View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Research Papers in Economics

Multinational …rms, Technology and Location

Pehr-Johan Norbäck

The Research Institute of Industrial Economics*

June 19, 2000

Abstract

This paper analyzes a three-stage optimization problem in which a …rm chooses (i) its technology, by deciding on a level of R&D, (ii) whether this technology is to be used in a domestic or a in foreign plant and (iii) the quantity produced and sold on the market. If technology transfer costs are low, "high-tech" or R&D-intensive …rms tend to produce abroad. At higher technology transfer costs, high-tech …rms tend to export. An empirical analysis using a data set of Swedish multinational …rms, con…rms the latter prediction.

Keywords: Multinational Firms, R&D, Location, Empirical Analyses

JEL classi…cation: L13, F23, O33

*Pehr-Johan Norbäck, the Research Institute of Industrial Economics Box 5501 SE-114 85 Stockholm. E-mail: PJN@iui.se, Internet: http://www.iui.se, Telephone: +46 8 665 45 22 and Telefax: +46 8 665 45 99.

1 Introduction and summary

In the literature, multinational firms (MNFs), that is, firms performing economic activities in multiple countries, are closely related to firm-specific assets.[1] Firm-specific assets, which include such things as marketing ability, product differentiation or Research and Development (R&D), can be seen as giving a firm a competitive edge, which enables it to expand production into foreign markets. Recent imperfect competition models of multinationals also show that firms are more likely to choose foreign direct investment (FDI) when firm-level fixed costs, such as R&D expenditures, are high, relative to plant level fixed costs. Seminal papers include Horstmann and Markusen (1992), Brainard (1993), Ethier and Markusen (1996) and Markusen and Venables (1998).

These models typically treat firm-specific fixed assets as fixed vis-a-vis the entry choice into a foreign market. However, when analyzing the relationship between R&D and FDI, say, this assumption overlooks the fact that a firm may not only expand sales abroad in order to draw on its technology asset, it may also be done to gain resources to develop this asset.[2] In this paper, I therefore extend the earlier work by modelling this interaction. Quite surprisingly, this slight modification of the standard model introduces an ambiguity in the relationship between R&D and FDI. Even more surprisingly, I find empirical evidence suggesting a negative relationship, which is quite the opposite of the traditional view.

I use a framework developed from Leahy and Neary (1996). I study a monopoly firm which makes three distinct choices: It invests in costly R&D to improve its technology, thereby decreasing the marginal cost. Then, it either implements the technology in an affiliate which supplies the market from a foreign plant, or in a domestic plant which supplies the market by export production. Given this location choice, the good is supplied.

The firm takes the fact that export production is subject to a trade cost into account. Moreover, I also assume that implementing the technology abroad is more costly, due to technology transfer costs.[3] The model predicts that when transfer costs are small, high-tech firms will choose foreign direct investment. At higher transfer costs, on the other hand, high-tech firms choose to export. High-tech or R&D-intensive firms then gain more by avoiding transfer costs of technology than by avoiding transport costs of physical units, since more complex technology demands larger resources for technology transfer.

These predictions are tested on a data set consisting of Swedish multinational firms, provided by the Research Institute of Industrial Economics (IUI) in Sweden. Both countries with foreign production and countries exclusively supplied by exports, are included in a two-stage estimation procedure, where I use the share of foreign sales accounted for by overseas affiliate production as the dependent variable in the OLS-regressions. The empirical analysis shows that exports is the preferred choice by R&D-intensive firms: There is a persistent negative correlation between R&D intensity and the affiliate share of foreign sales, on the one hand, and the probability that any affiliate sales are recorded, on the other.

These findings may also be contrasted to some recent work. Contemporaneously to this paper, Sanna-Randaccio and Petit (1998) have developed a similar framework in which investment in R&D leads firms towards foreign expansion but also that MNFs tend to invest more in R&D. Sanna-Randaccio and Petit also discuss transfer costs. On the basis that FDI predominantly occurs between developed countries, they argue that transfer costs should be small and derive the two-way relationship on this presumption, predicting that high-tech firms should be predominately multinational. In contrast, this paper shows evidence of the opposite relationship: high-tech firms are more inclined to export.

While the IUI data set has the advantage containing firm-level information, it is limited to firms with producing affiliates. How would then the inclusion of purely exporting firms affect the results? This may reverse the negative relationship between R&D and the probability of finding affiliates. However, the negative relationship between R&D and the affiliate share will not be affected since this regression, by definition, only includes firms with producing affiliates. Furthermore, it is informative make a comparison with Brainard (1997). She employs the same two-stage method to investigate the pattern of US foreign production and exports, using a cross section of industries and countries. Combining trade data from the US Bureau of Census and FDI data from the Bureau of Economic Analysis, she finds that R&D increases the probability of finding affiliate sales in a country. Based on her theory, R&D is, however, not included in her second-stage regression. She does however find that when levels of affiliate production and exports are separately regressed against R&D intensity; both increase in R&D, but the elasticity of exports is about two and half times larger.[4] She concludes that R&D is consistent with both exports and foreign production but makes no reflection to why the export bias is so strong. The mechanisms and results of this paper may indeed be used to explain this pattern.

Some restrictions of the theoretical model should also be noted. The model uses a monopoly set-up. This is purely for expositional reasons as the results in this paper also extend into oligopoly. I model R&D as cost-reducing, but the analysis can also be extended to quality improvements or the generation of new products. I abstract from any home market influence on the choice between FDI and exports. This assumption simplifies the analysis, but does not seem too restrictive when the focus is on a country like Sweden, where the home-market may be of neglible size for its large international firms. For functional forms, I use linear and quadratic functions.

The paper proceeds as follows: In section 2, a theoretical framework is derived. In Section 3, an empirical analysis based on the findings in section 2 is performed. Section 4 concludes.

2 Theory

In this section, I study the interaction between the R&D decision and the choice between foreign and export production, as alternative means of serving a market abroad.

2.1 Structure

The structure of the problem is the following. There is a single firm producing a homogeneous good. The demand is located in another country, which may be considered as the world market for the good in question. The firm makes three decisions: First, it invests in costly R&D at home. We assume the technological level of the firm to be represented by its cost level of production, and that R&D lowers the marginal cost. Then, the technology is implemented either in export production from a domestic factory (henceforth denoted E), or a direct investment is made (henceforth denoted FDI) and production takes place in foreign affiliate (henceforth denoted F). Finally, the market is supplied.

