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TECHNOLOGY TRANSFER TO FOREIGN AFFILIATES BY MULTINATIONAL ENTERPRISES

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Abstract - This paper examines whether Swedish multinational enterprises transfer R&D-generated knowledge to their foreign affiliates. The empirical results suggest that such technology transfer takes place from parent companies to affiliates, especially in the case of newly established affiliates. In process industries, R&D undertaken in the affiliates seems to facilitate the transfer from the parent, highlighting the role of "receiver competence." The findings also support the view that technology is "embodied" in intermediary goods deliveries from parents to foreign affiliates. Embodied transfer appears to be more important to affiliates located in developing countries.

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I. Introduction

Multinational enterprises (MNEs), undertake the bulk of the world's aggregate industrial R&D, and have increasingly been pointed to as the leading actors in the international transfer of technological knowledge. The commonly held view is that MNEs transfer technological assets across borders to their own foreign affiliates, rather than transact these assets in the market. The issue of international technology transfer to a large extent has been analyzed at the industry or national level. Even if it is plausible that aggregate studies capture the effects of technology transfer in MNEs, to date we have limited empirical evidence of these international technology flows at the firm level.[1]

This paper examines whether technology is transferred *from* parent companies (home operations) of MNEs *to* foreign affiliates. The econometric analysis is based on a data set of Swedish multinationals in the manufacturing sector and their foreign production affiliates over four separate periods spanning 1965-1990. By "technology" is here understood to be knowledge generated by past R&D expenditures, and by "technology transfer" we mean the measured effect of lagged parent R&D on affiliate total factor productivity growth. In effect, the rate of return on parent R&D in the affiliate is estimated. The empirical analysis first addresses the general issue of whether this kind of technology transfer does in fact take place. Second, it quantifies the impact of the transfer on affiliate productivity, and third, the analysis investigates factors influencing the extent of intra-firm technology transfer.

The study is organized as follows: Section II briefly discusses earlier theoretical and empirical contributions to the study of technology transfer within MNEs. The econometric

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[1]See Coe and Helpman (1995), for a study on R&D-spillovers between countries. Since MNEs dominate industrial R&D, the results should to a large degree be attributed to MNEs. Even if the technology transfer is intra-firm, the effect of R&D undertaken by MNEs in their home countries, should eventually show up in aggregate figures in the host countries where the firms operate.

model and data are presented in sections III and IV, and the empirical results discussed in section V. The final section concludes.

II. Technology transfer in multinationals

A firm based in a country (home) essentially faces three options with regard to the exploitation of its technological assets in foreign markets: it can either (i) export the good in which the technology is embodied, (ii) license the technology to foreign firms, or (iii) set up a foreign affiliate to produce the good locally, i.e. become a MNE.[2] The third option typically implies transfer of technology to the affiliate in order to produce the good.

Regarding exports it is well known that successful penetration of foreign markets can seldom be based on exports alone (see e.g. Dunning, 1992). On licenses, the transaction cost view suggests that the market for knowledge is prone to failure for a number of reasons, leaving explicit sales of technology to external agents as a less advantageous alternative.[3] This implies that the technological assets of firms to a large extent should be exploited abroad through the establishment of affiliates.[4] Blomström (1992) notes that intra-firm technology transfer should especially apply to a MNE's most advanced technologies, in order to avoid leakage to competitors, which could be the case in licensing agreements.

Empirical evidence from different countries indicate a positive relationship between a firm's (or an industry's) technological activities (commonly measured as R&D intensity),

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[2]Referred to by Caves (1996) as a horizontally integrated MNE, with the foreign affiliate producing the same good as the parent.

[3]Over 60% of the license revenues in Swedish MNEs come from their own foreign affiliates, i.e. through intra-firm transactions. This indicates that technology transfer is mainly conducted within the MNE, especially when considering that probably only a small part of intra-firm transfers are tied to explicit license payments. In comparison with R&D expenditures, for example, license revenues or payments are negligible.

[4]The same arguments could be applied to other intangible assets of a MNE, e.g. brand names and managerial expertise.

and outward foreign direct investment (see e.g. Caves, 1996 and Dunning, 1992). Fors and Svensson (1994) finds evidence of a positive simultaneous relationship between R&D intensity and internationalization in Swedish MNEs. This suggests that R&D is important for success in foreign markets, and at the same time that international operations may be a prerequisite for maintaining large scale R&D activities.

A large and highly internationalized firm can spread fixed R&D costs on many production plants, and obtain a higher rate of return on each R&D dollar spent. In a general equilibrium context, Markusen (1984) models a firm's R&D as a fixed cost incurred in one location (home), conferring firm-level economies of scale when the firm establishes plants abroad where the knowledge is used as an input. Mansfield *et al* (1979) report that US MNEs expect to earn over 30% of the returns on parent R&D from utilization of the knowledge in foreign markets.

