly more than 10 % of their production. This major difference is also reflected in the figures for export per employee. Taking the ratio of export value to export weight indicates that export oriented MNEs with headquarters outside Sweden are the most knowledge intensive category of firms in Sweden. Row 4 also reveals that MNEs that focus on the Swedish market are less knowledge intensive in their export. They are also less R&D-intensive and smaller than export oriented firms.

Rows 4-5 show that the difference between the two groups of firms are considerably smaller regarding import intensity.

A comparison of pairwise foreign and domestic export oriented firms and foreign and domestic non-export oriented firms respectively as in rows 7-9, shows that sales per employee, value added per employee and innovation sales (sales income from new products per employee) are the highest among the foreign owned enterprises. This finding is consistent with the literature, which shows that within countries, foreign-owned firms generally have higher productivity than local firms (see Ebersberger and Lööf 2005). The literature suggests some alternative explanations for the observed difference in performance between domestic and foreign firms, for instance, (i) only firms with superior technology or superior productivity are candidates for mergers and acquisitions (M&A) through inward FDI, (ii) inward FDI is oriented toward high productivity sectors, and (iii) M&A have a positive impact on firm efficiency *per se*.

It is also worth noting that we are using two different measures each for the intensity of human capital (the fraction of university educated personnel and wage per employee), for physical investments (gross investment and machinery investment only per employee) and for export (value per employee and fraction of sales). Econometric issues, related to controls in the selection equation and appropriate instruments in the GMM regression as well, motivate this. Moreover, the capital structure shows that export-oriented MNEs are more equity-financed than firms focusing on the Swedish market.

The bottom of Table 3 reports the fractions of firms that collaborate with the four categories of foreign and domestic (Swedish) R&D partners. Foreign-owned firms collaborate foremost with other units within the group across international borders and with suppliers and customers in Sweden, while the Swedish firms tend to collaborate most with partners within the national system of innovation (universities, customers, suppliers, competitors, consultants) and with foreign vertical partners.

Summarizing the information provided in Table 3 shows a fairly robust pattern: Export-oriented firms are more R&D intensive and have higher innovation sales than non-export oriented firms. They are bigger in size, more capital-intensive and have higher knowledge intensity (approximated by the ratio between export value and export volume) in their export products. However, their human capital intensity is lower. The latter is explained by a larger fraction of knowledge intensive services among non-export oriented firms.

Table 4 shows a correlation analysis for innovative MNEs producing for the global market and regional markets in Sweden respectively. The correlation coefficients presented in Table 4, Panel A

reveal that R&D, human capital, skill and export are strongly associated with innovation sales among export-oriented firms. All the variables in rows (1) - (2) and (4) - (5) are expressed in logarithm and per employee. Human capital is the share of employees with university education. Regarding the eight different dummy variables for R&D collaborators, the correlation coefficient is largest for units within the group but outside of Sweden (0.11) and quite marginal for other alternatives.

The order of magnitude of the correlation coefficients for human capital and export is considerably smaller when non-export oriented firms are considered (See Panel B) Interestingly a stronger association can be found between R&D collaboration and innovation output compared to MNEs producing for the global market. The correlation analysis also reveals a close correlation 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 do not separate R&D personnel from human capital, the importance of these variables will be underestimated due to double counting if both are included in the regressions. Therefore, we will exploit wage sum per employee as a proxy for human capital and hopefully reduce this problem. The assumption is that wage sum includes a skill premium. The information on human capital is, however, used as a determinant to engage in innovation in the first step of the selection model.

### **3. Hypotheses regarding R&D collaboration and innovation**

#### **3.1 Theoretical framework**

Several authors have used patent citation data in order to trace possible links between geographical proximity and innovation (Jaffe *et al* 1993, Almeida 1996, Eaton and Kortum 1999, Bottazzi and Peri 2002, Verspagen and Schoenmakers 2004). This research typically shows that proximity in the creation of economically useful knowledge is important. Some authors also suggest that investors increasingly use domestic knowledge more than foreign knowledge (Sonn and Storper 2003).

Another branch of the R&D literature focuses on how global knowledge spillover affects productivity. Inward FDI have often been emphasized as being one primary driving force for technology transfer across regions and countries (Keller and Yeaple 2003). A growing strand of the FDI literature is focusing particularly on the link between R&D and innovation. In this literature, it is possible to distinguish between the headquarters (HQ)-based theory or traditional view and the network-based approach.



As has been suggested by White and Poynter (1990), Nohria and Ghosal (1997), O'Donnell (2000), Narula and Zanfei (2005) and others, a drawback with the traditional theory on foreign direct investment in R&D, as originally suggested by Vernon (1966), is that it presumes that MNE has a single centre in the first place with rather homogenous foreign subsidiaries serving as a group of miniature replicas of the home country organization.

In order to allow for the possibility that the MNE may have no distinct home base for their core R&D activities but multiple affiliates as well as a variety of local and global cooperation partners, more recent models try to describe MNEs as a network of differentiated subsidiary units and R&D partners in formal and non-formal collaboration arrangements linked together by complex operating interdependencies across regions and nations (see for instance Kogut and Kulantilaka 1994 and Birkinshaw and Hood 1998). Subsidiary units are still central units of analysis, since they are assumed to be important providers of novel knowledge for the MNEs. But while the previous, more hierarchical view of MNE primarily concentrated on the relationship between headquarters and various subunits, the network-based theories attempt to incorporate factors such as extensive heterogeneity where no two units are the same, a high degree of complexity in the innovation processes, institutional and cultural differences and information asymmetries.

### **3.3 Taxonomies and hypotheses**

Following work by Dunning and Narula 1995, Archibugi and Michie 1995, Kuemmerle 1997, Nobel and Birkinshaw 1998, Gassmann and von Zedtwitz 1999, Archibugi and Iammarino 2002, Le Bas and Sierra 2002 and others, UNCTAD (2005) compiled two useful sets of taxonomies of R&D by foreign affiliates that include aspects of the traditional view and of the network approach as well.

Despite the fact that the taxonomies are mainly drawn from the large body of literature studying offshore R&D, we believe that they can also be applied to our observed sample of both foreign-owned and domestically owned MNEs. The most serious objection to our proposed application is that we can only observe the foreign-owned MNE unit in the host country and the domestically owned MNE unit in their home country. The ideal situation would include observations on R&D activities by foreign-owned as well as domestically owned MNEs globally. However, with this deficiency in mind, we will now introduce the two sets of taxonomies.

The first set is based on the *nature of technological activity* in foreign affiliates and reflects four different technological functions assigned to foreign affiliates: (i) Adaptive R&D in order to make existing technologies more efficient in new environments, (ii) Innovative R&D linked to production for local or regional markets, (iii) Global innovative R&D for new products or processes, or for basic

research; in this case, the local firm can be seen as the core innovating center placed on equal level with other centers of excellence globally within the MNE, (iv) Technology scanning monitoring unit, which does not require an R&D unit, but a business intelligence function. We will not consider the latter category of technological activities in the following.