For notation subscripts will denote location. For example, q_h is the output choice of the firm in location h, for $h = \{E, F\}$. Hence, q_E is the export quantity of the firm, whereas q_F is the production quantity when an affiliate is established.

2.2 The model

The marginal cost in production in location h for $h = \{E, F\}$, is given in (1):

$$c_h = C_h - \theta x_h; \qquad C_E = c_0 + t; \qquad C_F = c_0 \tag{1}$$

where θ and c_0 are positive constants. Several factors affect the production costs. From (1), we can see that the firm chooses levels of R&D, indicated by x_h, which lower its marginal costs. Export production is also subject to a transport cost or a tariff barrier, t, which can be avoided by FDI.

The inverse demand is given by (2):

$$P_h = a - \frac{q_h}{s} \tag{2}$$

where $a > 0$ is a demand parameter and $s > 0$ can be interpreted as a measure of the size of the market.

The total profit can then be written as (3):

$$\begin{aligned} \Pi_h &= (P_h - c_h) q_h - \frac{\gamma((1+\delta_h)x_h)^2}{2} - G_h \\ &= (P_h - c_h) q_h - \frac{\gamma (x_h)^2}{2} - T_h - G_h \end{aligned} \tag{3}$$

In (3), the first term indicates variable profits and the last three terms indicate different types of fixed costs. From the left to the right, these fixed costs are as follows:

First, R&D is assumed to incur quadratic costs, so that x_h gives rise to firm-specific fixed costs of $\frac{\gamma (x_h)^2}{2}$, where γ is a positive constant.[5] Note that this term corresponds to firm-specific costs discussed in the introduction, which are usually modelled as exogenous in the literature. Here, these costs are endogenous.

Second, the firm is assumed to have production units at home, but initiating production abroad involves additional plant-level investments. Plant-level fixed costs are then defined in (4):

$$G_h = \begin{cases} G; & \text{for } h = F \\ 0; & \text{for } h = E \end{cases} \tag{4}$$

Third, following Teece (1977), technology transfer costs for implementing the technology in a factory located abroad are assumed to be higher. To simplify, let us normalize such that new technology can be implemented at home without cost, whereas an additional cost T of transferring the technology abroad arises, since it must be adapted to local conditions.

More complex technologies may require closer interchange of information with manufacturing, thereby increasing communication and information costs if production is located abroad. The transfer cost is therefore made dependent on the actual level of R&D. This is done by introducing a parameter δ, such that $0 \le \delta_F < 1$, if foreign production is chosen and $\delta_E = 0$, if export production is chosen. It simply means that a given level of R&D, x, equally lowers the cost of production, irrespective of location (cf. equation (1)), but that the implementation of the technology abroad requires additional R&D efforts of δx. From (3), we can then restate the resulting transfer costs as:

$$T_h = \begin{cases} \frac{\delta(2+\delta)}{2}(x_h)^2 \geq 0; & \text{for } h = F \\ 0; & \text{for } h = E \end{cases} \tag{5}$$

where we note that $T(\cdot)$ is indeed increasing with the level of R&D, x[6].

Profit maximizing production quantities, q_h, and R&D expenditures, x_h, are chosen so that (6) must hold:

$$\frac{\partial \Pi_h}{\partial q_h} = P_h - c_h - \frac{q_h}{s} = 0; \qquad \frac{\partial \Pi_h}{\partial x_h} = \theta q_h - \frac{\gamma x_h}{(1+\delta_h)^2} = 0 \tag{6}$$

Using (2), and (6), optimal production quantities and optimal R&D levels are given by (7):

$$q_h = s\frac{a - c_h}{2}; \qquad x_h = \frac{\theta}{\gamma(1+\delta_h)^2} q_h \tag{7}$$

As shown by Leahy and Neary (1996), all endogenous variables can be solved in a parameter η, defined as:

$$\eta \equiv \frac{\theta^2 s}{\gamma} \geq 0 \tag{8}$$

η may then be interpreted as the relative return to R&D. Note that η is zero, if R&D is completely ineffective ($\theta = 0$), inexcessively expensive ($\gamma = \infty$) or if the size of the market is very small ($s = 0$).

To ensure well-behaved solutions, we will make two assumptions: (i) The parameter values are such that the firm always have a strict positive marginal cost which, by (1), implies that $c_h > \theta x_h$ holds. (ii) The parameter values support positive profits in both locations. This, in turn, implies cases where $\alpha\eta < 2$, where the parameter α is a measure of the impact of the transfer cost[7]:

$$0 < \alpha \equiv \frac{1}{(1+\delta)^2} \leq 1 \tag{9}$$

By using (1), (7), (9) , I can express the optimal production level for each location choice h in θ. These are given in (10):

$$q_E = s\frac{A - t}{2 - \theta}; \qquad q_F = s\frac{A}{2 - \alpha\theta} \tag{10}$$

where it will be assumed that $A - t > 0$ and $A = a - c_0 > 0$.[8]

We can then use (3), (4), (5), (6), (7) and (10), for deriving expressions for the total profits in the two alternative locations. Then, we have:

$$\begin{aligned} \Pi_E(\theta) &= \pi_E(\theta) - T_E - G_E \qquad (11)\\ &= \frac{1}{2s}(q_E)^2(2 - \theta) \\ \Pi_F(\theta) &= \pi_F(\theta) - T_F - G_F \qquad (12)\\ &= \frac{1}{2s}(q_F)^2(2 - \alpha\theta) - T - G \end{aligned}$$

where variable profits are denoted $\pi_h(\theta)$ and production quantities are given by (10).

2.2.1 The equilibrium location

Let us now characterize the equilibrium location of production. It is then useful to explore the variable profit function. It is easy to state and prove the following proposition:

Proposition 1 The variable profit for exporting $\pi(\theta)$ is increasing and the corresponding profit in foreign production $\pi_F(\theta)$ increasing or non-decreasing in the relative return to R&D, θ: Furthermore, define $\alpha = \bar{\alpha}$ as a critical value of technology transfer costs. Then, affiliate profits $\pi_E(\theta)$ increase at a faster rate in θ, compared to export profits $\pi_E(\theta)$ if transfer cost are sufficiently low, $\alpha > \bar{\alpha}$. The opposite holds if transfer costs are sufficiently high, $\alpha < \bar{\alpha}$.

