R&D AND TECHNOLOGY TRANSFER BY MULTINATIONAL ENTERPRISES

Gunnar Fors

STOCKHOLM SCHOOL OF ECONOMICS

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FOREWORD

The internationalization of firms has since long been a core research topic at the Industrial Institute for Economic and Social Research (IUI). In the four empirical essays contained in this thesis, Gunnar Fors examines various aspects relating to research and development (R&D) and technology transfer by multinational enterprises (MNEs). The analysis is based on a unique data material collected by IUI since 1965 covering Swedish MNEs in manufacturing.

The thesis focusses on two questions. First, to what extent do firms transfer technology to their affiliates located abroad? Second, what is the role of R&D undertaken in the MNEs' foreign affiliates? These issues are important for a broader understanding of technology transfer between countries, since MNEs perform the bulk of the world's industrial R&D, and are also key actors in the international diffusion of technological knowledge.

This book has been submitted as a Ph.D. thesis at the Stockholm School of Economics and is the 52nd doctoral or licentiate dissertation completed at the Institute since its foundation in 1939. IUI would like to thank Magnus Blomström and Mario Zejan of the dissertation committee for contributing their expertise and guidance.

Stockholm in April 1996

Ulf Jakobsson
Director of IUI

ABSTRACT

This thesis analyzes different aspects of research and development (R&D) and technology transfer by Swedish multinational enterprises (MNEs). Following an introductory chapter are four separate empirical studies.

Chapter II examines to what extent Swedish MNEs transfer technology to their foreign affiliates. The results suggest that R&D-generated knowledge is transferred from parent companies to the affiliates. Technology transfer has a larger impact on newly established affiliates, which may imply that foreign affiliates become more self reliant over time. R&D undertaken in the affiliates seems to facilitate technology transfer in the case of process industries. Moreover, knowledge appears to be "embodied" in intermediary-good deliveries from the parent, especially for affiliates located in developing countries.

In chapter III the utilization of R&D results in the home and foreign plants of the MNEs is analyzed. Four-fifths of the total gain in value-added attributed to home R&D was realized in the MNEs' home plants while the remaining fifth benefitted the foreign plants. Considering that around one-third of the MNEs' total output is attributed to their foreign operations, the gain of the foreign plants must be regarded as substantial. There is also some indication that the foreign gain has increased over time. Knowledge generated in foreign affiliates does not seem to be used as an input in home plants.

The simultaneous relationship between R&D and foreign sales in Swedish MNEs is analyzed in chapter IV. Positive effects were found in both directions, supporting the hypothesis of a two-way reinforcing relationship. The only previous study addressing this issue used data for U.S. firms, but did not find evidence of a simultaneous relationship. This may suggest that the link between R&D and foreign sales is stronger for MNEs from small countries, since these firms have limited growth opportunities at home.

Finally, chapter V investigates determinants of overseas R&D. The empirical evidence first suggests that the location of overseas R&D is motivated to a large extent by the need to adapt products and processes to conditions in foreign markets. When controlling for factors related to adaptation, we also find that the Swedish firms locate a higher share of their R&D expenditures to host countries that are relatively specialized technologically in their industry. This may suggest that one additional motive to locating R&D abroad is to gain access to knowledge in "centers of excellence" and to benefit from localized spillovers.

CONTENTS

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Stockholm in April 1996

Gunnar Fors

CHAPTER I

INTRODUCTION AND SUMMARY

The existence of multinational enterprises (MNEs) is to a large extent attributed to the creation and utilization of firm-specific intangible assets. These assets include technological knowledge, marketing know-how and managerial expertise, as well as specific properties like patents and brands. Technological assets are to a considerable degree generated by research and development (R&D). An important characteristic of intangible assets is that their productive use is not tied to a particular physical site or nation.

Multinationals undertake the bulk of the world's industrial R&D, and are also considered to be the key actors in the international diffusion of technological knowledge. In this thesis I specifically analyze technological knowledge generated by R&D, and the utilization and transfer of this knowledge between the MNEs' units located in different countries.

1. Theoretical and empirical background

In the literature on MNEs the starting point is generally the transaction cost theory (see, e.g., Caves, 1996). This theory argues that the market for intangible assets is imperfect in several ways. For instance, intangible assets are at least partially public goods, meaning that knowledge developed by one firm can be applied at little extra cost in production by other firms. Furthermore, the assets are not fully appropriable by their owner, and they are subject to information asymmetries between a potential seller and buyer. These features imply difficulties to contract upon intangible assets, and hence, raise the transaction costs related to them. It can therefore be expected that firms internalize the market for these assets, rather than transact them in the marketplace (Williamson, 1975). This reasoning relates to all kinds of firms and to the organization of economic activities in general.

Theory asserts that in order to compete successfully in a foreign market a firm must possess some intangible asset, like superior technological knowledge (Hymer, 1960). A firm holding such technological assets basically faces two options concerning the exploitation of these assets in foreign markets (apart from exporting). A firm can either license the technology to foreign firms, or set up a foreign affiliate and internalize the use of the technology. The latter option is typically assumed to involve transfer of technology to the affiliate. Technology and similar rent-yielding assets can usually be transferred more efficiently and cheaply within a firm than between independent firms, due to the high transaction costs associated with arm's-length trade in intangible assets (Buckley and Casson, 1976).

However, affiliate production and technology transfer are not without costs; both involve the commitment of both capital and managerial resources. Arm's length licensing could be expected to be encouraged by, e.g., barriers to entry in a foreign market, high risks to foreign investors, short economic life of the knowledge asset, simplicity or maturity of the technology, and by high capital costs for the potential foreign investor.

In the newer international trade theory incorporating MNEs, it is often assumed that technology transfer takes place within MNEs. Markusen (1984) models the cost of creating an intangible asset as a fixed cost of operating a firm, and assumes that this asset can be used as a joint input in all plants of the firm. In Horstmann and Markusen (1992), horizontally integrated MNEs arise endogenously in an environment of firm specific joint inputs. Helpman (1984) takes another approach and assumes that technology is an intermediary input produced in one country, and then utilized in the production of final goods.