The second set of R&D taxonomies relates to *technological objectivities of the parent company*:. In our application of this classification, we consider two categories for MNEs in the host-country (F-EXP and F-SWE) and two categories in the home country (D-EXP and D-SWE). One obvious deficiency here is that we will underestimate the importance of the link between the Swedish owned MNEs and regional innovation systems to the extent that the R&D output is exploited in non-observed foreign affiliates.

The types of father company motivated technological activities are (i) Technology-seeking: the observed MNE seeks to offset areas of weakness in the home-country innovation system by setting up R&D facilitates or acquiring local innovators in countries with complementary strengths, (ii) Home-base (or asset-) exploiting: the main function of R&D is to absorb and adapt technologies transferred by the parent company so that the MNE can effectively exploit its technological assets on regional markets in Sweden, and (iii) Home-base (or asset-) augmenting: the MNE undertakes R&D in technologies in which they simultaneously are strong at home and in which Sweden also has strengths.

Fischer and Frölich 2001 and Karlsson and Johansson 2004 offer a third useful category of taxonomy. It separates *knowledge for innovation* into three distinct forms: (i) scientific knowledge in the form of basic principles, (ii) technological knowledge in the form of “technical solutions”, and (iii) entrepreneurial knowledge about products, attributes, customer preferences and market conditions, business concepts, etc.

Fig 1: Hypotheses on motives for MNEs' R&D collaboration

<b>Hypothesis</b>	<b>Demand driven</b>	<b>Demand and supply driven</b>	<b>Supply driven</b>
Technological activities	Adaptive R&D	Innovative R&D for regional markets	Innovative R&D for global markets
Father-comp. motives	Technology-seeking	Home-base exploiting	Home-base augmenting
Required knowledge	On products, consumers, markets, concepts, etc.	Technical solutions	Scientific knowledge on basic principles

Figure 1 displays our hypothesized relationship between R&D collaboration and innovation output on the basis of demand- or supply-based motives. Column (1) illustrates that we assume that adaptive R&D, technology-seeking motives and entrepreneurial knowledge can be grouped together under the

heading “demand driven” (or market driven) R&D collaboration. Under the header “supply driven (or scientific driven) R&D collaboration, column (3) we group innovative R&D for the global market, home-based augmenting motives and scientific knowledge on basic principles. Column (2) is a mix between the two pure motives for foreign and regional arrangements on collaboration, which includes innovative R&D for regional markets, home-base exploiting motives and knowledge about technical solutions.

Although the firms have complex motives for R&D collaborations, we will test two different alternative influences on innovation output on the basis of the taxonomy above.

- First, since the typical F-SWE and D-SWE are selling about 90 % of their production to regional markets in Sweden, it can be assumed that most of their R&D collaboration is in conjunction with, or in response to specific locational conditions in Sweden. This means that their motives for R&D collaboration are mainly demand driven or are a combination of demand and supply driven. Thus, if the observed R&D collaborations are characterized mainly by demand driven motives we hypothesize the expected outcome of the estimations is that F-SWE and D-SWE are benefiting more from R&D collaboration than other firms.
- Second, since F-EXP and D-EXP sell three-quarter of their production on markets outside Sweden and on average they are considerably more R&D-intensive than firms producing mainly for the Swedish market, we conclude that their technological activities can be characterized by “innovative R&D for global markets.” In addition to that, we assume that the R&D activities of these firms at least partly are science based and home-base augmenting and therefore they can be classified as supply driven. We formulate our alternative hypothesis as follows: if the observed R&D collaborations are characterized mainly by supply driven motives the expected outcome of the estimations is that F-EXP and D-EXP are benefiting more from R&D collaboration than other firms.

To summarize, we will investigate whether a typical MNE whose innovation activities mainly are characterized as demand driven will benefit more from R&D-collaboration than a MNE with supply driven innovation activities. The supply and demand driven motives are derived from market orientation. In addition we ask if the outcome of the relationship between internal innovation and external collaboration is influenced by corporate ownership structure and by the location of the collaborating subunits. Although our data are incomplete in the sense that it only covers the return on R&D-collaboration that shows up in local establishment in Sweden and not in their subsidiary units elsewhere, we believe that our approach might lead to a better understanding of some recent empirical results indicating weak spillover from R&D collaboration.

## 4. Specification and methodology

### 4.1 Specification of the model

We estimate the magnitude of innovation output effects of R&D collaboration in a multi-market, multi-collaboration and a multi-industry context using a knowledge production model including traditional variables from the Schumpeterian literature plus information on finance and trade. The specification of the model is given by:

$$\log Y_i = \beta_1 \log(E_i) + \beta_2 \log(C_i) + \beta_3 \log(K_i) + \beta_4(F_i) + \beta_5(I_i) + \beta_6(S_i) + \varepsilon_i \quad (1)$$

where  $\varepsilon_i$  is an error term,  $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$  and  $\beta_6$  are parameters to be estimated and  $i$  is the individual firm.

The variables in the model are mainly traditional determinants of production in the innovation literature:  $C$  is physical capital, measured as machinery investments,  $K$  is knowledge measured as R&D and other innovation expenditures and wage per employee, which is a proxy for human capital. The reason for not using the observed fraction of employees with a university degree is that this information is partly captured by the R&D variable, since the major R&D cost is wages to the R&D personnel. We use capital structure ( $F$ ) as a measure of the financial situation, assuming that leverage or possibility to borrow externally, is positively correlated to innovation output.

The pattern of external collaboration on innovation ( $S$ ) is captured by dummy variables for R&D collaboration with partners in Sweden and collaboration with foreign partners, multiplied by corporate ownership structure. For each one of the four corporate ownership classifications (F-EXP, D-EXP, D-SWE and D-SWE) we will end up with 58 different collaboration alternatives estimated in 58 equations. In the equations, we also control for export ( $E$ ) and industry classification ( $I$ ). With the exception of capital structure (debt as a fraction of debt and equity), industry dummies and collaboration indicators, all variables are expressed in intensity terms (per employee) and as logs.

We now turn to the particular econometric concerns in our analysis: selectivity and endogeneity. Selectivity arises from the non-random sample, and endogeneity arises from correlations or other dependence between regressors and the error term. This correlation could be due to measurement error in the dependent variable, or simultaneity in determination of regressors and the disturbance process.

