A list of Working Papers on the last pages

No. 370, 1993

TECHNOLOGY TRANSFER TO FOREIGN MANUFACTURING AFFILIATES BY MULTINATIONAL FIRMS

by

Gunnar Fors

This is a preliminary paper. Quotation only with permission of the author. Comments are welcome.

March 1993

Technology Transfer to Foreign Manufacturing Affiliates by Multinational Firms

Gunnar Fors*

The Industrial Institute for Economic and Social Research (IUI)
Box 5501, 114 85 Stockholm, Sweden

Abstract: Technology transfer *from* the parent company of a multinational firm *to* its foreign manufacturing affiliates, is analyzed using unique micro data on Swedish multinationals 1965-1990. Econometric analysis produces strong evidence that; (1) technology transfer from the parent does occur, and this transfer adds on average approximately one percentage point to the annual growth rate in affiliate value added (for the period 1965-90 the annual growth rate in real value added increases from 7.1% to 8.1% when taking the transfer into account), (2) R&D undertaken in the affiliates exerts a positive influence on the transfer, by upgrading the affiliates' "receiver competence" of the parent company's technology, (3) the affiliates' degree of vertical integration in relation to their parent, forward or backward, has a positive effect on the transfer, and (4) more technology is transferred to new affiliates compared to old ones.

*The author wishes to thank Roger Svensson, IUI, for computer work and valuable comments regarding econometric issues. I am also indebted to Thomas Andersson, Erik Mellander, IUI, and seminar participants at IUI, for helpful suggestions. Financial support from the Nordic Economic Research Council is gratefully acknowledged.

1. Introduction

Research and Development (R&D) is generally considered as one of the most important factors for long run technological development and economic growth. Multinational firms (MNF) today perform the major part of total industrial R&D, and they are also the leading actors in the international diffusion and transfer of technology. In many cases, R&D is performed *both* in MNFs' headquarters and in their foreign affiliates, increasing the technological knowledge in the MNFs' domestic and foreign parts, respectively. The data set utilized in the present paper indicates that around 15% of total R&D in Swedish MNF's was performed abroad during the 1970's up to the mid 1980's, with the figure increasing to 17% in 1990 (IUI, 1991).

The R&D generated knowledge is applied in production throughout the MNF, as it is transferred between different units and countries. Previous studies on technology transfer by MNFs (c.f. Mansfield and Romeo 1980) have pointed out that the direction of transfers is mainly *from* the parent company (domestic part) *to* its foreign affiliates, which could be of concern for the MNF's home country[1]. Moreover, the cost of transferring R&D generated knowledge is a large fraction of the R&D expenditure itself (Teece 1977).

The prime reason for this one way transfer is probably that the R&D performed in the headquarter is of a more basic kind and generally more applicable, as compared with that in the affiliates. Descriptive data from the IUI MNF-database (IUI 1991) indicate that of the parent company's R&D expenditures for the year 1978, on average 11% was "R&D for long term (basic)", 45% was "R&D for new products/processes" and 44% "R&D for improvement of existing products/processes". The corresponding figures for the average R&D performing affiliate was 2%, 40% and 58% respectively. The R&D undertaken in affiliates is thus more oriented towards development and aims at increasing the affiliate's "receiver competence" of external technology. The importance of R&D as "learning" has been analyzed more generally by Cohen and Levinthal (1989), the concept of "receiver competence" is discussed by Eliasson (1990). Teece (1977) views the R&D activities in affiliates merely as one of the costs

---

[1] Statistical analysis of a possible technology transfer from the foreign affiliates to the domestic part of the MNF has been undertaken by the author, utilizing the same data material as in this paper. No transfer at all was found in that direction. Analysis of transfers between different foreign affiliates belonging to the same MNF has also been done, with preliminary results indicating no such transfers.

associated with transferring technology abroad, implying that knowledge obtained through the affiliate's own R&D activities, is essential in order to draw on the headquarters accumulated technological knowledge stock.