Taking a firm's R&D expenditures as an indicator of technological activity, the following two observations provide arguments that the direction of the transfer should mainly be *from* the parent company (home operations of the MNE) *to* its foreign affiliates. First, most R&D is undertaken in the MNEs' home operations - over 80% in the Swedish case - even though the share of overseas R&D is increasing.[5] Second, R&D performed in the home country is more basic, generally applicable and long term in character, compared with R&D in foreign affiliates, which is mainly oriented toward adapting technologies created at home to local conditions and regulations (Behrman and Fischer 1980).[6] Detailed case studies of

[5]Around 13-14% of total R&D in the Swedish MNEs was performed abroad during the 1970s up to the mid-1980s, while the figure had increased to 18% in 1990 (Fors and Svensson 1994).

[6]Considering data on a sample of 26 Swedish MNEs in 1978 that undertook R&D both at home and abroad, we note that for home R&D, 10% of expenditures were directed toward "long-term research", 48% for "new products and processes", and 42% for "improvement of existing products and processes." The corresponding figures for these firms' foreign R&D expenditures were 2%, 44% and 54%, respectively. These figures are taken from the same data set as used in the empirical analysis. More recent observations for Swedish MNEs also

individual MNEs confirm this direction of transfer (OECD 1978). In the case of Sweden, Blomström and Kokko (1994) note that domestic production is characterized by a relatively low R&D content, and that technologies created by the multinationals' R&D efforts in Sweden can be expected to be exported to foreign affiliates to a large extent.[7]

Based on case studies, Behrman and Wallender (1976), suggest five general mechanisms of technology transfer to foreign affiliates: (i) documentation in the form of manuals and specifications produced for specific purposes or through regular reporting from the parent company, (ii) instruction programs, i.e formal education and on-the-job training, (iii) visits and exchanges of technical personnel, (iv) development and transfer of specialized equipment to be used in the affiliate, and (v) continuous oral and written communication. To these points, the delivery of intermediary and capital goods from parents to affiliates, should be added.

III. Econometric specification

In this section, I derive the econometric model to test for the existence and economic impact of technology transfer from parent companies to their foreign affiliates. A Cobb-Douglas function is assumed to represent the production technology of foreign affiliate *i* in time *t*,[8]

suggest that affiliate R&D is mainly for adaptation (Håkansson and Nobel 1993).

[7]Regarding the opposite direction of transfer, i.e. from foreign affiliates to parent companies, Mansfield (1984) presents some evidence. However, his analysis was based on a sample of only 15 firms in the Chemical and Petroleum industry in the 1960s. Fors (1996), using the same empirical model as Mansfield, did not find any impact of affiliate R&D on the home operations of Swedish MNEs, using data covering 1965-90.

[8]More correctly, affiliate *ij* of parent company *j*, but subscript *j* is left out for notational convenience.

$$Q_{it}=\phi e^{\lambda t}C_{it}^{\alpha}L_{it}^{\beta}(K_A)_{it}^{\gamma_A}(K_P)_{it}^{\gamma_P}e^{\varepsilon_{it}} \quad , \tag{1}$$

where Q is output, Φ is a fixed effect, λ is the rate of disembodied technical change,[9] C is the stock of physical capital, L is labor input, K_A is the knowledge stock generated by the affiliate's own R&D, and K_P is the corresponding knowledge stock generated by R&D in the parent company. A denotes "affiliate", and P "parent".[10] The knowledge stock of P is explicitly included in A's production function as an input factor, since it is expected that knowledge is transferred from P to A. The parameters α, β, γ_A and γ_P are the elasticities relating to the four input factors, and ε is a random error term. Rewriting (1) in log form, and taking first differences, we obtain,

$$\Delta q_{it}=\lambda+\alpha\Delta c_{it}+\beta\Delta l_{it}+\gamma_A\Delta(k_A)_{it}+\gamma_P\Delta(k_P)_{it}+\Delta\varepsilon_{it} \quad , \tag{2}$$

with lower case letters denoting logs, and where

$$\Delta(k_s)_{it}=(k_s)_{it}-(k_s)_{it-1}=\log\left(\frac{(K_s)_{it}}{(K_s)_{it-1}}\right), \quad s=A,\, P \quad ,$$

which is approximately equal to $(K_{it}-K_{it-1})/K_{it-1}$ or $\Delta K/K_{it-1}$. As seen from (2) above, first differencing removes the time invariant fixed effect Φ.

Since data on knowledge stocks, K, are not available, and due to the problems associated with the construction of a reliable knowledge stock from flow data (Griliches 1979), the production function is transformed to enable utilization of data on R&D

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[9]Since this model is an attempt to explain part of the "Solow residual" by means of R&D, λ measures the R&D-corrected Solow residual.