### 4.2 Estimation methodology

As a point of departure for the discussion, we first consider the OLS linear model:

$$y = X\beta + \varepsilon \quad (2)$$

where, in matrix form,  $y$  is innovation sales,  $X$  is a matrix of different categories of possible influences on innovation performance and  $\varepsilon$  is the disturbance term. In order to account for possible selection bias, we will employ a multi-step estimator and use the two-step Heckman model estimator (Heckman 1976). Following the notation in Lewbel (2004), the model can be formally described as follows. In the first step, we estimate a latent binary choice (probit) model:

$$D = I(X'\hat{\gamma} + \varepsilon \geq 0) \quad (3)$$

for selection by maximizing a likelihood function  $L(D, X, \gamma)$ , yielding estimated parameter  $\hat{\gamma}$ .  $D$  in the equation is an observed dummy variable for innovation engagement that equals zero or one,  $X$  is a vector of observed determinants to innovation engagement,  $\hat{\gamma}$  is a vector to be estimated,  $\varepsilon$  is an unobserved error with variance equal to one and  $I$  is the indicator function that equals to one if its arguments are true and zero otherwise.

In a second step, we estimate parameters  $\hat{\beta}, \hat{\lambda}$  by applying the ordinary least squares to the linear regression model:

$$y = X'\beta + m(X'\hat{\gamma})\lambda + e \quad (4)$$

where  $y$  is (log) innovation sales,  $X$  is a vector of regressors,  $\beta$  and  $\lambda$  are vectors to be estimated,  $m(X'\hat{\gamma})$  is the estimated inverse mills ratio, IMR, and  $e$  is the error term. A significant coefficient of the IMR, denoted lamda, indicates that the selection model must be used to avoid inconsistency.

A concern with multi-step estimators such as the Heckman two-step model is that, while reducing the selection bias problem, they introduce some new problems. In particular, since they only account for estimation error in the second stage, the associated standard error is often incorrect. Newey (1984) suggested a theoretical solution to these problems by estimating  $\hat{\gamma}$  in the first stage and  $\hat{\beta}$  in the second stage by applying the method of moments (MM) or generalized method of moments (GMM) to some vector of known functions in step one and step two respectively. Empirically, the crucial issue is to identify a regressor that is special in a sense that one might call “very exogenous” (Lewbel, 2004). Since our dataset does not include any appropriate candidate to serve as such a variable, we construct an “augmented GMM” estimator by using the predicted IMR from the Heckman model as a regressor in GMM estimation.

Formally, the GMM estimator can be described as follows: consider first the linear model (2) above. If  $X$  and  $u$  may be correlated, we will obtain a consistent estimator by using instrumental variables (IV) estimation by using an instrument, defined as a matrix  $Z$ , that is highly correlated with  $X$  and at the same time independent of  $u$ . If appropriate tests show that we have a valid instrument, we will apply the GMM, which implies pre-multiplying (2) by  $Z$  as follows:

$$Z'y = Z'X\beta + Z'u \quad (5)$$

where  $X$  is a matrix including the key variables, the controls, the predicted IMR and the instrumented export variables, and  $Z$  is the instrument.

### 4.3 Specification of the model

We specify the Heckman model as follows: The dependent variable in the first step, i.e. the selection equation, indicates whether or not a firm is innovative. By innovative we mean a firm with positive R&D expenditures and positive innovation sales. Our explanatory variables are motivated from the Schumpeterian literature on R&D determinants: size, market, financing, technological opportunities and industry classification (Cohen and Levine, 1989, Crépon, Duguet and Mairesse et al., 1998, Klette, Moen and Griliches 2000, Hall 2005). More precisely, we specify the determinants to be log employment, human capital, log investment in machinery and equipment per employee, capital structure and, export as a fraction of sales and 10 industry dummies. In the outcome equation (step two), the regressand is log innovation expenditures explained by log employment, log investment in machinery and equipment per employee and industry.

The key equation in our analysis is the innovation function, for which we employ an augmented GMM-model. The emergence of new firm-level data, including the European Community Innovation Survey (CIS), has led to a surge of studies on innovation and firm behaviour. Following the seminal papers by Pakes and Griliches (1984), Cohen and Klepper (1996) and Crépon, Duguet and Mairesse (1998) one strand of this literature are explaining innovation output by R&D, human capital, physical capital and firm size controlling for both selectivity bias and simultaneity bias. This paper expands the covariates to also include also the impact of financing and trade. The importance of financing for technological change was suggested nearly 100 years ago by Schumpeter (1911) and recent literature on technology transfer suggests international trade one of the major channels for technology transfer.

In the GMM-model the dependent variable is log innovation sales per employee. The factors of innovation sales are specified to include the following: log innovation expenditures per employee, log wage per employee approximated by wage sum, since we cannot separate university-educated personnel from R&D personnel, log investment in machinery and equipment per employee, log firm size (employees), inverse mills ratio (predicted from the Heckman model), capital structure, log import per employee and log export per employee. Since innovation output and export can be assumed to be determined simultaneous, particularly in the case of the two categories of MNEs (F-EXP and D-EXP) which are selling the major fraction of their production outside Sweden, we need an instrument ( $Z$ ) that has the property that changes in ( $Z$ ) are associated with changes in export, but do not lead to changes in innovation output (aside from the indirect route via export).

The cross-sectional nature of the data restricts our choice of appropriate instruments, but the test statistics shows that log import value per employee and human capital fulfils the requirement on independence of the instruments and the disturbance process. See table A in the Appendix. Moreover they don't have any direct impact on innovation sales when export and skill is included in the innovation, and they are not correlated with the disturbance term. We now turn to the estimation results.

## 5. Empirical results

This section presents the regression estimates from an augmented GMM model fitted to 1,249 foreign and domestically owned MNEs' innovation and register data, in which the response variable is the logarithm of innovation sales per employee. In addition to observations of R&D collaboration, the data set contains an attribute of each observation's firm characteristics that the theoretical and empirical literature suggests will influence innovation output: R&D, human capital, physical capital, financial capital, firm size, import, export and industry classification. To rule out the possibility that results are driven by systematic differences across industries not captured by our controls, we include a set of 10 industry dummies among the independent variables.

Our research question relates to correlation between innovation and external knowledge through R&D collaboration *ceteris paribus*. R&D collaboration includes both regional innovation partners in Sweden and innovation partners in other countries (labeled "foreign" partners). In particular, we ask if the outcome of the relationship between internal innovation and external collaboration is influenced by supply and demand driven motives derived from market orientation, corporate ownership structure and the location of the collaborating partners, which are subunits within the firm, universities, suppliers, customers, competitors and consultancies.

From the economic theory, we would expect that the propensity to be innovative is an increasing function of firm size, human capital, gross investment and export, whereas 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 apriori assumption is that the influence on innovation output exerted by R&D, skill, physical capital, the capacity to leverage (to increase the ratio of debt to debt plus equity) is positive, while the importance of trade as an important channel of knowledge transfer is less studied at the firm level. However, some recent findings suggest a positive correlation (Keller 2001, Lööf 2008).