Few empirical studies have explicitly measured how much transfer of technology actually takes place within MNEs, or what is the economic impact of such intra firm transfer. Case studies of MNEs have suggested that intra firm technology transfer may be important (e.g. Behrman and Wallender, 1976), but most empirical papers have addressed the issue in a more implicit way. One exception is Mansfield *et al.* (1979), which studied how much of the returns from R&D projects some larger US multinationals expected to earn from "foreign application." The study found that around one-third of the returns were expected to come from either the use of technology in foreign affiliates, licensing, or exports of goods embodying the technology. However, from Mansfield *et al.* it is not possible to directly evaluate the extent of technology transfer to foreign affiliates, as the concept "foreign application" encompasses different modes of serving a foreign market.

Teece (1977) and Mansfield and Romeo (1980) address related issues concerning technology transfer: Teece concentrates on the costs associated with technology transfer within MNEs, and concludes that intra firm transfers are by no means free. Mansfield and Romeo examine, e.g., the age of technologies transferred abroad and the leakage of knowledge to foreign competitors due to technology transfer.

Several studies have analyzed firms' R&D intensity and degree of multinational involvement, and generally found a positive relationship between these two variables (see chapter IV for a survey). However, even in those cases where R&D intensity can be related to foreign affiliate sales, a positive association is still not any direct evidence that technology is actually transferred to the affiliates.

In this thesis, I attempt to measure technology transfer between parent companies and their foreign affiliates in chapter II. Then, in chapter III, the economic impact of technology transfer on the MNEs' foreign operations is compared with the impact of technology on the firms' home operations. In a more indirect way, the question of intra firm transfer is also addressed in chapter IV, studying the simultaneous relationship between R&D and foreign sales.

Multinationals perform R&D both in their home country and in foreign affiliates. Most of the R&D is concentrated to their home countries, although an increasing share is being undertaken in foreign affiliates. The location of R&D activities to foreign affiliates can be regarded as a transfer of technological capability by the MNEs to their affiliates. The main result from earlier empirical studies is that overseas R&D is motivated by the need to adapt products and processes to foreign markets.

This thesis also addresses different questions concerning overseas R&D. Chapter II includes an analysis of whether affiliate R&D facilitates technology transfer from the parent company, and chapter III attempts to measure if technology developed in foreign affiliates is also utilized in the firms' home operations. Finally, in chapter V, we analyze whether overseas R&D is undertaken to gain access to knowledge in foreign "centers of excellence," and to benefit from localized R&D spillovers.

2. Data material

Throughout this study, we use firm-level data on Swedish multinationals that have been collected by the Industrial Institute for Economic and Social Research (IUI) in Stockholm. A survey has been directed to all Swedish manufacturing firms (registered and owned to more than 50% in Sweden) with more than 50 employees and with at least one majority-owned production affiliate abroad. The survey has been undertaken for the years 1965, 1970, 1974, 1978, 1986 and 1990, and the response frequency has exceeded 90% over the years. In aggregate terms, the firms in the survey represent at least 90% of the total foreign employment of Swedish manufacturing firms, although we have excluded smaller MNEs. Comparison with official data also shows that the MNEs in the IUI survey together undertake almost all industrial R&D in Sweden. In 1990, for example, the R&D performed by these firms *in Sweden* contributed to at least 83% of total Swedish industrial R&D.

The data are available at two levels: first, at the level of the corporation, which in turn are available separately for domestic activities and foreign activities (and for some variables by individual host countries). Second, the MNEs report detailed information for each of their majority-owned production affiliates located abroad. The data on foreign affiliates usually correspond to an individual production plant. Data on different levels are used in the various chapters, depending on the issues studied. Besides firm-level data, the survey includes some variables at the industry level, e.g., the world market concentration in the MNEs' primary product market. Official country data taken from OECD, Statistics Sweden and the United Nations are employed together with the IUI data in the empirical analysis.

For each year mentioned above, information for more than 100 MNEs, with altogether between 400-750 foreign affiliates, is included. Some MNEs can be followed over the entire period 1965-90, but usually this is only possible for shorter time spans, since new MNEs enter the population, exit, are acquired or reorganized. This also applies to the individual foreign affiliates. The survey has contained roughly the same questions over time, although some variables are only available for certain years. Sample selection issues and further details on the data are discussed in each separate chapter. For a full documentation of the database, see Andersson *et al.* (1996).

3. A summary of the thesis

This thesis consists of four separate empirical essays dealing with R&D and technology transfer by Swedish multinational enterprises in manufacturing. Chapter II examines to what extent Swedish parent companies transfer technology to their foreign affiliates. The results suggest that R&D-generated knowledge is transferred to the affiliates. The transfer has a larger impact on newly established affiliates, which 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 to making productive use of the parent's technology. Moreover, the findings indicate that knowledge is "embodied" in intermediary-good deliveries from the parent, especially for affiliates located in developing countries.

In chapter III we analyze the utilization of R&D results in the home and foreign plants of the MNEs. The estimated rate of return on Swedish multinationals' home R&D in their home plants is positive, and in line with estimates obtained from other countries. In addition to being utilized in Swedish plants, the empirical results suggest that technology is transferred to foreign plants, in line with chapter II. Numerical calculations suggest that around four-fifths of the total gain in value-added attributed to home R&D is realized in the MNEs' home plants while the remaining fifth benefitted the firms' foreign plants. Taking into account that the foreign plants in the sample on average accounted for about a third of the total output of the MNEs, there is no support for the assertion that a disproportionate share of the gains from the R&D undertaken in Sweden is exploited in foreign affiliates. Yet, it is apparent that there is a substantial impact of home R&D on foreign affiliates. Analyses of separate periods give some indication that the foreign share of the gain has increased over time. No significant evidence could be found for technology transfer taking place from the MNEs' foreign plants to their home plants.

The simultaneous relationship between R&D and foreign sales in MNEs is analyzed in chapter IV. Positive and statistically significant effects were found in both directions, supporting the hypothesis of a two-way reinforcing relationship. The only previous study explicitly addressing this issue used data for U.S. manufacturing firms, but did not find evidence of a simultaneous relationship. Our results suggest that the link between R&D and foreign sales may be stronger for MNEs originating from small home economies. Industrial firms from small countries have limited growth opportunities in their home markets, and therefore are more dependent on foreign sales. When analyzing product- and process-related R&D separately, proxied by the MNE's industry classification, the two-way relationship is only confirmed for product-related R&D.