[10]In the empirical analysis "parent" corresponds to the total operations in the home country of a MNE, i.e. the sum of parent company and other companies controlled by a MNE located in Sweden.

expenditures. The terms containing k_A and k_P in (2) are rewritten in the following way:

$$\gamma_s \Delta k_s = \left(\frac{\partial Q}{\partial K_s}\frac{K_s}{Q}\right)\Delta k_s \approx \left(\frac{\partial Q}{\partial K_s}\frac{K_s}{Q}\right)\left(\frac{\Delta K_s}{K_s}\right) \approx \left(\frac{\partial Q}{\partial K_s}\right)\left(\frac{R_s}{Q}\right) \equiv \varrho_s\left(\frac{R_s}{Q}\right), \quad s{=}A, P \ ,$$

where R is the R&D expenditures in a year, R/Q is the corresponding R&D intensity that year and ϱ is the rate of return (or marginal productivity) of knowledge capital. Subscripts are left out for notational simplicity. Hence, it is assumed that the depreciation of K is negligible, and that R approximates the flow ΔK. The approach follows that of Griliches (1980).[11] The R&D intensity is considered in *t-1* as suggested by e.g. Scherer (1982), i.e. at the beginning of the period Δ, *[(t-1)-t]*. Moving from a stock, *K,* to a flow, *R,* measure of knowledge in the production function, we can rewrite (2) to

$$\Delta q_{it} = \lambda + \alpha \Delta c_{it} + \beta \Delta l_{it} + \varrho_A \left(\frac{R_A}{Q}\right)_{it-1} + \varrho_P \left(\frac{R_P}{Q}\right)_{it-1} + \eta_{it} \ , \qquad \textbf{(3)}$$

where ϱ_A and ϱ_P are the rates of return of affiliate R&D and parent company R&D in the foreign affiliates' production function, respectively, and η_{it} is the new random error term.

It should be noted that since K_P is taken to be exogenously given to the affiliate the interpretation of ϱ_P differs from that of ϱ_A; while ϱ_A measures the effect on affiliate output from an increase in affiliate R&D, ϱ_P measures the effect on affiliate output from a change in parent company R&D. The latter change, which is not explicitly modelled here, is determined from a (global) parent company maximization problem, across all operations, both foreign and domestic. Hence, K_P is a choice variable of the parent company, and not of an individual foreign affiliate.

The rates of return are interpreted as net of costs (Griliches 1980). In the case of ϱ_A,

[11]See Mairesse and Sassenou (1991) for a survey of firm-level studies using this method.

the major part of the costs of the affiliates' own R&D is already accounted for in the capital and labor input measures in the production function.[12] In the case of ϱ_P, the costs of parent R&D are mainly borne by the parent, and only to a limited extent by an individual affiliate. License fees and other explicit payments for the use of parent technology by affiliates are either negligible or zero in the Swedish firms. The extent to which the parents implicitly charge affiliates for the use of technology through e.g. transfer pricing and other intra-firm payments is not possible to evaluate using the present data.

Using the common expression of total factor productivity, $DTFP=\Delta q-\alpha\Delta c-\beta\Delta l$, and assuming constant returns to scale with respect to physical capital and labor ($\alpha+\beta=1$), allows reformulation of (3) in terms of growth in total factor productivity,[13]

$$DTFP_{it}=\lambda+\varrho_A\left(\frac{R_A}{Q}\right)_{it-1}+\varrho_P\left(\frac{R_P}{Q}\right)_{it-1}+\eta_{it}\ . \qquad \textbf{(4)}$$

A similar specification was used by Mansfield (1984), to study technology flows from affiliates to parents.

Since the data only contain information on affiliate R&D for certain periods, we consider a version of (4) excluding affiliate R&D as the main equation in the empirical analysis. The focus of the present paper is technology transfer from parent to affiliate, i.e. estimation of ϱ_P. Omission of affiliate R&D does, of course, introduce a bias in the estimations, but since less than 20% of all affiliates recorded any R&D (1965-74), this should not be a major problem. A smaller sample (including two periods covering 1965-74), with

[12]It was not possible to separate out the share of capital and labor input that was attributed to R&D in the Swedish MNEs. The resulting "double counting" of the inputs related to R&D does not pose a serious problem, as long as the rate of return is interpreted as net of costs (Schankerman 1981).

[13]Since most of the cost of affiliate R&D is already included in the physical capital and labor measures, and the parent R&D is treated as external to an individual affiliate, it is appropriate to assume constant returns with respect to physical capital and labor.

data on both parent R&D and affiliate R&D, is also analyzed.

Estimations are undertaken by ordinary least squares regression analysis. Additive dummy variables are included to take account of differences in the *DTFP* level over the four periods, different manufacturing industries, and country of location of the affiliate. A description of the variables and their definitions is provided in Table 1.

IV. Data

The data material has been collected by The Industrial Institute for Economic and Social Research (IUI), Sweden, for the years 1965, 1970, 1974, 1978, 1986 and 1990, and is a full sample of all Swedish firms in the manufacturing sector with more than 50 employees and with at least one majority-owned production affiliate abroad. The response frequency to the survey has exceeded 90% each year. This means that virtually all Swedish manufacturing firms investing abroad are covered. See Andersson *et al.* (1996) for a detailed description of the data material.