In order to save space, we will organize the presentation in the following way. Tables 4 and 5 report results from sensitivity analysis. In Tables 6-8 the key estimates from our 58 equations are shown in compressed shape; table 6 reports the results for collaboration arrangements between the foreign and domestically owned MNEs in Sweden and one or several foreign innovation partners; table 7 reports the impact of R&D collaboration between the MNEs in Sweden and a network that includes at least one foreign partner and at least one regional partner in Sweden; table 8 finally, shows the correlation between the MNEs innovation output and 1-3 regional innovation partners in Sweden. On this basis, below we start with the presentation of the baseline results and sensitivity analyses shown in Tables 5 and 6.

## **5.1 Comparison of models and baseline results**

Table 5 reports the correlation between log innovation sales per employee and a collaboration network that includes the local MNE in Sweden, one or several foreign units within the group and one or several foreign scientific partner. The four key variables are foreign multinationals in Sweden oriented towards markets outside Sweden (F-EXP), domestic multinationals in Sweden oriented towards markets outside Sweden (D-EXP), foreign multinationals in Sweden selling mainly on the Swedish market (F-SWE) and finally Swedish MNEs with mainly domestic customers (D-SWE). The columns correspond to different specifications and different models.

On the basis of the taxonomy discussed in Section 3, we assume that the innovation process of the export-oriented MNEs can be characterized as supply driven, while MNEs selling mainly on the local markets in Sweden have a more demand driven innovation process. Hence, the estimated correlation between R&D-collaboration and innovation output will indicate whether these arrangements foremost foster knowledge on how to adopt to local consumers and markets or if they mostly encourage scientific knowledge on basic principles and innovative R&D for global markets.



Consider first column (1) and our preferred model which is the augmented GMM controlling for both selectivity and simultaneity bias. The upper part of the column reports the parameter estimates of the correlation between innovation sales and four key variables of interest as well as 18 control variables including ten industry dummies and a predicted Mills ratio. In the middle section of column (1), the parameter estimates of the selection part of the Heckman equation are provided. The bottom part reports the test statistic for the GMM equation. The instrumented variable is log export per employee and we use log import per employee and human capital (the fraction of employment with a university degree) as instruments. Column (2) reports the GMM estimates without Mills ratio. Column (3) provides results from the Heckman two-step model. For comparison purposes, we also show the OLS estimates of the correlations.

Turning to the regressions results, we begin by estimation equation (1) using the augmented GMM model. The benefit of using this made is that we can control for both selectivity bias and simultaneity bias. We first consider the controls. The estimated effect of the control variables is mainly what can be expected from the literature. In the row 5 is the coefficient corresponding to levels of R&D-expenditures. The coefficients are positive, statistically highly significant, similar in size across the four models and consistent with the literature as reported by Lööf and Heshmati (2006), indicating that firms that decides to invest more in research and development experience greater innovation output.

In row 5 is the coefficient for international knowledge spillover through export. The results reveal that a larger export intensity is associated with a greater innovation output. Resent literature using micro data has found that export exerts a positive influence on productivity (Jensen et al 2007, Andersson et al 2007). Our results suggest that the productivity effect of global knowledge spillover goes through the innovation process. The positive effect of physical capital (row 6) is consistent with the literature. Our proxy for human capital is wage per employee, since this skill indicator is less correlated with R&D than university educated people. The coefficient estimates in row 7 are sizeable but only marginally significant in the two models that control for selectivity (augmented GMM and heckman). In line with the literature, innovation intensity is a decreasing function of firm size (row8), however the estimate is significant only in the two models that account for selectivity bias.

The point estimate for leverage is positive, highly significant and the order of magnitude is sizeable, suggesting the importance of access to external funding for innovative firms. Our final control the inverse Mills ratio, IMR, is significant and quite sizeable, indicating the importance of correcting for selection bias. In doing so, we have estimated the IMR from a Heckman two-step equation in two of the models (Augmented GMM and the Heckman model) and the middle section of

the Table 5 reports the coefficient estimates from the selection equation. The propensity to be engaged in innovative activities is an increasing function of firm size, human capital, export as a fraction of sales and gross investment. Leverage, which is significant determinant of the size of innovation output is not associated with the firms choice to innovate or not.

The bottom part of columns 1 and 2 looks at the test statistics. The result displays that the Andersson and Gragg-Donald statistics signal no problem of identification and that the Hansen J statistic signals no problem of overidentification. The tests for heteroskedasticity signal no serious problem in the estimated equation's disturbance process below the 5% level. Moreover, the Hausman test for endogeneity rejects exogeneity of the covariance matrix for the export variable.

Since the results from the covariates in the preferred GMM-model the test statistics and the first step of the heckman equation displayed in column 1 are consistent with the results for all 58 equations, these results will not be presented in Tables 6-8 in order to reduce space.

Now consider the coefficients on R&D collaboration shown in rows 1-4. An interesting and robust pattern emerges in these coefficients: the relationship between the assumed supply driven innovation processes among exporters and foreign collaboration within the firm and with one or several foreign scientific partners is non-significant. See column 1 and 2. On the contrary, rows 3-4 report significant or highly significant results suggesting that R&D collaboration is positively associated with demand driven innovation processes where the technological activities are adaptive and/or the motives of the father company is technology seeking and/or where the required knowledge is entrepreneurial about products, customer preferences, market conditions, business concepts etc. To confirm our hypothesis on the positive association between demand driven innovation and incorporation of external knowledge in the innovation process, we will estimate 58 different collaboration arrangements. In each of these equations we compare the impact of R&D-collaboration on innovation output with respect to corporate ownership structure and market orientation.

Comparing the two GMM models, it is shown that the size of the significant estimates for R&D collaboration is somewhat bigger when we account for selectivity bias, while the results for the augmented GMM-model and the heckman model are very similar. The interpretation here is that selectivity bias is a larger problem than simultaneity bias.

## 5.2 Robustness

Before estimating equation (1) using the preferred augmented GMM estimator and investigating the outcome of 58 different collaboration alternatives, we check the robustness of the model by comparing various specifications. The results are shown in Table 6. The columns correspond to different specifications. Column (1) starts with only one covariate and Column (8) concludes with seven covariates and 10 industry dummies. This specification coincides with the baseline result presented in the first column of Table 5.

We focus on the coefficients on four different MNEs each one multiplied with an indicator variable for a collaboration arrangement including one or several foreign affiliates and one or several foreign scientific partners.

For the export-oriented MNEs all point estimates are non-significant irrespective of specification. Considering non-exporting firms and controlling only for export, the point estimates is 0.60 for foreign-owned MNEs and 0.85 for domestic firms. Including industry dummies, R&D and size, the estimates reduces somewhat but they are still significant. When we control also for skill and physical capital, the estimated impact of collaboration is only marginally significant. Including capital structure and Mills increases the degrees of significance and the order of magnitude of the estimates as well.