Proof. See appendix A

What is the economic intuition behind proposition 1? First, the profit in export and foreign production increases in η simply because a higher return to R&D implies higher spending on R&D, thereby lowering the marginal costs.

Moreover, since FDI avoids the transport cost, larger sales in foreign production also imply increased spending on R&D, as compared to the alternative of exports. Therefore, the difference in marginal costs between the two location alternatives will tend to exceed the transport cost t, and this difference will be increasing in η. This trade-cost-effect will work towards making profits in affiliate production more responsive to a increase in the relative return to R&D η. However, locating production abroad implies that technology need to be transferred from home R&D labs to abroad. At an increasing relative return to R&D η, increasing technology transfer costs tend to restrict the firm's R&D which, in turn, limits the reduction of the marginal cost if affiliate production is chosen. This transfer cost-effect tends to make profits in export production more responsive to a increase in the relative return to R&D η

Which location of production is then actually chosen? Comparing total profits in the two alternatives, the following proposition applies.

Proposition 2 Suppose that parameter values are such are such that total profits are equal in export- and affiliate production at some η^*. If technology transfer costs are low $\alpha > \bar{\alpha}$, then a firm endowed with a high relative return to R&D, $\eta > \eta^*$ chooses FDI, whereas the firm exports if $\eta < \eta^*$: The opposite holds if technology transfer cost are high, $\alpha < \bar{\alpha}$.

Proof. See appendix A

Accordingly, the model predicts that when transfers of technology is less costly, …rms in knowledge-intensive industries, that is, industries with a relatively high relative return to R&D ´, are inclined to locate production abroad, while …rms in industries with a lower return to R&D choose to export. On the other hand, when it is more costly to transfer technology, high-tech …rms tend to export whereas low-tech …rms choose FDI. In the latter case, high-tech …rms gain more by avoiding transfer costs than by avoiding transport costs of physical units. These results are summarized in table 1.

The table also shows comparative statics result for both cases of transfer costs. The explicit expressions are given in appendix A. The …rst column indicates an increase in the exogenous variable z. The second and third columns reveals the e¤ect in the case of low transfer costs. More speci…cally, the second column shows the qualitative e¤ect on ´¤; whereas the third column translates this into the "marginal e¤ect" on the …rm's incentive to choose FDI and locate production abroad[9]. This sign can be interpreted as the e¤ect on the location decision in a marginal …rm endowed with a relative return to R&D of ´¤. Column three and four does the same thing for the case with high transfer costs.

The comparative statics results in table 1 reveal no surprises, so I will be very brief in commenting on them. Whatever the size of transfer costs, FDI is less likely when plant-level …xed costs G are higher and more likely when transfer costs are lower (® is larger) and when trade barriers t are higher. For example, in the low transfer cost case, an increase in t will lower ´¤ and induce the marginal …rm to produce abroad. In this case, the marginal cost in a¢liate production does not only decrease due to increased transport costs, but also due to the fact that a more extensive production increases

R&D expenditures. These effects magnify the difference in marginal costs between export and affiliate production, which, in turn, allows profits in these two alternatives to be equalized at a lower return to R&D η^*. Hence, higher transport costs favor FDI, since a larger range of η permits direct investment.

3 Empirical analysis

The theoretical section gives an ambiguous view of the relation between a firm's technology and its choice between affiliate and export production. Since different predictions arise depending on the importance or level of technology transfer costs, this provides an opportunity to test the impact of technology transfer cost.

3.1 Data

The primary data source is a data set from the Research Institute of Industrial Economics (IUI), based on a questionnaire sent to all Swedish MNFs every fourth year, on average. Data is available from seven surveys: 1965, 1970, 1974, 1978, 1986, 1990 and 1994. The survey covers almost all Swedish multinational firms in the manufacturing sector, and detailed information is available on variables such as R&D, employment, production and their distribution between domestic and foreign units, as well as on internal and external trade flows.

This rich data set has been used in the following way: (i) All firms with at least one production affiliate abroad are included in the sample. (ii) Within this set of firms with production affiliates, we focus on foreign sales to the OECD countries.[10] (iii) All exports sales are sales of final goods, that is, the impact of input goods is removed. (iv) Exports back to Sweden from the affiliates have been removed from affiliate production.

Let me briefly comment on these conditions. Ideally, firms without production affiliates should be included in the sample, but corresponding firm-level data for purely exporting firms is simply not available. I have chosen to focus on OECD countries, since the modelling framework does not emphasize differences in factor costs. In addition, sales to OECD countries cover the vast majority of foreign sales in these firms. Finally, the last two criteria are chosen to comply with the absence of input-goods and home-market effects in the theoretical section.

Additional information on country and industry specific variables are taken from World Development Indicators (1997), OECD (1997) and SCB.

3.2 The econometric model

The theory presented in the previous section predicts a firm's choice between implementing its technology in export or affiliate production. In translating this theoretical prediction into an empirical analysis, there are several caveats: The simple model involves a firm which produces a single final product, whereas many of the firms in the sample are large multi-affiliate firms with multiple product lines. Furthermore, within such firms, the location of technology cannot be directly observed from the data. I will follow Brainard (1997) and use the share of foreign sales accounted for by the affiliates as my dependent variable. This variable is labeled $AFSHARE_{ijt}$, and is defined:

$$AFSHARE_{ijt} = \frac{SQ_{ijt}}{SQ_{ijt} + SX_{ijt}} \tag{13}$$

where SQ_{ijt} denotes the level of production for firm i in country j at time t and SX_{ijt} is the corresponding export level. This relative measure then indirectly captures the implementation choices of the firms since the sales pattern must reflect location choices. It also subsumes the two endogenous variables, export and affiliate production, into a single variable.