Finally, chapter V investigates determinants of overseas R&D in Swedish MNEs. The empirical evidence first suggests that the location of overseas R&D is motivated to a large extent by the need to adapt products and processes to conditions in the foreign markets where the firms operate. This is consistent with the earlier literature. When controlling for factors related to adaptation, we also find that the Swedish firms locate a higher share of their R&D expenditures to host countries that are relatively specialized technologically in their industry. We measure a country's specialization in a particular industry in terms of R&D expenditures relative to other countries. This finding may suggest that one additional motive to locating R&D abroad is to gain access to knowledge in foreign "centers of excellence" and to benefit from localized spillovers. Hence, it is possible that the foreign affiliates could be seen as a MNE's interface with the technological knowledge in host countries.

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CHAPTER II

TECHNOLOGY TRANSFER TO FOREIGN AFFILIATES

1. Introduction

Multinational enterprises (MNEs), undertake the bulk of the world's industrial R&D, and are also 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 chapter examines to what extent 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 impact 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 effect 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 2 briefly discusses earlier theoretical

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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.

and empirical contributions to the study of technology transfer by MNEs. The econometric model and data are presented in sections 3 and 4, and the empirical results discussed in section 5. The final section concludes.

2. Technology transfer by 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), and outward foreign direct investment (see e.g. Caves, 1996 and Dunning,

[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.

1992). Fors and Svensson (1994) find 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 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

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

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.

3. 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]

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

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

[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. In chapter III of this thesis, I employ the same empirical model as Mansfield, but do not find any significant 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.

[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.

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,

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

with lower case letters denoting logs, and where

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

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 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 for affiliate and time 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 $t-1$

[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.

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

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

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

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, 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

[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).

($\alpha+\beta=1$), allows reformulation of (3) in terms of growth in total factor productivity,[13]

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

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

4. 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.

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

[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.

TABLE 1. DESCRIPTION OF VARIABLES

Variable name	*Description*
DTFP	Average annual growth rate over the period Δ (*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). Value-added and physical capital are expressed in 1990 SEK by use of Swedish producer price and capital price indices, respectively, for the different 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. The R&D intensity is based on 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. The R&D intensity is based on nominal SEK.
$R_P/Q x R_A/Q$	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. θ is based on 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).

for by defining *DTFP* as the 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 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 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%),

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

[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.

Electrical machinery (14%), Transport equipment (4%), and other industries (7%).

DTFP (and its underlying variables) are based on 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 based nominal SEK. Descriptive statistics for the data are provided in Tables A1 and A2 in the Appendix.

5. 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 group can be discerned. More detailed research

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[17] *Product industries* is here defined to comprise the following industries: Pharmaceutical, Metal products, Non-electricalmachinery, Electricalmachinery, 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	*F-value*
Overall sample (b) (n=1015)	1.46 E-4*** (3.73 E-5)	0.051	2.36
Product industries (c) *(n=537)*	1.23 E-4*** (3.31 E-5)	0.020	2.20
Process industries (d) *(n=478)*	6.10 E-4 (4.00 E-4)	0.041	3.05
Affiliates located in industrial countries (n=828)	7.91 E-4*** (1.65 E-4)	0.029	2.77
Affiliates located in developing countries (n=187)	1.23 E-4*** (3.61 E-5)	0.069	2.37
"New" affiliates (age 10 years or less in t-1) (n=461)	1.02 E-3*** (1.71 E-4)	0.067	3.36
"Old" affiliates (age > 10 years in t-1) (n=554)	9.50 E-5*** (3.15 E-5)	0.026	2.16

Notes: ***, ** 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. 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.

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 these 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 follows: $\varrho_P(R_P/Q)_{t-1}\ x100$. 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 technology transfer from the parent.[19]

The calculations indicate that technology transfer appears to have a larger effect

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[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.

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

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.

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* (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 follows: $\varrho_P(R_P/Q)_{t-1}\ x100$. Based on the estimations shown in Table 2, and means values provided in Table A1 in Appendix.

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

[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.

(1977), indicating that technology transfer from the parent is most important in the start-up phase.[21]

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 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 foreign affiliates is largely aimed at adapting the parent's technology to local conditions. Teece (1977) found that affiliate R&D seems to increase the "receiver competence" of parent technology, and 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]

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[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.

[22]The lack of effect of affiliate R&D may be attributed to the fact that only older data is considered. In chapter III of this thesis, analyzing the aggregate foreign operations of Swedish MNEs, using 1965-90 data, I find that parent as well as affiliate R&D had a positive and significant rate of return in the MNEs' 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.

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

Inserting this expression into equation (4) yields

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

where ϱ_{P0} is the parameter for the "constant" technology transfer (unrelated to affiliate R&D), and ϱ_{PI} the parameter for the interactive effect between affiliate R&D and parent R&D. The results from selected regressions shown in Table 4, indicate that R&D in the affiliates appears to facilitate technology transfer to affiliates in the case of process industries. The estimated parameter for the interactive effect, ϱ_{PI}, 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 foreign 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.

[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				
		R_P/Q	R_A/Q	$R_P/QxR_A/Q$	*Adj.* R^2	*F-value*
Overall sample (n=449)	*(i)*	9.60 E-4*** (3.15 E-4)	0.0565 (0.153)	--	0.025	1.97
	(ii)	9.28 E-4*** (3.14 E-4)	--	0.0177 (0.0129)	0.029	2.13
	(iii)	--	0.0244 (0.154)	--	0.0070	1.29
	(iv)	--	--	0.0198 (0.0130)	0.012	1.50
Process ind (b) *(n=231)*	*(i)*	-9.08 E-5 (6.69 E-4)	0.287 (0.260)	--	0.020	1.59
	(ii)	-2.46 E-4 (6.66 E-4)	--	0.0571** (0.0253)	0.037	2.10
	(iii)	--	0.288 (0.260)	--	0.024	1.82
	(iv)	--	--	0.0562** (0.0251)	0.041	2.39

Notes: ***, ** 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 $R_P/QxR_A/Q$ 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 $R_P/QxR_A/Q$, 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 $R_P/QxR_A/Q$ in the product ind. group. The parameter for R_P/Q was significant in the product ind. group at the 1% level.

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 related 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 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. However, since both the adjusted R^2 and F-values for the regressions with embodied transfer are low, we should interpret these results with caution.