The concluding finding is that our baseline results are somewhat sensitive to the manner of specification. However, the main message from the regression analysis are not an artifact of the specification but fairly robust across different specifications.

## 5.3 Premium on R&D collaboration

This section presents the estimated effect on innovation from various collaboration arrangements within and across the Swedish border. We first consider foreign collaborators. Several indicators suggest that globalization of innovation is an increasing phenomena. For instance, the share of R&D in foreign affiliates of Swedish owned MNEs rose between 1995 and 2001 from 35% to 48 % of the total R&D by Swedish MNEs. During the same period the fraction of R&D investment in Sweden conducted by foreign-owned MNEs increased from 20% to 40%.

Based on our preferred augmented GMM estimator and the baseline specification the estimated correlation between foreign collaborators and local MNEs in Sweden are reported in Table 7. Two regularities stand out: (1) MNEs producing in Sweden and selling to a foreign market do not benefit from foreign R&D collaboration. (2) Average innovation sales by foreign-owned firms oriented

towards local markets in Sweden are benefiting significantly from a network of foreign R&D collaborators. We consider 11 such networks and 10 of these have a positive and significant impact on innovation sales. Moreover, in 4 out of 11 cases foreign network contributes to innovation output also among Swedish MNEs selling on the home market.

Now consider R&D network including both foreign and Swedish partners. Table 8 reports the results from 30 equations estimating the importance of R&D collaboration with at least one national partner and at least one foreign partner. A similar pattern emerges in these coefficients: Spillovers to the exporters do not show up the innovation output performance. In 70% of the investigated collaboration arrangements a significant impact on innovation can be found among foreign MNEs operating on local and regional markets in Sweden. The corresponding figure for Swedish MNE selling mainly on the Swedish market is 20%.

Table 9 displays the results for 14 alternative collaboration arrangements with Swedish partners. Only two cases show a positive impact. It is foreign-owned MNEs selling mainly on the Swedish market and collaborating with a network consisting of vertical and horizontal partners and scientific, vertical and horizontal partners respectively. However, both estimates are only weakly significant.

Overall, our results suggest that knowledge spillovers via R&D collaboration typically take place as a network phenomena rather than a process between the local MNE and a single innovation partner. Participation of foreign innovation partners such subunits within the group, suppliers, universities, consultants and clients are crucial in the networks. In contrast to earlier work, we point out a significant difference between innovative firms oriented towards the global market and firms focusing on local markets in the home- or host country regarding premium on R&D collaboration. Foremost knowledge spillovers encourage innovative foreign-owned firms oriented towards local and regional markets in the host country.

## **6. Conclusions**

Nearly to two third of the innovative firms examined in this paper participate in external R&D collaboration within the group and with scientific, vertical and horizontal partners. Starting with a sample of 1,249 multinational in Sweden, we estimate how spillovers to 611 innovative MNEs in via R&D collaboration contribute to innovation output. Knowledge transfer provides a potential to increase the revenues from firm's investment in research and development through access to technological assets of other firms. The aim of the paper is to better understand some empirical results that have been shown in recent research on knowledge spillover and innovation. Although it is has

been suggested that multinational enterprises are in a special position to handle knowledge transfer, recent research in this area has identified difficulties in transferring knowledge across collaboration arrangements consisting of subunits and other innovation partners.

In this paper we distinguish between R&D-collaboration driven by demand and supply motives respectively. We assume MNEs oriented towards the local market mainly ask for entrepreneurial knowledge on products, consumers, markets, concepts and other demand driven knowledge in their R&D collaboration. In contrast, firms that are selling on the global market are supposed to be dominated by request of scientific knowledge in their R&D collaboration. In order to test this hypothesis we separate the firms between a group of firms that on average sell 75% of their production outside Sweden and a group that exports only slightly more than 10% of their production. Within both groups we distinguish between foreign-owned and domestically firms.

Applying an augmented GMM-estimator that accounts for both selectivity and simultaneity bias and considering 58 different network arrangements, our research has resulted in five distinct conclusions. First, we find that knowledge spillovers via R&D collaboration typically take place as a network phenomenon rather than a process between the local firm and a single innovation partner. Second, successful collaboration is conditional on foreign innovation partners in the network. Third, R&D collaboration is not found to have any significant effect on innovation by export-oriented MNEs. Fourth, innovation sales is an increasing function of R&D-collaboration among non-export oriented firms. Fifth, foreign MNEs selling mainly to local and regional markets in Sweden benefit more from R&D collaboration than other firms.

According to the taxonomy on which we based our hypotheses, the results show that demand driven motives that require entrepreneurial knowledge on how to adapt products to local consumers and markets are more important for successful R&D-collaboration than supply driven motives and requested scientific knowledge.

A possible factor that could explain why we estimate larger spillover effects on innovation output among foreign firms penetrating the Swedish market compare to other MNEs in Sweden is the incomplete data. The theoretical and empirical literature on MNEs has convincingly shown that the bulk of innovation activities of international firms remain concentrated in their home location. An important reason for the reluctance to globalize R&D in the same extent as manufacturing, sales and marketing is that these companies are embedded in various systems of innovation in their home countries. Many MNEs tend to utilize R&D laboratories and R&D-networks with scientific, vertical and horizontal partners in the home country for development of knowledge that are exploited by

affiliates abroad. Our data allows only to examine this type of spillover among foreign MNEs in Sweden while we don't observe the impact of knowledge transfer from Sweden to foreign subunits.

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Table 1: Summary statistics

	Total	Innovative
Observed multinational enterprises in Sweden	1, 249	49 %
<i>Panel A: Trade</i>		
Firms that export more than 50 % of its production	335	67 %
Firms that export 50 % or less of its production	914	42 %
<i>Panel B: Corporate ownership structure</i>		
Foreign owned firms selling mainly on export markets, F-EXP	180	61 %
Domestically owned firms selling mainly on export markets, D-EXP	155	74 %
Foreign owned firms selling mainly on Swedish markets, F-SWE	431	39 %
Domestically owned firms selling mainly on Swedish markets, D-SWE	481	46 %
<i>Panel C: Industry classes</i>		
Manufacture of food products, beverages and tobacco; Textile and textile products; Leather and leather products; Manufacturing N.E.C, %	170	43 %
Manufacture of pulp, paper and paper products: Publishing and printing, %	98	36 %
Manufacture of coke, refined petroleum products and man made fibres; Rubber and plastic products, %	115	65 %
Manufacture of other non-metallic mineral products; Basic metals and fabricated products, %	119	51 %
Manufacture of machinery and equipment, %	104	67 %
Manufacture of electrical and optical equipment, %	117	59 %
Manufacture of transport equipment, %	81	58 %
Wholesale and retail, %	117	40 %
Transport, storage and communication, %	122	27 %
Business activities, %	206	49 %