The dependent variable in (13) is censured - it can take on any values between zero and one. A closer look at the data set reveals that the firms only have production affiliates in a minority of the countries for which foreign sales are recorded. Thus, $AFSHARE_{ijt}$ contains a large number of zeros. Omitting these observations will result in a systematic selection bias causing any OLS-estimates on $AFSHARE_{ijt}$ to be both biased and inconsistent. Therefore, I will use a two-stage procedure. This procedure, given by (14) and (15), separates the probability- and marginal effects:

$$\begin{aligned} DAFSHARE_{ijt} = {} & \beta_0 + \beta_1 RD_{it} + \beta_2 TREMB_{ht} + \beta_3 DIST_j \\ & + \beta_4 AGE1_{it} + \beta_5 RD2_{it} + \beta_6 GSCALE1_{ht} \\ & + \beta_7 GDP_{jt} + \upsilon_{ijt} \end{aligned} \tag{14}$$

$$\begin{aligned} AFSHARE_{ijt} = {} & \alpha_0 + \alpha_1 RD_{it} + \alpha_2 TREMB_{ht} + \alpha_3 DIST_j \\ & + \alpha_4 AGE2_{ijt} + \alpha_5 RD2_{it} + \alpha_6 GSCALE2_{ht} \\ & + \alpha_7 GDP_{jt} + \alpha_8 \lambda_{ijt} + \varepsilon_{ijt} \end{aligned} \tag{15}$$

I first estimate the probability of finding affiliate sales in a country, using the dependent variable $DAFSHARE_{ijt}$, where $DAFSHARE_{ijt} = 1$ if $AFSHARE_{ijt} > 0$, $DAFSHARE_{ijt} = 0$ otherwise. Then, a two-stage selection biased corrected regression model from Heckman (1979) is employed, where the error correction variable λ_{ijt} is included. The explanatory variables are presented below. Logs are also used in all continuous variables.

3.3 Exogenous variables

In table 1, the independent variables and the corresponding exogenous variables from the theoretical section (for which they act as proxies), are presented. For convenience, I also reproduce their expected sign, based on my ...ndings in the theoretical section. Two kinds of independent variables will be used; core variables and additional variables.

3.3.1 Core variables

This group of independent variables is closely attached to the exogenous variables encountered in the theoretical section. R&D intensity, RD_{it}, de...ned as the share of R&D expenditures in the total sales of the ...rm, is used as a proxy for the relative return to R&D, ´. Since the focus in this paper is on the relation between technology and location, RD_{it} is the explanatory variable of most interest.[11]. Note that since R&D expenditures are endogenously determined in the theoretical section, there may be an endogenity problem with the R&D variable in the empirical analysis. The structure in our theoretical models - in which R&D expenditures are set before location decision and market interaction - suggests that a lagged R&D intensity should be considered. Ravenscraft and Scherer (1982) propose a lag of approximately ...ve years between R&D expenditures and pro...ts, which suggests that the four-year lag, corresponding the one period lag in terms of surveys, should be treated as endogenous. To reduce any simultaneity bias, the eight year lag on R&D intensity will be used instead[12].

However, since two surveys are lost in the lag procedure, and because of unbalanced nature of the data set as many ...rms disappear when they are acquired or reorganized over time, I will also report estimations, using the present R&D intensity. This avoids a massive loss of observations associated with the eight-year lag. Note also that given that R&D is conducted before any market interaction, R&D in time t should be uncorrelated with the error terms in (14) and (15).

Unfortunately, no direct measure of the plant level fixed costs G can be calculated, as the data base lacks information on individual plants in the Swedish part of the corporation. Information on plant size is available for affiliates, but using this information without care gives rise to two immediate problems: (i) If plant-level scale economies are sufficiently large, then we would suspect that domestic production is preferred, thereby indicating that proxies for G based solely on affiliate information may be misleading. (ii) Relating large affiliate plants directly to AFSHARE may give a spurious correlation - large affiliates should account for a large share of foreign sales, a relationship which may have little to do with the effect of scale economies on the location decision.

In the probit equation (14), I will use $GSCALE1_{it}$. It is defined as the ratio between the average number of employees in affiliates and the average number of employees in the corporations. To reduce the above problems, I aggregate to the three- or four-digit industry level. The OLS stage should be more sensitive, however, since it directly uses the continuous variable AFSHARE; whereas the probit stage involves the dichotomous variable DAFSHARE. Therefore, equation (15) uses $GSCALE2_{it}$, which is instead calculated from Swedish industrial statistics. It is defined as the average size of plants with more than one hundred employees divided by total industry mean size, at the three- or four-digit industry level to which the firm belongs.

Turning to measures of transport costs, $TREMB_{it}$ is calculated as the share of transport and packing costs in total variable costs, and once more, Swedish three- or four-digit industry level data are used. In addition to packing and transport costs, total variable costs include costs for electricity, raw materials and wages for blue-collar workers. The second measure, $DISTW_{jt}$, is an index measuring the geographical distance from Sweden to the respective countries.

It is very difficult to find a variable which accurately captures the effect of technology transfer costs. Following Swedenborg (1982), it may be argued that more experience of production abroad should lower technology transfer costs to units abroad, and that this should also be the case for firms performing R&D abroad[13]. To capture the effects of experience in foreign production, $AGE1_{it}$ reflects a weighted average of the age of the affiliates of a firm, irrespective of their location. $AGE2_{ijt}$ is simply the mean age of the affiliates in a particular country. To measure the effects of R&D abroad, we construct two dummy variables; $RD1_{it}$ takes on the value of one, if the firm performs any R&D abroad, and $RD2_{ijt}$, which takes on the value of one if the firm performs any R&D in the country in question.

3.3.2 Control variables

In addition to the core variables, a set of control variables will also be included. The first control variable is the size of the respective country measured as PPP-adjusted, deflated GDP, GDP_{jt}.[14] Following Brainard (1997), I also control for differences in factor proportions through the variable $INCOME_{jt}$, measuring per capita income differences between Sweden and the respective countries where the firm operates. $OPEN_{jt}$ is an openness index taken from Wheeler and Moody (1992), measuring the openness of a country to FDI. Finally, following Braunerhjelm and Svensson (1996), I control for the in‡uence of agglomeration e¤ects on the location decision through the variable $AGGLOM_{hjt}$. This variable is de…ned as the share of all employees in the manufacturing industry in the industry to which the investing …rm belongs, out of all employees in the manufacturing sector in the respective countries, divided by the share of employment in this sector in all countries. If pecuniary externalities in terms of cost and demand linkages are present in an industry, thereby attracting direct investments, such agglomeration forces should be captured by this variable.[15] Finally, I also control for speci…c e¤ects over regions, industries and time. The regions are EFTA, the EC, North America and the Far East. Industry dummies are employed at the two- or three-digit industry level.