[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	*F-value*
Overall sample *(n=986)*	8.89 E-4* (4.81 E-4)	0.0095	1.67
Affiliates located in industrial countries *(n=799)*	4.67 E-4 (1.34 E-3)	0.0020	1.12
Affiliates located in developing countries *(n=187)*	1.30 E-3** (5.55 E-4)	0.037	1.72
"New" affiliates (age 10 years or less in t-1) *(n=449)*	3.06 E-3** (1.38 E-4)	0.0033	1.11
"Old" affiliates (age > 10 years in t-1) *(n=537)*	6.02 E-4 (4.77 E-4)	0.015	1.64

Notes: ***, ** 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.

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

Note: Standard deviations in parentheses.

CHAPTER III

UTILIZATION OF R&D RESULTS IN HOME AND FOREIGN PLANTS

1. Introduction

The generation of new technologies is to a large extent dominated by multinational enterprises (MNEs). For example, 83% of aggregate Swedish industrial R&D was attributed to Swedish MNEs in 1990 (Fors and Svensson, 1994), and the corresponding figure for US multinationals was around 80% in 1982 (Dunning, 1988). Unlike non-multinational firms, MNEs can exploit the fruits of their R&D in production plants at home as well as abroad. Technological knowledge is to some extent a public good within the MNE, and can also be utilized in foreign affiliates.

The debate in several countries has revealed worries that the MNEs' exports of technology to foreign affiliates contribute to a de-industrialization or at least an erosion of the technological advantages of the home country. In the case of Sweden it has been argued that the R&D content of Swedish production is low, despite a national R&D intensity that ranks among the highest in the world (Blomström and Kokko, 1994). The R&D content in Swedish exports also appears to be low compared to what could be expected from the high R&D intensity (Lundberg, 1988, and Hansson and Lundberg, 1995). These findings may be an indication that the fruits of R&D efforts in Sweden have been utilized in foreign affiliates to a large extent.

The purpose of this chapter is to analyze *where* the technology generated by R&D performed by the Swedish MNEs is used. In the first part of the analysis, we study how the output gains from R&D undertaken in Sweden are divided between the MNEs' plants at home and abroad. Thereafter, we examine the impact of R&D performed in foreign affiliates on the plants in Sweden and abroad.

Earlier studies have not attempted to measure the distribution of the gains from R&D between plants in the home country and plants located abroad, although several authors have discussed these issues at a more general level (see e.g., Mansfield and Romeo, 1980, Globerman, 1994, and Blomström, 1990). There are numerous econometric studies estimating the returns to R&D at the firm level (for a survey see Mairesse and Sassenou, 1991), but these have typically not taken into account the impact on foreign affiliates, nor the possible effects of R&D undertaken in foreign affiliates on the home plants.[1] Chapter II of this thesis analyzes the extent and the determinants of technology transfer from Swedish parent companies to foreign affiliates at a more detailed level, but does not examine the distribution of gains attributed to R&D.

The study is organized as follows: In section 2, earlier studies on R&D by multinationals are briefly reviewed. The econometric model is derived in section 3, and the data material presented in section 4. Empirical results are provided in section 5, and the final section concludes.

2. R&D by multinationals

According to the transaction cost theory, the rationale for the existence of the multinational enterprise lies in the international utilization of intangible assets, such as technology, to avoid the market failures associated with such assets. Technological knowledge should therefore be transferred throughout the MNE (Caves, 1996). We expect that technology generated by R&D activities will be used as an input in the multinationals' plants located at home as well as abroad.

It is generally argued that the direction of technology transfer is *from* the MNEs' home country units *to* their foreign affiliates. Two empirical observations support this view. First, we know that R&D expenditures are concentrated to the MNEs' home country.[2] Second, it is noted that home R&D is more basic and long-term in character, compared to R&D undertaken in foreign affiliates, which is largely oriented towards

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[1]Mansfield (1984) is an exception. Lack of data on overseas R&D, on either the firm or industry level, provides one plausible explanation. Though many industrial firms do not perform any R&D outside their home country, still, the major part of aggregate industrial R&D is undertaken by MNEs, of which many do perform a substantial amount of R&D abroad.

[2]Although, an increased share of R&D is being undertaken in foreign affiliates. Around 18% of the Swedish MNEs' R&D was located abroad in 1990, as compared with 7% in 1965 (Fors and Svensson, 1994).

adaptation (Behrman and Fischer, 1980).[3]

Whether there is any impact of R&D performed in the foreign affiliates on the home operations is less obvious. To the best of my knowledge, the only study explicitly analyzing such effects is Mansfield (1984), which considered a small sample of US multinationals (fifteen firms in the chemical and petroleum sector).[4] Evidence was found for positive effects of both home R&D and R&D performed abroad on plants located in the US. In the same study, Mansfield also presents figures for 29 foreign laboratories of US firms, indicating that on average, 40% of these laboratories' R&D was related to technologies that were transferred to the United States. Furthermore, Behrman and Fischer (1980) suggest on the basis of case studies that MNEs that undertake R&D in foreign countries will gain easier access to foreign knowledge, which in turn can be transferred back to the home plants.

On the other hand, if R&D in foreign affiliates is predominately directed towards adaptation of the MNEs' technology to local conditions and regulations, little effect on the home operations is to be expected.[5] Håkanson and Nobel (1993), studying Swedish MNEs find that adaptation of home technology on average accounts for 32%, and adaptation to local regulations and political factors for 34%, of the R&D expenditures in the foreign affiliates. Econometric analysis of foreign affiliates in chapter II in this thesis suggests that affiliate R&D enhances exploitation of the technology created at home.

Adverse effects on home plants could be possible if the establishment of foreign R&D units speeds up the diffusion of a MNE's knowledge assets to competitors. Mansfield *et al.*, (1982) found that technology transfer in process industries accelerated

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[3]Considering averages for a sample of 26 Swedish MNEs in 1978 that undertook R&D both at home and abroad, we note for home R&D that 10% of R&D expenditures were directed towards "long term (basic) 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 were 2%, 44% and 54%, respectively. These figures are taken from the database used in the empirical analysis in this paper.

[4]The R&D data used by Mansfield was from the mid-1960s, while the corresponding productivity data covered the period 1960-76. Accordingly, the two data sets are not strictly confirmable, since R&D expenditures should be related to productivity changes in subsequent periods.