Table 2: Summary statistics, key variables, total sample 1,249 observations, and innovative firms 611 observations

	Mean	SD	Min	Max
<i>All firms</i>				
Selection variable; Innovative firms= R&D>0 and Innovation sales >0	0.49	0.50	0	1
Log size (employment), all	4.47	1.50	2.30	10.57
Capital structure (debt/ debt+equity)	0.68	0.22	0.1	1
Human capital (university education>=3 years/employment)	0.17	0.19	0	1
Export as a fraction of sales	0.20	0.34	0	1
Log gross investment per employee	11.18	2.06	0.69	17.50
<i>Innovative firms</i>				
Log size (employment)	4.78	1.51	2.30	9.87
Log R&D per employee	10.59	1.79	3.55	14.89
Log investment in machinery and investment per employee	9.67	2.57	0.69	14.09
Log innovation sales per employee	12.44	1.34	5.99	16.50
Human capital	0.19	0.20	0	0.88
Lag wage per employee	5.79	0.26	5.00	7.09
<i>Trade</i>				
Log export per employee	17.41	6.09	0	23.28
Log import per employee	17.13	5.39	0.01	23.54
<i>Corporate ownership structure</i>				
Foreign owned firms selling mainly on export markets, F-EXP	0.18	0.38	0	1
Domestically owned firms selling mainly on export markets, D-EXP	0.19	0.38	0	1
Foreign owned firms selling mainly on Swedish markets, F-SWE	0.27	0.44	0	1
Domestically owned firms selling mainly on Swedish markets, D-SWE	0.36	0.48	0	1
<i>Collaboration on innovation</i>				
Global Scientific, GS	0.16	0,36	0	1
Sweden Scientific, SwS	0.39	0.44	0	1
Global Group, GG	0.36	0.47	0	1
Sweden Group, SwG	0.23	0.41	0	1
Global Vertical, GV	0.41	0.49	0	1
Sweden vertical, SwV	0.49	0.50	0	1
Global Horizontal, GH	0.23	0.42	0	1
Sweden Horizontal, SwH	0.38	0,48	0	1

Table 3: Summary statistics for innovative firms after market focus and ownership (mean values)

	Mainly Global markets Export fraction > 50%		Mainly Swedish markets Export fraction <= 50%	
	F-EXP	D-EXP	F-SWE	D-SWE
Observations	110	114	167	220
<i>Trade</i>				
Export/Sales	0.74	0.75	0.12	0.13
Log export value per employee	21.21	21.07	15.60	14.97
Import/Sales	0.25	0.19	0.20	0.10
Log import value per employee	19.75	19.15	17.22	14.70
Knowledge intensity in exports approximated by log (export value/export weight)/emp	7.13	6.45	6.20	5.69
<i>Other firm characteristics</i>				
Log sales/emp	14.62	14.49	14.51	14.20
Log valued added/emp	13.36	13.24	13.23	13.17
Log Innovation sales/emp	12.73	12.63	12.42	12.21
Log R&D/emp	10.89	11.08	10.12	10.55
Employment	506	511	469	396
Human capital	0.15	0.18	0.19	0.23
Skill, log wage sum per employee	5.76	5.81	5.82	5.79
Log machinery and equip invest per emp.	10.23	9.98	9.62	9.16
Capital structure	0.63	0.63	0.68	0.69
Log gross investment per employee	11.92	11.79	11.39	10.97
<i>Collaboration on innovation</i>				
Global Scientific, GS	0.17	0.18	0.15	0.14
Sweden Scientific, SwS	0.14	0.25	0.16	0.30
Global Group, GG	0.53	0.32	0.44	0.23
Sweden Group, SwG	0.45	0.46	0.33	0.37
Global Vertical, GV	0.48	0.46	0.35	0.40
Sweden vertical, SwV	0.53	0.51	0.43	0.51
Global Horizontal, GH	0.30	0.25	0.19	0.20
Sweden Horizontal, SwH	0.40	0.50	0.30	0.36

Notes: Table 3 reports mean values of key variables for four different categories of multinational firms, classified after ownership and main market.

Table 4 Correlation analysis: Innovative firms

## Panel A: Innovative MNEs in Sweden focusing on the global market, n = 224

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Inn sales	.00												
2. R&D	.25	.00											
3. Hcap	.23	.55	.00										
4. Skill	.19	.42	.58	.00									
5. Export	.43	.19	.09	.24	.00								
6. GS	-.04	.20	.20	.16	.10	.00							
7. SwS	-.00	.15	.14	.18	.11	.46	.00						
8. GG	.11	.14	.04	.05	.18	.22	.31	.00					
9. SwG	.01	.04	-.03	.13	.20	.21	.27	.22	.00				
10. GV	-.04	.16	.15	.10	.03	.40	.51	.52	.18	.00			
11. SwG	-.04	.04	.03	.07	.02	.33	.52	.42	.32	.57	.00		
12. GH	-.04	.15	.11	.12	.07	.46	.46	.40	.12	.53	.40	.00	
13. SwH	.03	.20	.20	.20	.03	.35	.52	.43	.27	.47	.61	.46	.00

## Panel B: Innovative MNEs in Sweden focusing on the Swedish market, n = 387

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Inn sales	.00												
2. R&D	.22	.00											
3. Hcap	.04	.33	.00										
4. Skill	.16	.21	.58	.00									
5. Export	.10	-.00	-.37	-.22	.00								
6. GS	.19	.26	.19	.20	.07	.00							
7. SwS	.02	.19	.06	.08	.10	.40	.00						
8. GG	.11	.16	.10	.19	.08	.39	.44	.00					
9. SwG	-.04	.08	.00	.04	-.03	.23	.42	.32	.00				
10. GV	.14	.23	.15	.16	.13	.47	.53	.53	.37	.00			
11. SwG	.08	.20	.05	.07	.14	.31	.62	.55	.44	.59	.00		
12. GH	.11	.26	.18	.15	.10	.63	.49	.31	.28	.53	.40	.00	
13. SwH	.06	.14	-.00	.05	.12	.32	.60	.36	.35	.52	.59	.48	.00

Notes: Table 4 reports correlation analysis for innovative multinationals. Panel A shows the correlation for firms focusing on the global market, that is, firms that are selling more than 50 % of their production on the export markets. Panel A shows the corresponding variables for firms selling 50 % or more of their production on local and regional markets in Sweden

Table 5: Sensitivity analysis. Comparison of four different models  
 Collaboration premiums. Dependent variable is log innovation sales per employee. Collaboration is an arrangement that includes the local MNE in Sweden, a foreign affiliate and a foreign scientific partner.