3.4 Estimation results

Table 3 reports the results from estimating (14) and (15). Speci…cation (i), uses the contemporaneous R&D intensity, whereas speci…cation (ii) uses the eight-year lag on R&D intensity. The …rst two columns shows the probability and marginal e¤ects, whereas the third column shows a 2SLS estimation on equation (15) where the error correction variable is omitted. The contempemperaneous R&D-intensity is used as instrument for the four year lag in R&D-intensity in speci…cation (i). The eight-year lag on R&D intensity is used as an instrument for the four year lag in R&D-intensity in speci…cation (ii).

Irrespective of speci…cation, both the probability- e¤ect and the marginal e¤ect are signi…cantly negative for $RDINT$. This is also the case for the 2SLS estimates. That is, the larger the R&D intensity, the smaller the probability that a …rm locates production in a country and - given that production is established - the smaller is the share of foreign sales accounted for by the a¢liates. Note that this negative, signi…cant sign lends supports the relationship predicted when transfer costs were assumed to be high, thereby rejecting the prediction when transfer costs were assumed to be low.

Turning to transport costs, TREMB has the predicted, positive sign in all equations. DIST is statistically signi…cant, but appears with di¤erent signs in the probit and the regressions. Thus, when the geographical distance increases, the probability of a …rm locating production in a country decreases, whereas - given that a¢liates are established - a larger distance favors local production. The latter result is predicted in the theory section, whereas the former is somewhat unexpected. As Ekholm (1998) argues, it may be the case that a larger distance also re‡ects cultural and institutional factors, in which case the increasing cost of FDI dominates the e¤ects of transport costs.

Variables AGE1; RD1 and GSCALE1 all have the predicted signs in the probit stage in both speci…cations. Hence, more experience in foreign production clearly increases the probability of producing abroad, whereas scale economies at the plant-level work in the opposite way. Turning to the regressions, the corresponding variables, AGE2; RD2 and GSCALE2, reveal similar information. Thus, if the …rm has established R&D laboratories in a host country, this obviously facilitates transfers of technology and production to such a country. We also note that a sample selection bias indeed exists, as the coe¢cient on LAMBDA is positive and highly irrespective of speci…cation.

The GDP-variable GDP exerts a signi…cant positive in‡uence - the size of a country is of great importance for a …rm's decision to establish production. Turning to the second-stage regressions, once affiliates are established, local production seems be chosen over exports to a larger extent, when country size increases. Overall, the OLS and 2SLS estimations provide quite close results. The only exception is the GDP-variable, where the 2SLS estimations suggest that firms on the margin favors to export to large countries rather than produce locally. This is somewhat surprising, but suggests that size of country has a stable influence on a firm's decision to establish production, whereas the effect is less clear once production has already been established.[16]

3.4.1 Robustness of results

Table 4 checks the robustness of the results in table 3 by first adding more control variables. Specification (iii) reestimates (14) and (15), adding the three new variables: INCOME, OPEN and AGGLOM. The parameter estimates are quite robust to the inclusion of the extra variables. In particular, the negative relationship between R&D intensity and foreign production, as measured by DAFSHARE and AFSHARE, persists.

The coefficients on INCOME, proxying for differences in relative factor endowments, does not seem to affect the probability of finding affiliates, but is positive and significant in the OLS. Hence, within this set of OECD countries, factor proportions seem to explain some of the variation in the dependent variable once affiliates are established: The openness of a country to FDI has the positive predicted sign, but is not significant. Finally, pecuniary externalities in the shape of cost and demand linkages in the host countries seem important, as AGGLEM significantly increases both the share of foreign sales of the affiliates and the probability of establishing production.

Next, I undertake panel estimations controlling for firm-specific effects, since unobservable firm-characteristics may drive the results. In specification (iv), I reestimate augmented versions of (14) and (15) separately, controlling for firm-specific, time-specific and country-specific effects. To allow for fixed effects, I use a logit formulation in (14). Since there is no within-variation in the distance variable, $DIST_j$ and the openness measure for FDI, $OPEN_j$, these variables are dropped. I choose to use the present R&D intensity in all specifications. This allows me to exploit the full time-series variation of the data. It also avoids a large loss of observations associated with using lagged R&D as the data is heavily unbalanced. The panel results in specification (iv) produce no drastic changes. In particular, there is again a negative correlation between R&D intensity and the propensity to produce abroad as measured by either the affiliate share of foreign sales or the probability that any affiliate sales are recorded. This is also the case for specification (v), which controls for firm-country-pair fixed effects and time-specific effects.

4 Conclusions and discussion

In the literature, high R&D intensity is often associated with multinational firms. It should then be expected that higher R&D intensity should lead firms to choose overseas production relative to exporting. In this paper, I have shown that this is not necessarily the case. On the contrary, using a unique data set of Swedish multinational firms, I find that R&D intensity is negatively related to the share of foreign sales accounted for by the affiliates on the one hand, and the probability of finding affiliate production in a country on the other. That is, on the margin, there is a negative relationship between technology and overseas production. I have suggested that one way to explain this puzzle is to take into account that it is costly to transfer technology abroad. R&D intensive …rms may then …nd it more pro…table to avoid technology transfer costs rather than physical transport costs.

This also points to a natural extension of the analysis, since a way for a …rm to avoid technology transfer costs associated with foreign production could be to place the development of its technology abroad. Based on earlier studies of Swedish MNFs, however, adapting technologies to local conditions and regulations rather than developing new technology, seems to have been the primary motive for locating R&D abroad.[17] But it should be noted that the average share of R&D performed abroad has increased from around 9 % in the early observations to 25 % in the latest. While this shows that the major part of R&D still takes place at home, the increasing share of foreign R&D might also indicate that R&D to a larger extent takes place abroad to develop new products and technologies. Future research should therefore investigate the interaction of the production- and R&D location more closely.