In this study, data on 567 foreign, majority-owned affiliates (corresponding to 116 Swedish parent companies) were pooled over four separate periods: 1965-70, 1970-74, 1974-78 and 1986-90. The fact that the periods are not of equal length is adjusted for by defining *DTFP* as average annual growth rate. No survey was undertaken in the early 1980s, implying that there is a gap in the time series, using a period length of 4-5 years.

Pooling the data over the four periods generated a cross-section time-series sample of 1015 observations. Of the 567 separate affiliates considered, 36 were observed in all four periods, 120 in three periods, 100 in two periods, and 311 affiliates in one period.[14] A smaller

[14]The 1015 observation were distributed across time periods as follows: *1965-70* (20%), *1970-74* (26%), *1974-78* (29%) and *1986-90* (25%).

TABLE 1. DESCRIPTION OF VARIABLES

Variable name	*Description*
DTFP	Average annual growth rate over the period Δ (i.e. *t-1* to *t*) in total factor productivity (log form) for the foreign affiliate, calculated as follows: $DTFP = \Delta q - a\Delta c - b\Delta l$, where Δq, Δc and Δl are average annual growth rates (log form) of value-added (wages+operating income before depreciation and financial items), physical capital (book value of equipment, machinery and property), and labor input (average number of employees). Δq and Δc are expressed in 1990 SEK by use of Swedish producer price and capital price indices by industries as below. b is the calculated labor coefficient (wage share in value-added, average of *t-1* and *t*), and a is the coefficient for physical capital calculated as $a=1-b$.
R_P/Q	R&D-intensity in the foreign affiliate with respect to parent R&D, in the beginning of the period Δ (in *t-1*), calculated as parent R&D-expenditures divided by affiliate value-added. R&D and value-added are expressed in nominal SEK.
R_A/Q	R&D-intensity in the foreign affiliate with respect to the affiliate's own R&D, in the beginning of the period Δ (in *t-1*), calculated as affiliate R&D-expenditures divided by affiliate value-added. Only available for 1965-70 and 1970-74. R&D and value-added are expressed in nominal SEK.
$R_P/Q{*}R_A/Q$	Interaction term between parent R&D and affiliate R&D (see above descriptions on each R&D measure). Only available for 1965-70 and 1970-74.
$\theta R_P/Q$	Variable for R&D generated knowledge embodied in intermediary goods deliveries from parent to affiliates. θ is defined as the value of intermediary goods deliveries from the parent divided by affiliate sales, and R_P/Q as above. The components in θ are expressed in nominal SEK.
Industry dummies	Food,beverages & tobacco Textiles, clothing & leather Pulp & paper Paper products & printing Chemicals Iron & steel Metal products Non-electrical machinery Electrical machinery Transport equipment
Period dummies	1965-70 1970-74 1974-78 1986-90 (reference period)
Country dummies	Country of location of the affiliate. 26 different country dummies
	Sources: All data from the IUI-data base on Swedish multinationals, except for producer price indices and physical capital price indices, which are taken from Statistics Sweden (1991).

sample of 449 observations covering the two first periods is also analyzed, as these periods contain data on affiliate R&D.[15] Since more than half of the affiliates are only observed during one period, and few affiliates are observed in all four periods, I do not take into account of the partial panel characteristic of the data. In addition, the use of 4-5-year averages in the dependent variable reduces the risk that affiliates' residuals are correlated over time.

We assume that the R&D intensity at the beginning of a period has an effect on the annual average growth rate of *TFP* over a 4-5 year-period. For example, the R&D intensity in 1965 is related to *DTFP* over 1965-70. This lag structure is consistent with earlier econometric studies on industrial R&D. Branch (1974) found that the effect of R&D on productivity peaked after two years, which is roughly in the middle of the period length used in the present paper. Ravenscraft and Scherer (1982) suggest 4-6 years when analyzing R&D and profits.[16]

The 1015 observations were distributed across ten different manufacturing industries and one residual group as follows: Food,beverages & tobacco (1%), Textiles, clothing & leather (2%), Pulp & paper (3%), Paper products & printing (6%), Chemicals (20%), Iron & steel (0.3%), Metal products (23%), Non-electrical machinery (22%), Electrical machinery (14%), Transport equipment (4%), and other industries (7%).

DTFP (and its underlying variables) are expressed in 1990 SEK, by use of producer price indices and capital indices, respectively, for the different manufacturing industries included (taken from Statistics Sweden, 1991). R&D intensities are expressed in nominal

[15]In the smaller sample, data on 294 different affiliates (corresponding to 73 different parents) are included, of which 155 affiliates were observed in two periods and 139 in one period.