	Augmented GMM controlling for selectivity and endogeneity		Ordinary GMM, controlling for endogeneity		Heckman, controlling for selectivity		OLS, not controlling for selectivity or endogeneity	
Observations	1,249		1,249		1,249		611	
Collaboration partners	GS + GE		GS + GE		GS + GE		GS + GE	
<i>MNE and market focus</i>	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err	Coeff	Std Err
F-EXP	-.086	.482	-.036	.479	-.095	.333	-.030	.328
D-EXP	.093	.372	.190	.380	.080	.382	.182	.376
F-SWE	.629**	.269	.522**	.261	.617**	.248	.514**	.252
D-SWE	.629***	.239	.548**	.242	.629**	.291	.529*	.297
<i>Controls</i>								
Log R&D/ emp	.143***	.033	.161***	.033	.145***	.030	.164***	.030
Log exp/emp	.048**	.020	.052**	.020	.027***	.010	.022*	.012
Log invest in machinery and equipment /emp	.059***	.022	.064***	.022	.064***	.020	.071***	.020
Skill <sup>1</sup>	.466*	.266	.641**	.256	.407*	.222	.586***	.217
Log firms size	-.100**	.039	-.053	.036	-.095**	.043	-.038	.037
Capital structure	1.152***	.236	1.000***	.242	1.144***	.246	.950***	.224
IMR	-.686**	.295	-	-	(-.875***)	(.006)		
10 Industry dummies	Included		Included		Included		Included	
<i>Prob to be innovative</i>								
Log firms size	.093***	.025			.093***	.025		
Human capital	1.019***	.198			1.019***	.198		
Capital structure	-.259	.170			-.259	.170		
Export/Sales	.751***	.114			.751***	.114		
Log Gross invest/emp	.050***	.019			.050***	.019		
<i>Test statistics</i>	Coeff	P-value	Coeff	P-value				
Anderson corr LR stat	256.7***	.000	258.5***	.000				
Gragg-Donald stat	153.8***	.000	155.3***	.000				
Hansen J stat	.212	.644	2.35	.124				
Pagan-Hall, general	26.63	.363	21.65	.359				
Pagan-Hall, normality	35.81*	.092	27.76	.115				
White/Koeneker	23.26	.330	27.39	.319				
Breuch-Pagan	32.90**	.047	33.52*	.061				

Notes: \*\*\* p<0.01, \*\* p<.005, \*p<0.10, Definition: F-EXP - foreign owned MNE with mainly global market. D-EXP - domestically owned MNE with mainly global market. F\_SWE- foreign MNE with regions within Sweden as the main market. D-SWE - domestically owned MNE with regions within Sweden as the main market.

Interpretation of test statistics; Anderson corr LR stat: The null hypothesis that the model is underidentified. Gragg-Donald stat: The Null hypothesis is weak identification. Hansen J-stat: Null hypothesis is not overidentified. Pagan-Hall, general, Pagan-Hall, normality, White/Koeneker, Breuch-Pagan: The null hypothesis is that the disturbances are homoskedastic.

Table 6.

Sensitivity analysis. Augmented GMM with different specifications

Collaboration premium. Dependent variable is log innovation sales per employee. Collaboration is an arrangement between the local MNE in Sweden, a foreign scientific partner (GS) and foreign subunit/father company (GG). Number of observations is 1,249

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff	Coeff
F-EXP	.220	.165	-.130	-.099	-0.121	-.115	-.036	-.086
D-EXP	.223	.275	.227	.268	0.216	.212	.190	.093
F-SWE	.602**	.630**	.512**	.537**	0.495*	.472*	.522**	.692**
D-SWE	.854***	.814***	.525***	.538**	0.536**	.486*	.548**	.629***
Export	.046***	.064***	.057***	.058***	.060***	.048**	.052**	.048**
Additional covariates	None	Industry	Industry R&D	Industry R&D Firm size	Industry R&D Firm size Skill	Industry R&D Firm size Skill P.Capital	Industry R&D Firm size Skill P. Capital Capstr	Industry R&D Firm size Skill P. Capital Capstr Mills

Notes: \*\*\* p<0.01, \*\* p<.005, \*p<0.10, Column 1 reports the estimates for R&D collaboration with a foreign affiliate within the group (GG) , Column 2 reports the estimates of R&D collaboration with foreign scientific partners (GS), Column 3 reports the estimates of foreign R&D collaboration with foreign vertical partners, that is suppliers and customers (GV), Column 4 reports the estimates of foreign collaboration with horizontal partners, that is firms within the same industry and consultants (GH) .

F-EXP: foreign owned MNE with mainly global market, D-EXP: domestically owned MNE with mainly global market,

F-SWE: foreign MNE with regions within Sweden as the main market, D-SWE - domestically owned MNE with regions within Sweden as the main market.

Table 7.

Regression results: Collaboration premium. Global R&D collaboration with one partner, two partners or three partners. Dependent variable: Log innovation sales per employee. Coefficient estimates and frequency (fraction of firms collaborating). Number of observations is 1,249

Panel A

	GS		GG		GV		GH		GG + GS		GS + GV		GS + GH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.079	.17	.210	.53	-.010	.30	-.134	.48	-.086	.14	-.040	.15	-.043	.15
D-EXP	-.225	.18	.182	.17	-.252	.25	-.197	.46	.093	.10	-.244	.17	-.166	.11
F-SWE	.607**	.15	.200	.48	.249	.19	.437*	.35	.629**	.15	.541*	.14	.749***	.13
D-SWE	.241	.15	-.001	.30	.015	.20	-.091	.40	.629***	.08	.246	.13	.191	.10

Panel B

	GG + GV		GG + GH		GV + GH		GS+GG+GV		GS+GG+GH		GS+GV+GH		GG+GV+GH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	.171	.39	-.008	.25	-.056	.28	-.048	.13	-.061	.12	-.057	.23	.078	.23
D-EXP	.217	.26	.364	.17	-.300	.22	.092	.10	.242	.08	-.239	.14	.312	.14
F-SWE	.265	.32	.492**	.18	.448*	.17	.565**	.14	.772***	.13	.686**	.16	.479*	.16
D-SWE	.060	.18	.230	.08	.104	.18	.685***	.08	.696**	.05	.175	.07	.461*	.07

Notes: The table reports the parameter estimates of the correlation between innovation sales and 4 key variables of interest using the augmented GMM estimator. The table also reports the frequency of collaboration. In the regression 17 control variables are included. \*\*\*: p<0.01, \*\*: p<.005, \*: p<0.10, F-EXP - foreign owned MNE with mainly global market, D-EXP - domestically owned MNE with mainly global market, F-SWE - foreign MNE with regions within Sweden as the main market, D-SWE - domestically owned MNE with regions within Sweden as the main market.