Acknowledgement

I am grateful to Harry Flam at the Institutute for International Economics at Stockholm University (IIES), for useful discussions and suggestions. I am also grateful to Jim Markusen at University of Colorado at Boulder for his comments and suggestions. At the Research Institute of Industrial Economics (IUI), I want to express my gratitude to Roger Svensson, Karolina Ekholm, Pontus Braunerhjelm, Jörgen Nilson, Per Thulin, Erik Mellander, Petter Lundvik, Karl-Markus Modén, Henrik Braconier and Mattias Ganslandt. The comments made by two referees also significantly improved the paper. Finally, I take the full responsibility for any remaining errors or misinterpretations in text.

References

Blomstrom, M. and Y. Wang, 1992. Foreign investment and technology transfer: A simple model, European Economic Review 36, 137–155.

Brainard, S.L., 1993. A simple theory of multinational corporations and trade with a trade-o¤ between proximity and concentration, NBER Working Paper No. 4269.

Brainard, S.L., 1997. An empirical assessment of the proximity-concentration trade-o¤ between multinational sales and trade, American Economic Review 87, 520–544.

Braunerhjelm, P. and R. Svensson, 1996. Host country characteristics and agglomeration in foreign direct investment, Applied Economics 28, 833–40.

Caves, R.E., 1996. Multinational Enterprise and Economic Analysis. 2nd edition, (Cambridge University Press, Cambridge and New York).

Cheng, L., 1984. International competition in R&D and technological leadership, Journal of International Economics 17, 15–40.

Dunning, J.H., 1977. Trade, location of economic activities and the MNE: A search for an eclectic approach, in P.-O. Hesselborn, B. Ohlin and P.-M. Wijkman, eds., The International Allocation of Economic Activity, (MacMillan, London), 395–418.

Ekholm, K., 1998. Proximity advantages, scale economies and the location of production, in P. Braunerhjelm and K. Ekholm, eds., The Geography of Multinational Firms, (Kluwer Academic Publishers, Boston), 59–76.

Ethier, W.J. and J.R. Markusen, 1996. Multinational …rms, technology di¤usion, and trade, Journal of International Economics 41, 1–28.

Fors, G., 1997. Utilazation of R&D results in the home and foreign plants of multinationals, Journal of Industrial economics 45, 341-358.

Heckman, J., 1979. Sample selection bias as a speci…cation, Econometrica 47, 153–161.

Horstmann, I. and J.R. Markusen, 1987. Strategic investments and the development of multinationals, International Economic Review 28, 109–121.

Horstmann, I. and J.R. Markusen., 1992. Endogenous market structures in international trade (natura facit saltum), Journal of International Economics 32, 109–129.

Lall, S., 1980. Monopolistic advantages and foreign involvement by U.S. manufacturing industry, Oxford Economic Papers, 32 105–122.

Leahy, D. and P. Neary, 1996. International R&D rivalry and industrial strategy without government commitment, Review of International Economics 4, 322–338.

Markusen, J.R., 1984. Multinationals, multi-plant economies, and the gains from trade, Journal of International Economics16, 205–26.

Markusen, J.R., 1995. The boundaries of multinational enterprises and the theory of international trade, Journal of Economic Perspectives 9, 169–89.

Markusen, J.R. and A.J. Venables, 1998. Multinational …rms and the new trade theory, Journal of International Economics 46, 183-203.

OECD, 1997. Economic Outlook No 61: Annual Data (OECD Publishers).

Ravenscraft, D. and F. Scherer, 1982. The lag structure of returns to research and development, Applied Economics 14, 603–620.

Sanna-Randaccio, F. and M. Petit, 1998. Technological innovation and multinational expansion: a two-way link?, forthcoming in Journal of Economics (Zeitshrift fur Nationalokonomie).

SCB, Industristatistiken. (Statistiska Central Byrån).

Swedenborg, B., 1982. Swedish Industry Abroad. An Analysis of Driving-Forces and E¤ects, (IUI, Stockholm).

Teece, D.J., 1977. Technology transfer by multinational …rms: The resource cost of transferring technological know-how, Economic Journal 87, 242–61.

Venables, A.J., 1996. Equilibrium locations of vertically linked industries, International Economic Review 37, 341–359.

Wheeler, D. and A. Mody. , 1992. International investment location decisions: The case of U.S. …rms, Journal of International Economics 33, 57–76.

White, H., 1980. A heteroscedasticity-consistent covariance matrix estimator and a direct test for heteroscedasticity, Econometrica 48, 827–838.

World Bank, 1997. World Development Indicators (World Bank).

A Appendix:

First, the statements in propositions 1 and 2 are proved, then table 5 is derived. Finally, second-order conditions are shown.

A.1 Proof of proposition 1

By calculation:

$$\frac{@¼_E}{@´} = \frac{1}{2}s\frac{(A ¡ t)^2}{(2 ¡ ´)^2} > 0; \qquad \frac{@¼_F}{@´} = \frac{1}{2}s\frac{A^2®}{(2 ¡ ®´)^2} ¸ 0 \qquad \text{(A.1)}$$

which veri…es the …rst part of proposition. Then, de…ne the di¤erence in variable pro…ts as $4¼ = ¼_E ¡ ¼_F$. From (A.1), it is easy to see that ® = 0 (in…nite transfer costs) implies $\frac{@4¼}{@´} > 0$, whereas ® = 1 (no transfer costs) implies $\frac{@4¼}{@´} < 0$: Also note that (A.1) implies that $\frac{@4¼}{@´}$ must be monotonously decreasing in ®: Hence, there is a critical ® = ®̄; such that $\frac{@4¼(´:®̄)}{@´} = 0$: This veri…es the second part of the proposition.