[16]It can be discussed whether the lag should be longer for international technology transfer within MNEs, compared with the effect of a firm's domestic R&D on its domestic productivity. Mansfield and Romeo (1980) found that new technologies were transferred to foreign affiliates around six years after they were introduced at home. However, as firms' R&D intensities generally exhibit slow shifts over time, the exact lag adopted should not alter the results dramatically.

SEK. Descriptive statistics for the data are provided in Tables A1 and A2 in the Appendix.

V. Empirical results

From Table 2 we notice that the estimated parameter for parent R&D in the affiliate, ϱ_P, is positive and significantly different from zero at the 1% level, using a two tailed t-test. Hence, there is a positive association between lagged parent R&D and growth in total factor productivity in the affiliates. According to the framework adopted in the present paper, this suggests that technology is transferred from parent companies to foreign affiliates. This finding supports the transaction cost theory of the multinational enterprise, which says that MNEs will utilize intangible assets in foreign affiliates.

In the table we also report the results from the analysis of a number of sub-samples. First, we distinguish between *product-* and *process*-related R&D, proxied by the affiliates' industry classification.[17] The estimated parameter for the product group is positive and significant, while this is not the case for the process group. This is in line with Mansfield (1984), who found that firms in process industries are more hesitant to transfer technology to foreign affiliates as compared with firms in product industries. He argues that once process technologies are diffused to foreign countries, it is difficult to determine whether foreign competitors are illegally imitating them. However, when an interaction dummy variable is included in the overall sample, *no significant difference* between ϱ_P in the product and process

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[17]*Product industries* is here defined to comprise the following industries: Pharmaceutical, Metal products, Non-electrical machinery, Electrical machinery and Transport equipment. *Process industries* here comprises: Food, beverages & tobacco, Textiles, clothing & leather, Pulp & paper, Paper products & printing, Chemicals (excluding Pharmaceutical), and Iron & steel.

To analyze the difference between product- and process-related R&D, it would be preferable to have the R&D-data reported by these two categories. Since this kind of data is not available, I use industry classification as a proxy. For example, in a product industry such as electrical machinery there is of course both product- and process-R&D taking place. On average it is, however, likely that a larger share of R&D in a product industry is geared towards product innovations.

TABLE 2. REGRESSION RESULTS. POOLED DATA 1965-90
DEPENDENT VARIABLE: *DTFP* IN FOREIGN AFFILIATES

Regression (a)	*Parameter estimate for* R_p/Q	*Adj.* R^2
Overall sample (b) *(n=1015)*	1.46 E-4*** (3.73 E-5)	0.051
Product industries (c) *(n=537)*	1.23 E-4*** (3.31 E-5)	0.020
Process industries (d) *(n=478)*	6.10 E-4 (4.00 E-4)	0.041
Affiliates located in industrial countries *(n=828)*	7.91 E-4*** (1.65 E-4)	0.029
Affiliates located in developing countries *(n=187)*	1.23 E-4*** (3.61 E-5)	0.069
"New" affiliates (age 10 years or less in t-1) *(n=461)*	1.02 E-3*** (1.71 E-4)	0.067
"Old" affiliates (age more than 10 years in t-1) *(n=554)*	9.50 E-5*** (3.15 E-5)	0.026

Note: ***, ** and * indicate significance at the 1, 5 and 10% level, respectively, using a two tailed t-test. Standard errors in parentheses. Means of variables are provided in Table A1. in the Appendix.
(a): The intercept is allowed to vary across industries and time in all regressions, by inclusion of industry dummies and period dummies (see Table 1). The results are not reported here, but available on request.
(b): For the overall sample, the intercept is also allowed to vary across country of location (26 dummies), in addition to industry and time, see (a) above. Inclusion of country dummies, does not alter the results with respect to R_p/Q. It only raises the adj. R^2, compared with the same regression with industry and time dummies, where adj. R^2=0.020.
(c): *Product industries*: Pharmaceutical, Metal products, Non-electrical machinery, Electrical machinery, and Transport equipment.
(d): *Process industries*: Food, beverages & tobacco, Textiles, clothing & leather, Pulp & paper, Paper products & printing, Chemicals (excluding Pharmaceutical), and Iron & steel.

group can be discerned. More detailed research on the differences between product- and process-related R&D is needed to draw any further conclusions.

Separate regressions of the other sub-samples, affiliates located in industrial and developing countries, and "new" and "old" affiliates, all produce positive and significant results with respect to ϱ_P. To evaluate possible differences between the categories of affiliates, interaction dummy variables are included in the overall sample. The results indicate that ϱ_P is *significantly lower* for affiliates located in developing countries compared with those in industrial countries, and that ϱ_P is *significantly lower* in "old" affiliates relative to "new" ones. These categories are discussed further in the next sub-section.