It is also pointed out in the literature that a large fraction of MNFs' overall technology transfer, as compared with licensing for example, is undertaken via majority owned affiliates. Caves (1982), among others, addresses the problems involved in arm's length transactions of knowledge. Between 50 and 60% of the license revenues in Swedish MNFs come from foreign affiliates, indicating that a large fraction of the total transfer is conducted within the MNF (IUI, 1991), especially when considering that probably only a small part of the transfers are tied to license payments.

This paper models and estimates technology transfer from the parent company (domestic part) of a MNF to its foreign manufacturing affiliates, utilizing unique micro data on Swedish multinationals 1965-90. Analysis is undertaken regarding how an affiliate's own R&D, its degree of vertical integration and its age influence technology transfer from its parent. There exists limited empirical evidence on the presence and determinants of intra-firm technology transfer. Earlier empirical attempts to address these issues have mainly been smaller scale surveys based on interviews of R&D executives, e.g. Teece (1977) investigates the costs of intra-firm transfers. The present paper utilizes econometric methods for productivity growth analysis and considers samples with almost 900 affiliates. Section 2 presents a simple theoretical framework and section 3 derives the econometric model. The data is described in section 4 and the results presented in section 5. Section 6 concludes.

2. Theoretical framework

The focus of analysis is majority owned foreign manufacturing affiliates (denoted A), which produce according to,

$$Q = F(C, L, K_A, K_M) \tag{1}$$

where F is the production function, Q output, C physical capital stock, L labor input, K_A and K_M the technological knowledge stocks of the affiliate and the parent company (denoted M), emanating from accumulated R&D expenditures in A and M respectively. Since the stocks K_A and K_M are not considered homogenous, as pointed out in the introduction, these stocks are not aggregated into a total technological knowledge stock, as done in e.g. Bernstein and Nadiri (1989) analyzing intra-industry spillovers. The knowledge stock of M (i.e. the parent company of the MNF) is thus explicitly included in A's production function (1), since it is expected that knowledge is transferred from M to A and that this knowledge is a factor of production in the affiliate. The function G below is defined in order to empirically investigate the determinants of the technology transfer from M to A;

$$TechnologyTransfer \equiv G\left[\left(\frac{R_A}{Q}\right), V_F, V_B, T\right] \tag{2}$$

It is hypothesized that the technology transfer is positively influenced by A's own R&D intensity (R_A/Q), implying that the affiliate's absorption of knowledge from its parent company increases with its own R&D (i.e. increases the affiliate's "receiver competence"). The affiliates' degree of vertical integration in relation to M is also hypothesized to affect the transfer in a positive way. If the affiliate is vertically integrated *forward* in production (denoted V_F), meaning that the affiliate processes input materials delivered from M, the R&D generated knowledge from M will be "embodied" in the inputs that M delivers to A. If the affiliate instead is vertically integrated *backward* (denoted V_B), meaning that A is a subcontractor to M delivering inputs to its parent, M may specify the inputs, send "blueprints" and engineers to A, in order to assure that the right inputs of the required quality are produced. In both cases the parent company "shares" its technological knowledge stock with the affiliate.

Teece (1977), among others, suggests that the technology transfer from M to A is most important when the manufacturing affiliate is new. This implies that the age of the affiliate (denoted T) would exert a negative impact (at a decreasing rate) on the transfer from M. Affiliates will thus over time become more self-reliant in terms of technological knowledge, and become more independent from their parents.

3. Econometric model

A four factor Cobb-Douglas production function characterizes the technology of the foreign affiliate i in time t,

$$Q_{it}=\phi e^{\lambda t}C_{it}^{\alpha}L_{it}^{\beta}(K_A)_{it}^{\gamma_A}(K_M)_{it}^{\gamma_M}e^{\varepsilon_{it}} \tag{3}$$

where Q is the affiliate's production measured as value added (wages+operating profits before depreciation and interest payments/receipts), Φ a constant, λ the disembodied technical change, C the stock of physical capital (book value of equipment, machinery and buildings), L labor (average number of employees during the year in question), K_A the affiliate's knowledge stock generated by R&D activities in the affiliate, K_M defined as above but for the parent company of the MNF that affiliate i belongs to, i.e. the stock generated by R&D performed in the home country of the MNF. α, β, γ_A and γ_M are the elasticities relating to the four factors of production and ε the error term. The analysis in this paper is conducted within MNFs, more specifically the transfer of knowledge from M_j (domestic part of MNF j) to each of its foreign manufacturing affiliates A_{ij}. Subscript j is excluded in the formulas for notational simplicity. Taking logarithms of (3) yields;