A.2 Proof of proposition 2

First, de…ne the di¤erence in total pro…ts as $4¦ = ¦_E ¡ ¦_F$ where $¦_E$ is de…ned in (11) and (12) and note that $\frac{@4¦}{@´} = \frac{@4¼}{@´}$. Then, if there is a $´ = ´^¤$ such that $4¦(´^¤; z) = 0$, $¦_E(´^¤; z) = ¦_F(´^¤; z)$; where z is the vector of exogenous variables, it follows from the proof in proposition 1 that $¦_E < ¦_F$ for $´ > ´^¤$ and ® > ®̄, whereas $¦_E > ¦_F$ for $´ > ´^¤$ and ® < ®̄:

A.3 Comparative statics in table 1

Using the equality $\Pi_E(\eta^*; z) = \Pi_F(\eta^*; z)$; implicit differentiation yields:

$$\frac{d\eta_B}{dz} = -\frac{\frac{\partial(\Pi_E - \Pi_F)}{\partial z}}{\frac{\partial(\Pi_E - \Pi_F)}{\partial \eta}} = -\frac{\frac{\partial M\pi}{\partial z}}{\frac{\partial M\pi}{\partial \eta}}$$

where we can use:

$$\frac{\partial(\Pi_E - \Pi_F)}{\partial \eta} \begin{cases} < 0 : \alpha > \bar{\alpha} \\ > 0 : \alpha < \bar{\alpha} \end{cases}; \qquad \frac{\partial(\Pi_E - \Pi_F)}{\partial t} = -s\frac{A - t}{2 - \eta} < 0$$

$$\frac{\partial(\Pi_E - \Pi_F)}{\partial G} = 1 > 0; \qquad \frac{\partial(\Pi_E - \Pi_F)}{\partial \alpha} = -\frac{1}{2}s\frac{A^2\eta}{(2 - \alpha\eta)^2} < 0$$

A.4 Appendix: Second-order conditions

In this appendix, we check the firm's second-order conditions for the maximization of (3). To have a well-posed maximization problem, the Hessian, defined in (A.2), must be negative definite:

$$Q_h = \begin{bmatrix} \Pi_{h;q_h;q_h} & \Pi_{h;q_h;x_h} \\ \Pi_{h;x_h;q_h} & \Pi_{h;x_h;x_h} \end{bmatrix} \tag{A.2}$$

where, for example, $\Pi_{h;q_h;x_h} = \frac{\partial^2 \Pi_h}{\partial q_h \partial x_h}$. This, in turn, requires that $|Q_h| > 0$; $\Pi_{h;q_h;q_h} < 0$ and $\Pi_{h;x_h;x_h} < 0$. I can show that this will hold if $\alpha\eta < 2$ since:

$$|Q_E| = \frac{\gamma}{s}(2 - \eta); \quad \Pi_{E;q_E;q_E} = -\frac{2}{s} < 0; \quad \Pi_{E;x_E;x_E} = -\gamma < 0$$

$$|Q_F| = \frac{\gamma}{s}\left(\frac{2}{\alpha} - \eta\right); \quad \Pi_{F;q_F;q_F} = -\frac{2}{s} < 0; \quad \Pi_{F;x_F;x_F} = -\alpha\gamma < 0$$

Notes

[1]See Dunning (1977) and Markusen (1995).

[2]This have been been suggested by Caves (1996).

[3]Teece (1977) provides strong evidence for the existence of such technology transfer costs.

[4]Brainard finds that the elasticity of affiliate sales with regard to R&D is 0:1840. The corresponding elasticity for exports is 0:4599. Hence, the affiliate share of foreign sales should decrease in R&D intensity.

[5]See Cheng (1984).

[6]The assumption of a quadratic transfer cost is not essential. What is important is that the transfer cost influences the level of R&D, x.

[7]In appendix A.4, it is shown that the latter assumption guarantees that the second-order condition for the firm's maximization of (3) is fulfilled.

[8]These conditions are necessary in order to guarantee that production is profitable.

[9]A decrease in ´¤ is indicated by a minus sign, an increase in ´¤ by a plus sign.

[10]The countries included are: Belgium, France, Italy, Holland, Germany, Luxemburg, UK, Norway, Ireland, Denmark, Spain, Portugal, Greece, Finland, Austria, Switzerland, USA, Canada, Japan, Australia and New Zealand. The last two countries are combined into one single country observation.

[11]It can be shown that R&D intensity, defined as the share of R&D expenditures in total sales, is positively correlated with our theoretical measure of return to R&D, ´.

[12]The eight-year lag is constructed by lagging R&D two surveys back. This produces eight-year lags for most observations. The exception is 1986, where the lag is taken from 1974. Similarly, the four-year lag used in 1986 is taken from the 1978 survey. I have taken this approach because no survey was undertaken in 1982.

[13]R&D performed at home completely dominates total R&D expenditures in the firms of this sample, even though the share of R&D performed abroad has increased over the period.

[14]The reason why size is only used as a control variable is that s is included in the definition of ´, and therefore affects the R&D intensity. But since I aim at capturing the implementation choices of new technologies through AFSHARE, it is still necessary to control for size effects.

[15]This type of externalities may involve the use of joint networks of suppliers and distributions (see, for example, Venables (1996)).

[16]There is a similar pattern in table 4 where a comparison is made with panel analysis

[17]See, for example, Fors (1997).

Table 1: Description of variables.

Variable name	Proxy for	Expected sign	Description and source
RDINT	´		share of a …rm's total R&D expenditures in its total sales, lagged eight years in speci…cation (ii) and (vi) present intensity in speci…cations (i), (iii)-(v) and (vii). (IUI).
TREMB	t	+	share of transport and packing costs in total variable costs divided by the total industry mean at the three- or four-digit level in the Swedish industry to which the …rm belongs (SCB).
DIST	t	+	distance from Sweden to the respective countries where the …rm records foreign sales. (IUI).
AGE1	®	+	weighted average of the mean age of the …rm's a¢liates in the respective countries where production takes place. Weights calculated as the share of the …rm's total foreign sales attributed to the individual countries. (IUI).
RD1	T	+	dummy variable that takes on the value of one if the …rm undertakes any R&D abroad, zero otherwise. (IUI).
GSCALE1	G	¡	average size of the a¢liates divided by the average size of the …rms in terms of employees at the three- or four-digit industry level to which the …rm belongs. (IUI).