[5]Such R&D can be regarded as a "transfer cost" relating to international application of the firms' home technology (Teece 1977).

the imitation by foreign firms, while this was not the case in other industries.[6]

To sum up, the firms' R&D performed in the home country is expected to be used as an input in both the MNEs' home and foreign plants, while it is less obvious whether R&D performed in the foreign affiliates will be used as an input in home plants. It remains an empirical question to evaluate this effect; however, it is expected that R&D in the foreign affiliates will have a positive effect on the affiliates undertaking the R&D in question. In the next section a model is set up to test for these effects, and to allow for a quantitative assessment of the distribution of the output gains attributed to the R&D undertaken at home between the MNE's home and foreign plants, respectively.

3. Econometric specification

It is assumed that the production technologies of firm i's home and foreign plants can both be represented by Cobb-Douglas functions. For notational simplicity, I will begin by making no distinction between the two production functions. Hence, in time t the output of the i:th firm is given as

$$Q_{it}=\Phi e^{\lambda t}C_{it}^{\alpha}L_{it}^{\beta}(K_H)_{it}^{\gamma_H}(K_F)_{it}^{\gamma_F}e^{\varepsilon_{it}}\,, \tag{1}$$

where Q is output, Φ is a constant, λ is the rate of disembodied technical change,[7] C is the stock of physical capital, L is labor input, K_H is the knowledge stock generated by R&D activities in the home country, and K_F is the corresponding knowledge stock generated by R&D in foreign affiliates.[8] The elasticities α, β, γ_H and γ_F relate to the four

[6]It has also been suggested that R&D in foreign affiliates may lead to a "hollowing out" of home R&D. Norgren (1992) investigated a number of product areas in Swedish firms within the engineering sector and found that an expansion in affiliate R&D in general implied a subsequent specialization and narrowing of technological competence in the firms' Swedish R&D departments.

[7]As a matter of interpretation, it should be noted that this model constitutes an attempt to explain part of the "Solow residual" by means of resources spent on R&D. Thus, λ measures the R&D-corrected Solow residual.

[8]This is the standard modelling approach when considering R&D capital as an input factor (c.f. Griliches 1979). The extension here is that overall R&D capital is decomposed into a home and a foreign component, or rather that the foreign component is added.

factors of production, and ε is a random error term. Subscript H denotes "home" and F "foreign." "Home" is the sum of the MNE's operations in the home country, i.e. parent company plus units controlled by the MNE located in Sweden. "Foreign" is the aggregate of the MNE's plants located in different foreign countries.

It is hence assumed that K_H and K_F are available for use as inputs throughout the MNE.[9] The conventional inputs C and L, on the other hand, are tied to their location, e.g. home's labor is only used as a factor of production in the home plants. Rewriting (1) in log form, and taking first differences, we obtain

$$\Delta q_{it} = \lambda + \alpha \Delta c_{it} + \beta \Delta l_{it} + \gamma_H \Delta (k_H)_{it} + \gamma_F \Delta (k_F)_{it} + \Delta \varepsilon_{it} \quad , \qquad (2)$$

with lower case letters denoting logs, and where

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

which is approximately equal to $(K_{it}-K_{it-1})/K_{it-1}$ or $(\Delta K)/K_{it-1}$. Since data on knowledge stocks, K, are not directly available, and in view of the obstacles associated with the construction of reliable knowledge stocks from flow data (Griliches 1979), the production function is transformed to enable utilization of data on R&D expenditures.

The terms containing k_H and k_F in (2) are rewritten in the following way,

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

where R is the R&D expenditures in one year, (R/Q) the corresponding R&D intensity that year and ϱ the rate of return on R&D (subscripts for firm and time are left out for notational simplicity). Hence, it is assumed that the depreciation of K is

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[9]The Cobb-Douglas specification (1) implies that the two kinds of knowledge stocks are assumed to be substitutes with an elasticity of substitution equal to one. If R&D in foreign affiliates is aimed at adaptation of home technologies for local use, as discussed above, a complementary relationship would be possible between the two stocks in the foreign plants. However, modelling the stocks interactively in the foreign production function (3F) below, does not produce any empirical results suggesting complementarity. We therefore maintain the simple Cobb-Douglas framework.

negligible, and that R approximates the flow ΔK. The approach follows that of Griliches (1980).[10] In the empirical implementation, the R&D intensity is measured in t-1 as suggested by e.g. Scherer (1982), that is, at the beginning of Δ, the period $[(t-1)-t]$. Moving from a stock, K, to a flow, R, measure of knowledge, we can rewrite (2) to

$$\Delta q_{it} = \lambda + \alpha \Delta c_{it} + \beta \Delta l_{it} + \varrho_H \left(\frac{R_H}{Q}\right)_{it-1} + \varrho_F \left(\frac{R_F}{Q}\right)_{it-1} + \eta_{it} \ , \qquad \textbf{(3)}$$

where ϱ_H and ϱ_F are the rates of return on the R&D performed in the home country and in the foreign affiliates, respectively, and η_{it} is the new random error term. Estimation of (3) by ordinary least squares (OLS) is undertaken separately for the home and foreign plants, according to equations (3H) and (3F) below.[11] Hence, for MNE i's home plants,

$$\Delta q_{Hit} = \lambda_H + \alpha_H \Delta c_{Hit} + \beta_H \Delta l_{Hit} + \varrho_{HH} \left(\frac{R_H}{Q_H}\right)_{it-1} + \varrho_{FH} \left(\frac{R_F}{Q_H}\right)_{it-1} + \eta_{Hit} \qquad \textbf{(3H)}$$

and for MNE i's foreign plants,

$$\Delta q_{Fit} = \lambda_F + \alpha_F \Delta c_{Fit} + \beta_F \Delta l_{Fit} + \varrho_{HF} \left(\frac{R_H}{Q_F}\right)_{it-1} + \varrho_{FF} \left(\frac{R_F}{Q_F}\right)_{it-1} + \eta_{Fit} \ . \qquad \textbf{(3F)}$$

In the case of the home and foreign plants' "own" R&D, ϱ_{HH} and ϱ_{FF} are the rates of return on R&D, net of costs, since the costs of capital and labor used in the R&D are already accounted for in the production function (Griliches, 1980).[12] For ϱ_{FH} and ϱ_{HF} the interpretation is net of costs as well, since the explicit cost of the R&D is external to H and F, respectively. A description of the variables is provided in Table 1.

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[10] For a survey of firm-level studies using this method, see Mairesse and Sassenou (1991).