Calculations of DTFP effects

The estimates of ϱ_P obtained by regression of the separate sub-samples, or with interaction dummies applied to the overall sample, only yield limited information about the economic impact of technology transfer in the different categories of affiliates. One reason is that the levels of the means of R_P/Q vary considerably between the sub-samples, *ceteris paribus* influencing the values of the estimated parameters (see Table A1. in Appendix).[18]

To examine differences between the categories regarding the impact of technology transfer on affiliate *DTFP*, we undertake numerical calculations around estimated parameter values and corresponding variable means. The percentage point impact on affiliate *DTFP* of the transfer is calculated as $\varrho_P * R_P/Q$. The results are provided in Table 3. For the overall sample, it is first noted that 0.21 *percentage points* of *DTFP* in the affiliates are attributed to

[18]The "low" estimates in Table 2 for ϱ_P are partly due to the high values (by definition) of the corresponding variables, R_P/Q, which relates to a MNE's overall Swedish R&D divided by the value-added of an individual foreign affiliate.

technology transfer from the parent.[19]

The calculations indicate that technology transfer appears to have a larger effect on *DTFP* in affiliates located in industrial countries compared with those in developing countries. It is possible that more advanced technologies (with higher *DTFP* effects) are transferred to affiliates in industrial countries. On this point, Blomström and Kokko (1995) find that MNEs undertake more intra-firm technology transfer to host countries with a higher educational level.

Turning to the results on "new" and "old" affiliates, where "new" refers to affiliates established between 1 and 10 years ago, and "old" to affiliates established more than 10 years ago,[20] it seems that technology transfer is substantially more important for the newly established affiliates. This suggests that affiliates may become more self reliant in terms of technology over time, which is in line with the results in Teece (1977), indicating that technology transfer from the parent is most important in the start-up phase.[21] Almost 1.4 *percentage points* of the mean *DTFP* in the "new" group are attributed to technology transfer.

Effects of affiliate R&D

The results from estimations of the smaller sample of pooled data for the two periods 1965-70 and 1970-74, containing information on affiliate R&D, are shown in Table 4. First, the parameter for technology transfer, ϱ_P, is positive and significant, as in the above analysis

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[19]No calculations are made for the product and process groups, as the result for the process group was not significant.

[20]Measured in *t-1*, i.e. at the beginning of the period analyzed. 10 years was chosen rather arbitrarily to divide the overall sample roughly in half. It is plausible that an affiliate that has operated for more than ten years has entered a more mature stage. The results with respect to "new" and "old" are not sensitive to the exact age limit adopted: e.g. a limit ranging between 8-12 years produces similar results.

[21]Separate treatment of new and old affiliates in industrial and developing countries, respectively, indicate that affiliates in developing countries remain dependent of parent technology over time.

TABLE 3. NUMERICAL CALCULATIONS: EFFECT OF TECHNOLOGY TRANSFER ON AFFILIATE *DTFP*

Regression	*Mean of affiliate DTFP, percent* (a)	*Percentage points of affiliate DTFP attributed to technology transfer from parent* (b)
Overall sample	4.08	0.21
Industrial countries	4.31	0.68
Developing countries	3.07	0.50
"New" affiliates	5.94	1.36
"Old" affiliates	2.53	0.15

Notes:
(a): Average annual growth rate (log form) in total factor productivity Pooled data 1965-90 (see Table 1 for the included years).
(b): calculated with the estimated parameters and mean values of the corresponding variables as $\varrho_P * R_P / Q$. Based on the estimations shown in Table 2.

of the overall sample. Second, we observe that the estimated rate of return on the affiliates' own R&D, ϱ_A, is not significant. Regressions on the same sub-samples as shown in Table 2 do not produce any significant results either. This applies as well to a separate regression of affiliates recording R&D.[22]

Above we noted that R&D in affiliates is largely aimed at adapting the parent's technology. Teece (1977) found that affiliate R&D seems to increase the "receiver competence" of parent technology. Cohen and Levinthal (1989), present empirical evidence suggesting that R&D for "learning" is generally important in order to absorb external technology. To test if affiliate R&D facilitates technology transfer to foreign affiliates, we employ an alternative specification of equation (4). The parameter measuring technology transfer, ϱ_P, is assumed to be a function of the R&D intensity in the foreign affiliate, according to[23]

$$\varrho_P \equiv \varrho_{P0} + \varrho_{P1}\left(\frac{R_A}{Q}\right) .$$

Inserting this expression into equation (4) yields

$$DTFP_{it} = \lambda + \varrho_A\left(\frac{R_A}{Q}\right)_{it-1} + \left[\varrho_{P0} + \varrho_{P1}\left(\frac{R_A}{Q}\right)\right]\left(\frac{R_P}{Q}\right)_{it-1} + \eta_{it} \ , \qquad \textbf{(5)}$$

where ϱ_{P0} is the parameter for the "constant" technology transfer (unrelated to affiliate R&D), and ϱ_{P1} the parameter for the interactive effect between affiliate R&D and parent R&D. The

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[22]The lack of effect of affiliate R&D may be attributed to the fact that only older data is considered. Fors (1996), analyzing the aggregate foreign operations of Swedish MNEs, using 1965-90 data, finds that parent as well as affiliate R&D had a positive and significant impact on productivity in foreign operations. Since R&D in affiliates of Swedish MNEs appears to have shifted to more advanced activities in more recent times (Norgren 1992), it is possible that analysis of newer data would have generated different results.