$$q_{it}=\varphi+\lambda t+\alpha c_{it}+\beta l_{it}+\gamma_A(k_A)_{it}+\gamma_M(k_M)_{it}+\varepsilon_{it} \tag{4}$$

with lower case letters denoting logs. By differentiating (4) with respect to time we obtain;

$$\Delta q_{it}=\lambda+\alpha\Delta c_{it}+\beta\Delta l_{it}+\gamma_A\Delta(k_A)_{it}+\gamma_M\Delta(k_M)_{it}+\Delta\varepsilon_{it} \tag{5}$$

where for example

$$\Delta q_{it}=q_{it}-q_{it-1}=\log\left(\frac{Q_{it}}{Q_{it-1}}\right) \tag{6}$$

which is practically equal to, for small variances, the rate of growth of Q_{it}, i.e.$[(Q_{it}-Q_{it-1})/Q_{it-1}]$ or $[(\Delta Q)/Q_{it-1}]$, (Mairesse and Sassenou 1991). Since our statistical material does not contain information on knowledge stocks, and due to the obstacles associated with the construction of a reliable knowledge stock measure (Griliches 1979), the production function is transformed to enable utilization of our data on R&D expenditures instead of knowledge stocks. The approach follows that of Terleckkyj (1974) and has been applied by scholars studying the relation between R&D and productivity growth at the firm and industry level, for surveys see Mairesse and Sassenou (1991) and Griliches (1979). Scherer (1982) analyzes flows of R&D generated technology between industries with this method. It should be noted that the econometric methodology applied here has not, to the author's knowledge, previously been used to analyze intra-firm technology transfer. The terms containing k_A and k_M in equation (5) are rewritten in the following way

$$\gamma_s \Delta k_s = \left(\frac{\partial Q}{\partial K_s}\frac{K_s}{Q}\right)\Delta k_s = \left(\frac{\partial Q}{\partial K_s}\frac{K_s}{Q}\right)\left(\frac{\Delta K_s}{K_s}\right) = \left(\frac{\partial Q}{\partial K_s}\right)\left(\frac{R_s}{Q}\right) = \varrho_s\left(\frac{R_s}{Q}\right), \quad s=A,\, M \tag{7}$$

where R is the R&D expenditures in one year, *(R/Q)* the corresponding R&D intensity that year and ϱ the marginal product of R&D, subscripts left out for notational simplicity. Hence, it is assumed that K depreciates only marginally in one year, and that R approximates the flow of ΔK during that year. The R&D intensity is considered in t-1 as suggested by Scherer (1982), i.e. the beginning of Δ which is the period *[(t-1)-(t)]*. The variables Δq, Δk and Δl in equation (5) consider the average yearly growth rate in log form. Moving from a stock *(K)* to a flow *(R)* measure of knowledge in the affiliate's production function, and utilizing (6) and (7), we can rewrite equation (5) to,

$$\Delta q_{it} = \lambda + \alpha\Delta c_{it} + \beta\Delta l_{it} + \varrho_A\left(\frac{R_A}{Q}\right)_{it-1} + \varrho_M\left(\frac{R_M}{Q}\right)_{it-1} + \eta_{it} \tag{8}$$

where ϱ_A and ϱ_M are the marginal products, or rates of returns, of the affiliate's own R&D and the parent company's R&D, respectively. η_{it} is the new error term. A positive and statistically significant ϱ_M is thus an indication that a transfer of knowledge from M to A has occurred. The larger ϱ_M , the larger the transfer, for a given (R_M/Q). In this context ϱ_M can be considered as an indirect measure of technology transfer from the parent company to the affiliate. Rather than considering ϱ_M as a constant and estimate it, as other authors have done in studying firm or industry R&D and productivity (c.f. the survey on firm-level studies by