[11] In addition to the OLS-analysis,"Seemingly Unrelated Regressions"analysis is also undertaken, since the residuals of the two equations (3H) and (3F) for company i, may be dependent on each other.

[12] It was not possible in the present data set to separate out the share of capital and labor input that was attributed to R&D. The resulting "double-counting" of the inputs related to R&D, however, does not pose a problem if the rate of return is interpreted as "excess rate of return" (Schankerman, 1981). According to Verspagen (1995) the difference between estimation results based on corrected and uncorrected data, with respect to the double-counting, is limited.

TABLE 1. DESCRIPTION OF VARIABLES

Variable	*Description*
Δq_H	Average annual growth rate in output (log form) for home plants. Output is measured as value-added (value-added=wages+operatingincome before depreciation and financial items). Value-added is expressed in 1990 SEK by use of Swedish producer price indices for the different industries as below.
Δq_F	Average annual growth rate in output for foreign plants (defined as above)
Δc_H	Average annual growth rate in physical capital (log form) for home plants. Physical capital is measured as book value of equipment, machinery and property. Physical capital is expressed in 1990 SEK by use of Swedish capital price indices for the different industries as below.
Δc_F	Average annual growth rate in physical capital for foreign plants (defined as above).
Δl_H	Average annual growth rate in labor input (log form) in home plants. Labor input is measured as average number of employees during the year in question.
Δl_F	Average annual growth rate in labor input in foreign plants (defined as above).
R_H/Q_H	Home R&D divided by home value-added in the beginning of Δ. Based on nominal SEK.
R_F/Q_H	Foreign affiliate R&D divided by home value-added in the beginning of Δ. Based on nominal SEK.
R_H/Q_F	Home R&D divided by foreign affiliate value-added in the beginning of Δ. Based on nominal SEK.
R_F/Q_F	Foreign affiliate R&D divided by foreign affiliate value-added in the beginning of Δ. Based on nominal SEK.
Industry dummies	Food,beverages & tobacco
	Textiles, clothing & leather
	Pulp & paper
	Paper products & printing
	Chemicals
	Iron & steel
	Metal products (reference industry in regressions)
	Non-electrical machinery
	Electrical machinery
	Transport equipment
Period dummies	1965-70
	1970-74
	1974-78
	1986-90 (reference period in regressions)

Sources: All data from the IUI database on Swedish MNEs, except for producer price and capital price indices, which are taken from Statistics Sweden (1991).

4. Data

The data set used in the estimations has been collected for 1965, 1970, 1974, 1978, 1986 and 1990 by The Industrial Institute for Economic and Social Research (IUI), Sweden. The survey is directed to all Swedish MNEs in the manufacturing sector that have more than 50 employees and at least one majority-owned production affiliate abroad. The response frequency has exceeded 90 percent over the years.

In this study, data on 121 Swedish MNEs were pooled over four separate time 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 the Δ-variables as the average annual growth rate over the period in question. Of the 121 separate firms considered, 11 occurred all four time periods in the sample, 22 firms in three periods, 25 in two periods, and 63 in one period. This yielded an overall pooled cross-section time-series sample of 223 observations.[13] Out of the sample of 223 observations, 75 recorded R&D both in Sweden and abroad, 107 only in Sweden, 3 only abroad, and the remaining 38 no R&D at all.[14]

The partial panel characteristic of the data set is not taken into account in the present analysis for several reasons. First, more than half of the firms are only observed during one period, while as few as 11 firms are observed all four periods. *A priori* it can therefore be expected that a panel approach would not contribute significantly to the analysis. Second, looking at the estimation results reported below, we find that the residuals for firms observed in more than one period do not exhibit a systematic pattern.[15] The most intuitive reason for this finding is that the use of four/five-year period averages in the dependent variable reduces the probability that firms' residuals are correlated over time. The autocorrelation problem would, of course, be more

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[13]The observations were distributed across time periods as follows: 1965-70 (23%), 1970-74 (26%), 1974-78 (29%) and 1986-90 (22%).

[14]The industry distribution of the 223 observations was as follows; Food,beverages & tobacco (4%), Textiles, clothing & leather (8%), Pulp & paper (10%), Paper products & printing (4%), Chemicals (19%), Iron & steel (7%), Metal products (12%), Non-electrical machinery (13%), Electrical machinery (6%), Transport equipment (7%), other industries (5%) and mixed industry classification (4%).

[15]For example, out of the 33 firms observed for either three or four periods, only four firms had residuals of the same sign in all periods.This holds both for the estimation of the firms' home and foreign production function, i.e. equations (3H) and (3F).

prominent in the context of yearly data.

We assume that the R&D intensity at the beginning of a period has an effect on the annual average growth rate of output over a four/five-year period. For example, the R&D intensity in 1965 is related to growth in output over the period 1965-70. According to the notation above, the R&D intensity in *t-1* is related to growth in output over the period Δ (i.e. *t-1* to *t*). 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 falls roughly in the middle of the period-length used in the present paper. Ravenscraft and Scherer (1982) suggest four to six years when analyzing R&D and profits.

The variables Δq and Δc are based on constant, 1990 SEK, for both Swedish and foreign plants, by use of Swedish producer price indices and capital price indices, respectively, for each of the ten different manufacturing industries included (taken from Statistics Sweden, 1991). R&D intensities (*R/Q*:s) are based on nominal SEK for both Swedish and foreign plants. For descriptive statistics, see Table A1 in the Appendix.

5. Empirical results

Table 2 reports the results from OLS analysis of the home plants. The estimated rate of return of the MNEs' home R&D in their home plants equals 0.13, and is significantly different from zero at the 5% level using a two tailed t-test. Analysis of the smaller sub-sample of MNEs undertaking R&D abroad yields a rate of return ranging between 0.11 and 0.13, depending on the specification. Estimation of equations (3H) and (3F) as "seemingly unrelated regressions" (SUR) produces similar results.

This rate of return of R&D is in line with other studies using the same production function framework, analyzing the effect of firms' home R&D on their home plants. The survey by Mairesse and Sassenou (1991) reports, for example, rates of returns in the range of 0.07-0.27 for US chemical firms, and 0.11-0.22 for Japanese manufacturing firms. Verspagen (1995) reports a rate of return estimate of 0.13 from a cross-country regression, and the study by Mansfield (1984) mentioned earlier finds the rate of return to be around 0.19 for US multinationals.