[23]Jaffe (1986) used a similar specification analyzing the interaction between firm's own R&D and spillovers from other firms in an industry.

results from selected regressions shown in Table 4, indicate that affiliate R&D appears to facilitate technology transfer to affiliates in the case of process industries. The estimated parameter for the interactive effect, ϱ_{P1}, is positive and significant at the 5% level. At the same time ϱ_{P0} is not significant in process industries. No interactive effect is found for the overall sample or for product industries.

Hence, in process industries, "receiver competence" may be a prerequisite in order to utilize technology from the parent. This finding suggests that the introduction of new process technologies requires a higher level of competence in the affiliate. It is plausible that the introduction of a new process technology in a foreign affiliate is a more complex task compared with the introduction of a new product variety.

Embodied technology transfer

Finally, I turn to the issue of whether technology is embodied in intermediary goods delivered from parent companies to affiliates.[24] Coe and Helpman (1995) find that international R&D spillovers are positively related to trade flows between countries. In a study of US manufacturing industries, Scherer (1982) presents evidence that R&D spillovers between industries are associated with the transactions of intermediaries.

To examine the hypothesis of embodied technology transfer, the variable for parent R&D in the affiliate's production function is rewritten so that technology transfer is proportional to intermediary-good deliveries from the parent. The new variable in equation (4), replacing R_P/Q, is $\theta R_P/Q$, where θ is defined as the value of intermediary-good deliveries

[24] It would have been desirable to also use deliveries of capital goods from parents to affiliates, since technology can be embodied in capital goods as well. Blomström and Kokko (1995) used the flow of capital goods as one proxy for technology transfer.

TABLE 4. REGRESSION RESULTS. POOLED DATA 1965-74
DEPENDENT VARIABLE: *DTFP* IN FOREIGN AFFILIATES

Regression (a)		*Parameter estimate for*			*Adj.* R^2
		R_P/Q	R_A/Q	$R_P/Q*R_A/Q$	
Overall sample (n=449)	*(i)*	9.60 E-4*** (3.15 E-4)	0.0565 (0.153)	--	0.025
	(ii)	9.28 E-4*** (3.14 E-4)	--	0.0177 (0.0129)	0.029
	(iii)	--	0.0244 (0.154)	--	0.0070
	(iv)	--	--	0.0198 (0.0130)	0.012
Process ind (b) *(n=231)*	*(i)*	-9.08 E-5 (6.69 E-4)	0.287 (0.260)	--	0.020
	(ii)	-2.46 E-4 (6.66 E-4)	--	0.0571** (0.0253)	0.037
	(iii)	--	0.288 (0.260)	--	0.024
	(iv)	--	--	0.0562** (0.0251)	0.041

Note: ***, ** and * indicate significance at the 1, 5 and 10% level, respectively, using a two tailed t-test. Standard errors in parentheses. Means of variables are provided in Table A2. in the Appendix. Only selected regression results are reported. It was not possible to include R_A/Q and $R_P/Q*R_A/Q$ in the same regression, since the two variables were highly correlated. Notice that neither R_P/Q and R_A/Q, nor R_P/Q and $R_P/Q*R_A/Q$, were significantly correlated in the overall sample or the process ind. group.
(a): The intercept is allowed to vary across industries and time in all regressions, by inclusion of industry dummies and period dummies (see Table 1). The results are not reported here, but available on request.
(b): See Table 2. No significant results were obtained with R_A/Q or $R_P/Q*R_A/Q$ in the product ind. group. The parameter for R_P/Q was significant in the product ind. group at the 1% level.

from the parent divided by affiliate sales.[25] The ratio θ can also be interpreted as an affiliate's degree of forward vertical integration. We expect technology transfer to be of particular importance if an affiliate is highly integrated in the production system of a MNE.

The estimation results from the analysis of embodied transfer are provided in Table 5.[26] For the overall sample the result with regard to $\theta R_p/Q$ is positive, but only significant at the 10% level. Separate regressions on different categories of affiliates, indicate that the delivery of intermediary goods to affiliates located in developing countries is associated with technology transfer, while this appears not to be the case for affiliates in industrial countries. A possible explanation is that MNEs need to deliver more advanced intermediaries (embodying technology) from the home base to affiliates in developing countries, since such intermediaries are not available from local suppliers. Export of intermediary goods may therefore be one vehicle of technology transfer to developing countries. Comparing the new and old affiliates, we notice that embodied transfer is only significant for newly established affiliates, strengthening the earlier finding on the role of affiliate age.

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[25] A similar specification was used in the study by Coe and Helpman (1995). They related national imports to GDP, and multiplied the R&D variable with this import share.