Mairesse and Sassenou 1991), I here estimate the determinants of the technological knowledge transfer ϱ_M. The following equation, derived from (2) and the theoretical discussion in section 2, models the determinants of the technology transfer,

$$\varrho_M \equiv \varrho_{M0} + \varrho_{M1}\left(\frac{R_A}{Q}\right) + \varrho_{M2}(V_F) + \varrho_{M3}(V_B) + \left[\varrho_{M41}(T) + \varrho_{M42}(T)^2\right] \tag{9}$$

where ϱ_{M0} is a constant and (R_A/Q) defined as above. V_F denotes the affiliate's degree of forward vertical integration in relation to M (measured in t-1 as the ratio of input material deliveries from M to the affiliate in question and Q_A). V_B the affiliate's degree of backward vertical integration relative to M (measured in t-1 as the ratio of deliveries to M and Q_A). The affiliate's age (years) in t-1 is denoted by T, and is modelled both as a first and a second order effect, to take into account the assumed decreasing effect of age on the transfer. Inserting the expression (9) for ϱ_M in equation (8) yields,

$$\Delta q_{it} = \lambda + \alpha \Delta c_{it} + \beta \Delta l_{it} + \varrho_A \left(\frac{R_A}{Q}\right)_{it-1} + \left[\varrho_{M0} + \varrho_{M1}\left(\frac{R_A}{Q}\right)_{it-1} + \varrho_{M2}(V_F)_{it-1} + \varrho_{M3}(V_B)_{it-1} + \left[\varrho_{M41}(T)_{it-1} + \varrho_{M42}(T)^2_{it-1}\right]\right]\left(\frac{R_M}{Q}\right)_{it-1} + \eta_{it} \tag{10}$$

This is the equation to be estimated. ϱ_{M0} is the constant marginal product of R&D performed in the parent company, and ϱ_{M1}, for example, is the parameter for the interaction variable $[(R_A/Q)(R_M/Q)]_{it\text{-}1}$. A simplified version of equation (10) as below, without the affiliate's own R&D, is also estimated (11). Excluding affiliate R&D enables utilization of a larger sample spanning over longer time.

$$\Delta q_{it} = \lambda + \alpha \Delta c_{it} + \beta \Delta l_{it} + \left[\varrho_{M0} + \varrho_{M2}(V_F)_{it-1} + \varrho_{M3}(V_B)_{it-1} + \left[\varrho_{M41}(T)_{it-1} + \varrho_{M42}(T)^2_{it-1}\right]\right]\left(\frac{R_M}{Q}\right)_{it-1} + \eta_{it} \tag{11}$$

Equations (10) and (11) are estimated by ordinary least squares (OLS) regression analysis. The data are pooled and dummy variables included to take into account possible fixed effects of the different time periods analyzed.

4. Data

The confidential dataset used in the estimations has been collected by The Industrial Institute for Economic and Social Research (IUI), Sweden. The survey has been undertaken for the years 1965, 1970, 1974, 1978, 1986 and 1990, and is a full sample of all Swedish MNFs in the manufacturing sector with production abroad, with detailed information regarding foreign manufacturing affiliates. The response frequency to the survey has over the years exceeded 90%. The variables Δq and Δk are deflated to real terms by industry level producer price indices and capital indices respectively (SCB, 1991).

Affiliates belonging to the following industries are included in this study; Chemicals, pulp and paper, paper products and printing, metals, metal fabrication, machinery, electrical and electronic, transport and instruments. The only industries excluded in our analysis from the dataset are textiles and food, see c.f. Branch (1974). These two industries are plausible to exclude since they are under extensive government regulation (e.g. tariff protection) in many countries including Sweden.

Four time periods are considered in the present study; 1965-70, 1970-74, 1974-1978 and 1986-90, i.e. three four year periods and one five year period, labelled periods 1 to 4 respectively. The fact that the periods are not equal, is adjusted for by setting all Δ variables as the average yearly growth rate over the period in question.