Analyses of separate samples over time indicate that the rate of return on the

MNEs' home R&D in their home plants has increased, from around 0.11 in 1965-74 to 0.16 in 1974-90.[16] An additional result is that the impact of R&D appears to be stronger in engineering industries, where the rate of return equals 0.34 (using 1965-90 data), compared with other industries in manufacturing.[17]

TABLE 2. OLS-REGRESSION RESULTS. HOME PLANTS (EQUATION 3H)
DEPENDENT VARIABLE: ANNUAL GROWTH RATE IN OUTPUT

Explanatory variables	*Overall sample* (n=223)	*MNEs with overseas R&D* (n=78)
INTERCEPT (a)	0.0089 (0.015)	-0.0031 (0.018)
Δc_H	0.10*** (0.033)	-0.11 (0.066)
Δl_H	0.70*** (0.070)	0.90*** (0.11)
R_H/Q_H	0.13** (0.063)	0.11* (b) (0.064)
R_F/Q_H	-0.027 (0.22)	0.12 (0.21)
Adj. R^2	0.54	0.66
F-value	16.0	9.8

Notes: ***, ** and * indicate significance at the 1, 5, and 10%-level, respectively, using a two tailed t-test. Standard errors in parentheses.
(a): The intercept refers to the Metal products industry in 1986-90. Additive dummy variables are included for the other nine industries and three time periods, but the results are not reported here (see Table 1 for the different industries included).
(b) Estimation without R_F/Q_H included, yields a parameter for R_H/Q_H of 0.13, significant at the 5% level.

[16]Analysis of each of the four time periods separately produced no significant results. "1965-74" consists of the observations obtained when pooling 1965-70 and 1970-74 data, while "1974-90" consists of the observations from 1974-78 and 1986-90.

[17]The *Engineering* industry includes: metal products, non-electrical machinery, and electrical machinery.

In order to assess the distribution of the output gains attributed to the firms' home R&D between home and foreign plants, we also have to examine the impact of home R&D in foreign plants. This has been investigated in greater detail at the affiliate level in chapter II of this thesis, but the objective in the present study is to analyze the effect of home R&D on the MNEs' overall foreign operations, and compare this effect with the impact of home R&D on home operations.

As seen from Table 3, the rate of return on home R&D in the MNEs' foreign plants equals 0.0056, and is significant at the 10% level.[18] The results from SUR estimations are similar. We interpret a positive parameter as a sign that R&D-generated knowledge is transferred from home to foreign plants.

This estimated rate of return is, however, not directly comparable with the above figures regarding home R&D in home plants, or other studies. The reason is that R&D undertaken in one unit (home plants) is modelled in another unit's (foreign plants) production function. To overcome this problem, I calculate the numerical effect of home R&D in foreign plants by multiplying the estimated parameter with the mean of the corresponding variable:

$$\hat{\varrho}_{HF}\left(\frac{\bar{R}_H}{Q_F}\right)_{t-1} x100 \ .$$

This computation indicates that around 0.4 *percentage points* of the annual growth rate in output in foreign plants can be attributed to the MNEs' home R&D. This can be compared to an impact of 0.80 *percentage points* by the firms' home R&D in home plants.

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[18]Estimation of equation (3F) without R_F/Q_F included yields a parameter for R_H/Q_F of 0.0064, which is significant at the 5% level (see Table A2 in Appendix for the complete statistical results). Hence, a higher significance is obtained when the other R&D variable is removed. This may imply problems of multicollinearity; however, as the parameter estimates between the versions of (3F) are rather stable, this should not be a major problem. Moreover, the two R&D variables are only weakly correlated (Pearson correlation coefficient equals 0.18).

TABLE 3. OLS-REGRESSION RESULTS. FOREIGN PLANTS (EQUATION 3F)
DEPENDENT VARIABLE: ANNUAL GROWTH RATE IN OUTPUT

Explanatory variables	*Overall sample* (n=223)	*MNEs with overseas R&D* (n=78)
INTERCEPT (a)	0.0072 (0.022)	-0.0032 (0.028)
Δc_F	0.062 (0.042)	0.11 (0.095)
Δl_F	0.80*** (0.050)	0.72*** (0.086)
R_H/Q_F	0.0056* (b) (0.0029)	0.0026 (0.0029)
R_F/Q_F	0.13* (0.077)	0.21*** (0.076)
Adj. R^2	0.73	0.74
F-value	35.6	13.6

Notes: *** and * indicate significance at the 1 and 10 % level, respectively, using a two tailed t-test. Standard errors in parentheses.
(a): The intercept refers to the Metal products industry in 1986-90. Additive dummy variables are included for the other nine industries and three time periods, but the results are not reported here (see Table 1 for the different industries included).
(b): Estimation without R_F/Q_F included, yields a parameter for R_H/Q_F of 0.0064, significant at the 5% level (see Table A2 in Appendix for the complete statistical results).

Distribution of gains between home and foreign plants

Having assessed the separate effects of the firms' home R&D in the plants at home and abroad, we are able to calculate the distribution of the gain in value-added attributed to home R&D between home and foreign plants. From the above figures relating to rates of return and growth in output, it appears that gains are to be found both at home and abroad.

The volume gains for the home and foreign plants, respectively, are calculated as follows: the *percentage point* contribution of home R&D to average annual growth in output (over the period *t-1* to *t*), multiplied by the average "initial value" of output in *t-1*.[19] Hence, the gain for the home plants is computed according to:

$$\left[\hat{\varrho}_{HH}\left(\frac{\bar{R}_H}{Q_H}\right)_{t-1} x100\right]\bar{Q}_{H\,t-1}\ ,$$

and the gain for the foreign plants according to:

$$\left[\hat{\varrho}_{HF}\left(\frac{\bar{R}_H}{Q_F}\right)_{t-1} x100\right]\bar{Q}_{F\,t-1}\ .$$

These numerical computations are performed around estimated parameters and corresponding sample means, as in the previous sub-section. The gains in the home and foreign plants are then added to a total figure, and the home and foreign shares are simply calculated as the share of that total. Computations according to the above formulas indicate that 81% of the total gain in value-added, attributed to the MNEs' home R&D, was realized in home plants, while the remaining 19% was realized in the firms' foreign plants.