GS – scientific collaboration with a global partner, GG collaboration with foreign affiliates within the group, GV –vertical collaboration with a global partner, GH – horizontal collaboration with a global partner.



Table 8.

Regression results: Arrangements for R&D collaboration including both foreign partner(s) and regional partner in Sweden. Dependent variable: Log innovation sales per employee. Number of observations is 1,249

Panel A

	GS+ SwS		GS + SwV		GS + SwH		GG+ SwS		GG+ SwV		GG+ SwH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.044	.16	-.001	.16	-.093	.14	.136	.32	.265	.38	.175	.33
D-EXP	-.284	.18	-.138	.15	-.153	.16	.331	.22	.252	.26	.235	.26
F-SWE	.660**	.12	.725***	.13	.754**	.11	.311*	.29	.250	.38	.341*	.27
D-SWE	.329	.12	.422*	.12	.402	.09	-.139	.16	-.070	.20	-.077	.12

Panel B

	GV + SwS		GV + SwV		GV + SwH		GH + SwS		GH + SwV		GIH + SwH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.001	.33	.058	.39	.138	.27	-.062	.25	-.113	.26	-.127	0.22
D-EXP	-.152	.36	-.034	.39	-.153	.39	-.157	.21	-.122	.20	-.155	0.24
F-SWE	.176	.24	.268	.31	.322	.23	.374	.16	.472*	.17	.449*	0.16
D-SWE	-.099	.27	.012	.34	-.092	.25	-.186	.16	.213	.17	-.038	0.15

Panel C

	GS + GG+SwS		GS +GG+SwV		GS+GG+SwH		GG+GV+SwS		GG+GV+SwV		GG+GV+GwH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.049	.13	-.035	.13	-.184	.12	.131	.26	.241	.32	.222	.25
D-EXP	.001	.09	.102	.10	.149	.09	.334	.19	.301	.24	.249	.22
F-SWE	.676**	.12	.727***	.13	.756**	.11	.198	.23	.298*	.30	.353*	.23
D-SWE	.751***	.07	.642**	.07	.694**	.05	.001	.13	.063	.17	-.090	.11

Panel D

	GG +GH+SwS		GG +GH+SwV		GG+GH+SwH		GS + GV +SwS		GS+ GV + SwV		GS+GV+GwH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.014	.21	-.012	.22	-.018	.20	-.047	.15	-.010	.15	-.056	.12
D-EXP	.449	.13	.442	.14	.357	.16	-.318	.16	-.143	.15	-.214	.15
F-SWE	.439*	.16	.495**	.17	.504*	.16	.578*	.11	.655**	.12	.680**	.11
D-SWE	.173	.07	.465*	.07	.422	.07	.316	.12	.398*	.12	.394	.0

Panel E

	GS+GH+SwS		GS+ GH+ SwV		GS+GH+SwH		GV+GH+SwS		GV+GH+SwV		GV+GH+GwH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.056	.15	-.025	.15	-.037	.10	-.037	.23	-.045	.25	-.0341	.20
D-EXP	-.247	.11	-.107	.10	-.255	.11	-.255	.18	-.142	.19	-.248	.21
F-SWE	.662**	.11	.719***	.13	.751**	.11	.3332	.14	.404	.16	.409	.15
D-SWE	.061	.10	.424	.10	.358	.09	.044	.15	.194	.16	.119	.15

Notes: The table reports the parameter estimates of the correlation between innovation sales and 4 key variables of interest using the augmented GMM estimator. The table also reports the frequency of collaboration. In the regression 17 control variables are included. \*\*\*: p<0.01, \*\*: p<.005, \*: p<0.10, F-EXP - foreign owned MNE with mainly global market, D-EXP - domestically owned MNE with mainly global market, F-SWE - foreign MNE with regions within Sweden as the main market, D-SWE - domestically owned MNE with regions within Sweden as the main market.

GS – scientific collaboration with a global partner, GG collaboration with foreign affiliates within the group, GV –vertical collaboration with a global partner, GH – horizontal collaboration with a global partner, SwS – scientific collaboration with a Swedish partner, SwG collaboration with a Swedish affiliates within the group, SwV –vertical collaboration with a Swedish partner, SwH – horizontal collaboration with a Swedish partner

Table 9. Regression results: R&D collaboration with Swedish partner or partners  
 Dependent variable: Log innovation sales per employee. Number of observations is 1,249

## Panel A

	SwS		SwG		SwV		SwH		SwS + SwG		SwS + SwV		SwS + SwH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.219	.45	-.81	.14	-.146	.53	-.192	.49	-.299	.10	-.099	.36	-.002	.29
D-EXP	-.126	.46	.072	.25	.011	.51	-.113	.50	.186	.18	-.021	.37	-.093	.38
F-SWE	.212	.33	-.094	.16	.146	.43	.293	.46	.087	.13	.256	.29	.311	.24
D-SWE	-.230	.37	-.167	.30	-.002	.51	-.165	.41	-.346	.21	-.083	.34	-.186	.26

## Panel B

	SwG + SwV		SwG + SwH		SwV + SwH		SwS+SwG +SwV		SwS+SwG +SwH		SwG+SwV +SwH		SwS+SwV +SwH	
	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq	Coeff	Freq
F-EXP	-.156	.13	.283	.09	.2031	.35	-.301	.10	-.536	.07	-.278	.09	.110	.25
D-EXP	.223	.20	.163	.19	-.039	.42	.183	.16	.309	.16	.273	.16	-.019	.32
F-SWE	-.121	.14	.024	.09	.329**	.28	.068	.11	.025	.09	.134	.08	.433**	.22
D-SWE	-.223	.26	-.125	.20	-.106	.31	-.316	.20	-.135	.16	-.208	.18	-.022	.25

Notes: The table reports the parameter estimates of the correlation between innovation sales and 4 key variables of interest using the augmented GMM estimator. The table also reports the frequency of collaboration. In the regression 17 control variables are included. \*\*\*, p<0.01, \*\*, p<.005, \*, p<0.10, F-EXP - foreign owned MNE with mainly global market, D-EXP - domestically owned MNE with mainly global market, F-SWE - foreign MNE with regions within Sweden as the main market, D-SWE - domestically owned MNE with regions within Sweden as the main market.

SwS – scientific collaboration with a Swedish partner, SwG collaboration with a Swedish affiliates within the group, SwV – vertical collaboration with a Swedish partner, SwH – horizontal collaboration with a Swedish partner.

## Appendix

Table A. The correlation between the instrumented variable export, the two instruments import and human capital and the residual.

	Export	Import	Human capital	Residual
Log export per employee	1.00			
Log import per employee	0.69	1.00		
Human capital	-0.34	-0.29	1.00	
Residual	-0.06	0.01	0.01	1.00