The R&D's lag on productivity growth has been discussed at length by a number of authors, i.e. after how many years does R&D expenditures pay off in terms of increased productivity? Probably not immediately as R&D must be considered an investment, and the length of the lag will be longer for basic research compared to development work. The assumption in this paper is that the R&D expenditures in t-4 (or t-5) will have an effect on the yearly average value added growth (Δq) over the period t-4 to t (or t-5 to t). This is consistent with the earlier econometric studies on industrial R&D; e.g. Scherer (1982) investigating R&D expenditures and productivity growth during a five year period and Branch (1974) estimating the lag structure and concluding that effect of R&D on productivity peaked after two years, i.e. in the middle of the period considered in the present paper. Ravenscraft and Scherer (1982) suggest 4-6 years when analyzing R&D and profits. Periods 1 and 2 are pooled and analyzed in (10), which includes variables on affiliate R&D, and data for periods

1 to 4 are utilized in estimating (11). Table 1 below lists the mean values of variables relating to R&D and technology transfer.

Table 1

Mean values	**Periods 1-2** (N=417)	**Periods 1-4** (N=876)
$(R_M/Q)_{t-1}$	7.82	15.30
$(R_A/Q)_{t-1}$	0.013	-------
$(V_F)_{t-1}$	0.35	0.35
$(V_B)_{t-1}$	0.094	0.11
T	20.18	19.89

5. Results

The obtained results, displayed in table 2 below, provide strong support for the hypothesis that technology transfers do occur from parent companies to their foreign affiliates. The constant marginal product of the knowledge stock K_M is positive and significant at the 1% level in both versions of the model (i.e. equations 10 and 11).

Note that the generally low parameter estimates in table 2 for the knowledge transfer variables are partly due to the high values (per definition) of the corresponding variables, i.e. R_M/Q and the interaction transfer variables (see table 1). Since the parameter estimates therefore are difficult to interpret, it is important to calculate numerically the quantitative effect of the technology transfer on affiliate value added growth. If we insert into equation (10) all the estimated parameters and mean values for the corresponding variables, and predict a growth rate with and without the technology transfer from M, calculations yield that the average annual growth rate in affiliate value added rises from 8.6% to 9.8%, i.e. the transfer adds 1.2% to the growth rate. When the same calculations are done with the larger sample in equation (11) (covering all periods) annual growth rate increases from 7.1% to 8.1 %.

When estimating equation (11) over different industries (statistical results not reported here), and calculating the quantitative effect of the transfer on the affiliate growth rate in value added as described above, we get the following results: *Chemical:* transfer adds 0.9% to growth rate, *metal fabrication*: 1.8%, *machinery:* 0.8%, *electronic:* 1.2%, and *transport* 1.7%. It should be noted here that the transfer in the *chemical* regression was only significant at the 10% level (with t=1.742). It was not possible to make separate regressions on the other industries in the manufacturing industry, due to the small number of observations.

Research and development in the affiliates does surprisingly not have any *direct* effect on affiliate value added growth[2]. However, as expected, affiliate R&D does have a positive significant (1% level) *indirect* effect on the growth through its positive effect on the technology transfer, which in turn has an positive impact on value added growth as discussed above. This is consistent with the earlier literature, e.g. Teece (1977) who argues that affiliate R&D is part of the transfer costs and aimed at increasing the affiliate's "receiver competence" of the parent company's technological knowledge.

The degree of vertical integration *forward* is found to influence the technology transfer in a positive way as expected. The results for vertical integration *backward* is somewhat mixed, but with a positive result at the 5% significance level when analyzing the larger sample in equation (11). Affiliate age has, as expected, a negative impact on the transfer, but at a decreasing rate due to the positive second order effect of the age variable.

---

[2]Except for the electronics industry when separate industry regressions of model (10) were undertaken. The estimated rate of return for affiliate R&D in electronics was 0.33 (significant at the 5% level), to be compared with around 0.20 reported for electronics by Mairesse and Sassenou (1991).