Table 2: Continued

Variable name	Proxy for	Expected sign	Description and source
AGE2	®	+	mean age of a …rm’s a¢liates in a speci…c country. (IUI).
RD2	®	+	dummy variable that takes on the value of one if the …rm undertakes any R&D in a country, zero otherwise. (IUI).
GSCALE2	G	¡	average size of plants with more than one hundred employees divided by total industry mean size at the three- or four-digit level Swedish industry, to which the …rm belongs. (SCB).
GDP			PPP-adjusted, de‡ated GDP. (OECD, World Bank).
INCOME			ratio between PPP-adjusted, de‡ated GDP per capita in Sweden and the respective countries where the …rm records foreign sales. (OECD, World Bank).
OPEN			index measuring the openness of a country to FDI. (Wheeler and Moody (1992)).
AGGLEM			share of total employment in an industry at the three- or four-digit industry level in the respective countries where a …rm records foreign sales. (Braunerhjelm and Svensson (1996) and OECD).

Note: Column two describes the exogenous variable to which the proxy refers. As the theoretical section involves two models with both di¤erent variables and di¤erent predictions, the top row for each exogenous variable corresponds to model 1, whereas the bottom row corresponds to model 2.

Table 3: Two-stage Heckman estimation and 2SLS.

Variables	Specification (i)			Specification (ii)		
	Probit	OLS	2SLS	Probit	OLS	2SLS
RDINT	-0.104	-0.251	-0.333	-0.116	-0.173	-0.236
	(-4.107)	(-11.095)	(-9.775)	(-3.274)	(-5.311)	(-5.102)
TREMB	0.020	0.085	0.097	0.095	0.088	0.114
	(0.386)	(2.400)	(2.448)	(1.120)	(1.737)	(2.104)
DIST	-0.566	0.123	0.381	-0.511	0.213	0.419
	(-11.544)	(2.499)	(7.544)	(-8.238)	(3.095)	(6.998)
AGE1	0.245			0.231		
	(11.041)			(5.683)		
RD1	0.225			0.276		
	(4.102)			(3.207)		
GSCALE1	-0.275			-0.414		
	(-7.429)			(-7.494)		
AGE2		0.114	0.125		0.146	0.126
		(7.278)	(5.762)		(5.613)	(4.948)
RD2		0.263	0.254		0.167	0.204
		(6.718)	(5.386)		(3.187)	(3.737)
GSCALE2		-0.947	-0.108		-0.213	-0.320
		(-1.787)	(-1.466)		(-1.989)	(-2.964)
GDP	0.347	0.061	-0.040	0.390	0.124	-0.023
	(14.547)	(2.250)	(-1.869)	(12.290)	(3.141)	(-0.904)
LAMBDA		0.545			0.613	
		(5.974)			(5.167)	
Prediction errors (%)	22.6			27.9		
Chi2	817.68			333.43		
R^2		25.4	23.6		30.4	29.0
F		13.15	11.55		8.92	9.30
No. of var.	26	27	25	24	25	24
No. of obs.	4283	1462	1065	2102	797	775

Note 1: The dependent variable in the OLS columns is the affiliates share of foreign sales for firm i in country j at time t. The dependent variable in the probit columns is a dummy variable which equals one if production is registered, zero otherwise. In the 2SLS regressions, the eight year lag- and the present intensity are respectively used as instruments for the four year lag in R&D-intensity.

Note 2: Numbers in parenthesis are t-statistics. Prediction errors are formed at a critical probability of 0.5. All variables are in logs, except RD1, RD2 and LAMBDA. Sample size differences reflect missing observations. Intercept and dummies for region, industry and time are not shown for Specifications (ii) and (iii).

Table 4: A comparison with panel analysis.

Variables	Specification (iii)		Specification (iv)		Specification (v)	
	Probit	OLS	Logit	OLS	Logit	OLS
RDINT	-0.111	-0.235	-0.311	-0.204	-0.578	-0.112
	(-4.163)	(-10.478)	(-2.430)	(-4.327)	(-2.684)	(-2.696)
TREMB	0.013	0.067	-0.211	0.092	0.152	0.129
	(0.259)	(1.829)	(-0.875)	(1.128)	(0.401)	(1.743)
DIST	-0.453	0.173				
	(-6.979)	(3.406)				
AGE1	0.236		0.203		0.511	
	(10.246)		(2.225)		(3.432)	
RD1	0.215		0.293		0.794	
	(3.806)		(1.620)		(2.517)	
GSCALE1	-0.288		-0.257		-1.808	
	(-7.526)		(-1.809)		(-4.233)	
AGE2		0.126		0.106		0.058
		(6.353)		(5.385)		(2.455)
RD2		0.255		0.201		0.195
		(6.420)		(3.976)		(3.477)
GSCALE2		-0.075		-0.138		-0.115
		(-1.445)		(-2.341)		(-2.241)
GDP	0.319	0.048	1.078	-0.166	2.215	-0.484
	(11.574)	(1.920)	(1.023)	(-0.409)	(1.080)	(-1.115)
INCOME	-0.011	0.127	-0.014	0.122	0.105	-0.015
	(-0.120)	(1.900)	(-0.068)	(1.507)	(0.247)	(-0.174)
OPEN	0.200	0.009				
	(1.346)	(0.086)				
AGGLOM	0.139	0.181	0.216	0.129	-0.517	0.282
	(2.208)	(3.487)	(1.694)	2.137)	(-0.903)	(1.673)
LAMBDA		0.553				
		(5.885)				
Prediction errors (%)	23.7		34.5		39.4	
Chi2	699.90		635.65		102.90	
R^2		26.6		20.9		0.2
F		11.58		9.39		3.98
No. of var.	28	29	32	32	14	15
No. of obs.	3811	1343	3716	1285	696	1040
No. groups			177	141	186	319

Table 5: Comparative statics results in model 1

Variable:	Low transfer costs, $\alpha > \bar{\alpha}$: (FDI when $\eta > \eta^*$) Effect on η^*	ME on FDI	High transfer costs, $\alpha < \bar{\alpha}$: (FDI when $\eta < \eta^*$) Effect on η^*	ME on FDI
G	(+)	-	(-)	-
α	(-)	+	(+)	+
t	(-)	+	(+)	+

Note: Note that an increase in alfa implies a decrease in technology transfer costs.