[26] Since there are some missing values of θ, these estimations are based on slightly smaller samples, compared with the results presented in Table 2. The analysis utilizes data from all four periods, implying that affiliate R&D is not included in the estimations.

TABLE 5. REGRESSION RESULTS EMBODIED TECHNOLOGY TRANSFER
DEPENDENT VARIABLE: *DTFP* IN FOREIGN AFFILIATES

Regression (a)	*Parameter estimate for* $\theta R_P/Q$ (b)	*Adj.* R^2
Overall sample *(n=986)*	8.89 E-4* (4.81 E-4)	0.0095
Affiliates located in industrial countries *(n=799)*	4.67 E-4 (1.34 E-3)	0.0020
Affiliates located in developing countries *(n=187)*	1.30 E-3** (5.55 E-4)	0.037
"New" affiliates (age 10 years or less in t-1) *(n=449)*	3.06 E-3** (1.38 E-4)	0.0033
"Old" affiliates (age more than 10 years in t-1) *(n=537)*	6.02 E-4 (4.77 E-4)	0.015

Note: ***, ** and * indicate significance at the 1, 5 and 10% level, respectively, using a two tailed t-test. Standard errors in parentheses. Means of variables are provided in Table A3. in the Appendix. Only selected regression results are reported.
(a): The intercept is allowed to vary across industries and time in all regressions, by inclusion of industry dummies and period dummies (see Table 1). The results are not reported here, but available on request.
(b): When θ was included in the estimations on its own or together with $\theta R_P/Q$, the parameter for θ did not turn out significant, and did not alter the basic results.

VI. Concluding remarks

Analysis of Swedish multinational enterprises suggests that R&D-generated knowledge is transferred from parent companies to foreign affiliates. This finding supports the view that MNEs utilize intangible assets, created at home, in foreign plants. Technology transfer appears to have a larger impact on newly established affiliates. This may imply that affiliates become more self reliant in terms of technology over time. For foreign affiliates in process industries, R&D undertaken in the affiliates seems to facilitate technology transfer, suggesting that "receiver competence" may be crucial in order to make productive use of the parent's technology. Moreover, the findings indicate that knowledge is "embodied" in intermediary-good deliveries from the parent, especially in the case of affiliates located in developing countries.

Since the results on the whole suggest that technology transfer in MNEs does take place, it should be relevant to incorporate intra-firm transfer in the study of international technology transfer in a broader sense. As this paper has analyzed the effects at the firm level, future research in the area would include an assessment of the effects of intra-firm technology transfer on host countries. It is plausible that foreign affiliates are important links between MNEs and the local host economy, with respect to international R&D spillovers, for example.

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Appendix

TABLE A1. MEANS OF VARIABLES. POOLED DATA 1965-90
OVERALL SAMPLE AND DIFFERENT SUB-SAMPLES

Sample	*DTFP*	R_P/Q
Overall sample *(n=1015)*	0.041 (0.13)	14.6 (123.4)
Product industries *(n=537)*	0.037 (0.13)	21.7 (168.8)
Process industries *(n=478)*	0.054 (0.14)	6.51 (15.5)
Affiliates located in industrial countries *(n=828)*	0.043 (0.13)	8.61 (27.7)
Affiliates located in developing countries *(n=187)*	0.031 (0.13)	40.9 (280.6)
"New" affiliates (age 10 years or less in t-1) *(n=461)*	0.059 (0.14)	13.3 (38.8)
"Old" affiliates (age more than 10 years in t-1) *(n=554)*	0.025 (0.12)	15.6 (163.3)

Note: Standard deviations in parentheses

TABLE A2. MEANS OF VARIABLES. POOLED DATA 1965-74
OVERALL SAMPLE AND PROCESS INDUSTRY

Sample	*DTFP*	R_P/Q	R_A/Q	$R_P/Q*R_A/Q$
Overall sample *(n=449)*	0.046 (0.13)	7.67 (18.9)	0.012 (0.040)	0.069 (0.47)
Process ind. *(n=231)*	0.050 (0.14)	6.30 (13.8)	0.0076 (0.036)	0.042 (0.36)

Note: Standard deviations in parentheses.

TABLE A3. MEANS OF VARIABLES. POOLED DATA 1965-90. REGRESSION FOR EMBODIED TECHNOLOGY TRANSFER OVERALL SAMPLE AND SELECTED SUB-SAMPLES

Sample	*DTFP*	$\theta R_f/Q$	θ
Overall sample *(n=986)*	0.041 (0.13)	1.24 (9.03)	0.078
Industrial countries *(n=799)*	0.044 (0.13)	0.73 (3.50)	0.080
Developing countries *(n=187)*	0.031 (0.13)	3.41 (19.32)	0.071
"New" affiliates *(n=449)*	0.060 (0.14)	1.21 (5.03)	0.094
"Old" affiliates *(n=537)*	0.026 (0.12)	1.26 (11.34)	0.065

Notes: Standard deviations in parentheses.