Table 2

Dependent variable: Δq_{it}	**equation 10** (N=417,adj R^2=0.4685)	**equation 11** (N=876,adjR^2=0.4151)
Knowledge transfer variables:		
Constant effect of R_M/Q	0.002525***	0.001384***
	(5.427)	(7.981)
Affiliate R&D's effect on transfer	0.042406***	----------------
	(2.678)	
Forw. vert. integration	0.000387***	0.000188**
	(3.856)	(2.563)
Backw. vert. integration	-0.002856*	0.000846**
	(-1.911)	(2.028)
Affiliate age, first order effect	-0.000253***	-0.000156***
	(-2.963)	(-7.227)
Affiliate age, second order effect	0.00000547***	0.000003951***
	(3.198)	(4.675)
Other variables		
Affiliate R&D's direct prod. effect	-0.156928	--------------
	(-0.959)	
Labor	0.810866***	0.678044***
	(13.966)	(16.781)
Capital	0.020407	0.082719***
	(0.534)	(3.292)
Intercept (λ)	0.056377***	0.056367***
	(6.657)	(6.686)

*, ** and *** significant at the 10, 5 and 1 % level respectively

t-values in parentheses

6. Concluding remarks

International technology transfer has in earlier empirical studies mainly been analyzed at the industry or macro level. In a world of large firms, it is however essential to consider the technology transfer that takes place within firms, i.e. between the firms′ units located in different countries. The issue of intra-firm technology transfer, only to a limited degree addressed in the literature, is the focus of the present paper.

Technology transfer *from* the parent company of a multinational firm *to* its manufacturing affiliates abroad, and factors influencing this transfer, are analyzed. With technology is here understood technological knowledge generated by past R&D activities. Econometric analysis, based on unique micro data on Swedish multinationals 1965-1990, produces strong evidence that; (1) technology transfer from the parent company does occur, and this transfer adds on average approximately one percentage point to the annual growth rate in affiliate value added (for the period 1965-90 the annual growth rate in real value added increases from 7.1% to 8.1% when taking the transfer into account), (2) R&D undertaken in the affiliates exerts a positive influence on the transfer, by upgrading the affiliates′ "receiver competence" of the parent company′s technology, (3) the affiliates′ degree of vertical integration in relation to their parent, forward or backward, has a positive effect on the transfer, and (4) more technology is transferred to new affiliates compared to old ones.

The statistical results indicate that technology transfer within firms has considerable economic effects. It should hence be important to take into account these effects when analyzing the issue of international technology transfer and its economic implications in a broader sense. Interesting future extensions of research in this area would include; (i) analysis of economic effects that intra-firm transfers have on the multinational firms′ home and host countries respectively, (ii) more detailed studies of the actual transfer process, and (iii) analysis of how different characteristics of the technology receiving affiliate influences the transfer, e.g. if the affiliate is located in a developed or a developing country and various aspects of the affiliate′s organization.

References

Bernstein, J. and Nadiri, I. (1989), "Research and Development and Intra-industry Spillovers: An Application of Dynamic Duality", *Review of Economic Studies*, **56**, 249-269

Branch, B. (1974), "Research and Development Activity and Profitability: A Distributed Lag Analysis", *Journal of Political Economy*, **82**, no 5, 999-1011.

Caves, R. (1982), Multinational Enterprise and Economic Analysis, Cambridge University Press.

Cohen, W. and Levinthal, D. (1989), "Innovation and Learning: The two Faces of R&D", *The Economic Journal*, **99**, September, 569-596

Eliasson, G. (1990), "The Firm as a Competent Team", *Journal of Economic Behavior and Organization*, **13**, no 3, 275-298

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

IUI, 1991, Multinational data-base

Mairesse, J. and Sassenou, M. (1991), "R&D and Productivity: A Survey of Econometric Studies at the Firm Level", NBER Working Paper # 3666.

Mansfield, E. and Romeo, A. (1980), "Technology Transfer to Overseas Subsidiaries by US-Based Firms", *Quarterly Journal of Economics*, December, 737-750.

Ravenscraft, D. and Scherer, F.M. (1982), "The Lag Structure of returns to Research and Development", *Applied Economics*, **14**, 603-620.

SCB, 1991, Statistisk Årsbok (Statistical Yearbook for Sweden) and other SCB material

Scherer, F.M. (1982), "Inter Industry Technology Flows and Productivity Growth", *Review of Economics and Statistics*, **LXIV**, 627-634.

Teece, D.J. (1977), "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-how", *The Economic Journal*, **87**, 242-261.

Terleckyj, N. (1974), Effects of R&D on the Productivity Growth of Industries: An Exploratory Study, National Planning Association, Washington DC.