Taking into account that the foreign plants in the sample on average accounted for 32% of the total output of the MNEs, there is no support for the assertion that a disproportionate share of the gain from the R&D undertaken in Sweden is exploited in foreign plants. Yet, it is apparent that there are substantial flows of technology to the foreign plants from the Swedish parent companies.

When separate regressions are run for the two time periods 1965-74 and 1974-90, the share of the gain realized in foreign plants increases, from 16% in the earlier period, to 43% in the later period. This is partly a reflection of the increased relative size of the foreign operations over time. However, even after correcting for the relative size, the gains during 1974-90 were to a disproportionately high degree realized in foreign plants.

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[19]The output in *t-1* is expressed in 1990 SEK and the R&D intensity is based on nominal SEK.

Thus, R&D undertaken in the home operations of Swedish MNEs appears to become increasingly geared towards utilization in the MNEs' foreign plants.[20]

R&D in foreign affiliates

Table 2 reports a non-significant rate of return on the firms' foreign R&D in their home plants. This applies to both the overall sample and the sub-sample of MNEs undertaking R&D abroad. Estimations with SUR instead of OLS did not alter the basic results. Separate regressions of different time periods and industries do not produce any significant results either. Thus, the findings for Swedish MNEs do not verify Mansfield's (1984) conclusion that technologies developed in foreign affiliates are systematically transferred to the home plants.[21]

The estimated rate of return on the foreign affiliates' own R&D equals 0.13, and is significant at the 10% level (Table 3), which is the same rate of return that was obtained in the estimation of home R&D in home plants. This is a comforting result: on theoretical grounds we should expect the MNE to locate its R&D activities such that it yields the same rate of return in the home and foreign plants.

Since no signs of technology transfer from foreign affiliates to home plants could be found, the question arises whether there are any effects of foreign activities in general on the home plants of the Swedish MNEs. To investigate this in a very simple way, the degree of internationalization of a MNE (proxied by the share of a firm's total labor force employed abroad) was included additively in the production function [equation (3H)] as a component of the disembodied technological change (λ_H). The results from this regression show that the level of internationalization in the beginning of a four to five year period was not significantly associated with the average annual growth of

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[20]Some caution should be exercised in the interpretation, since the overall sample analyzed earlier is here split in two. This implies that partly different populations of firms are included in the two sub-samples.

[21]Mansfield (1984) employed a similar model, but used a prior measurement of growth in total factor productivity (DTFP) from a source other than his R&D data as dependent variable. The model estimated in the present paper has growth in output as the dependent variable. Since the rate of return interpretation with respect to R&D is identical when using growth in output or DTFP, equation (3H) can be rewritten and estimated with DTFP as dependent variable. However, doing so did not change the results.

output in the home plants over that period. A more elaborate analysis is, of course, necessary in order to draw any conclusions on the impact of internationalization on home plants.

6. Concluding remarks

The estimated rate of return on Swedish multinationals' home R&D in their home plants is positive, and in line with estimates obtained from other countries. The rate of return also appears to have increased over time. In addition to being utilized in home plants, the empirical results suggest that R&D-generated knowledge is transferred to foreign plants.

Numerical calculations suggest that around four-fifths of the total gain in value-added attributed to the firms' home R&D is realized in the home plants while the remaining fifth benefitted the MNEs' foreign plants. Taking into account that the foreign plants in the sample on average accounted for less than a third of the total output of the MNEs, there is no support for the assertion that a disproportionate share of the gain from the R&D undertaken in Sweden are exploited in foreign plants, at least when considering the 1965-90 sample. Yet, it is apparent that there are substantial flows of technology to the foreign plants from the Swedish parent companies.

Analyses of separate periods give some indication that the foreign plants' share of the gain has increased over time. This may imply that R&D undertaken in Sweden is becoming more oriented towards utilization in foreign plants. However, in order to sustain large-scale R&D units at home, it is crucial for the MNEs to utilize R&D-generated knowledge world-wide in their operations.

No significant evidence could be found for technology transfer taking place from the firms' foreign plants to their home plants. In view of the orientation of R&D in foreign affiliates towards more adaptive work, this finding comes as no surprise. Even if some degree of technology transfer probably does take place in this direction, the positive effects are either too small to measure, or offset by negative effects, such as increased leakage of home technology. Perhaps we are also looking at foreign plants at different stages in the value-added chain. Foreign affiliates could be downstream which might imply that their R&D is not applicable to the parent company's production.

Areas for future research along the lines of the present paper include an assessment of the impact of MNEs' foreign activity on their home operations, taking into account variables other than R&D. In this respect it would also be valuable to analyze the impact on the home country outside the boundaries of the MNE. In addition, it would be interesting to follow up the present analysis with newer data to examine whether the utilization of Swedish R&D in foreign affiliates is increasing over time.

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Appendix

TABLE A1. MEAN VALUES OF VARIABLES
HOME AND FOREIGN PLANTS

Variable	*Overall sample (n=223)*	*MNEs with overseas R&D (n=78)*
Δq_H	0.021 (0.096)	0.016 (0.087)
Δc_H	0.030 (0.16)	0.034 (0.10)
Δl_H	-0.0040 (0.077)	-0.00018 (0.065)
R_H/Q_H	0.064 (0.091)	0.12 (0.12)
R_F/Q_H	0.019 (0.025)	0.030 (0.036)
Δq_F	0.14 (0.19)	0.13 (0.16)
Δc_F	0.11 (0.22)	0.094 (0.15)
Δl_F	0.090 (0.19)	0.092 (0.17)
R_H/Q_F	0.72 (2.43)	0.84 (3.61)
R_F/Q_F	0.025 (0.091)	0.072 (0.14)

Note: Standard deviations in parentheses.

TABLE A2. OLS-REGRESSION RESULTS. FOREIGN PLANTS (EQ. 3F)
DEPENDENT VARIABLE: ANNUAL GROWTH RATE IN OUTPUT

Explanatory variables	*Overall sample (n=223)*
INTERCEPT (a)	0.0092 (0.022)
Δc_F	0.057 (0.042)
Δl_F	0.81*** (0.050)
R_H/Q_F	0.0064** (0.0029)
Adj. R^2	0.73
F-value	37.4

Notes: ***, ** and * indicate significance at the 1, 5, and 10 % level, respectively using a two tailed t-test. Standard errors in parentheses.
(a): The intercept refers to the Metal products industry in 1986-90. Additive dummy variables are included for the other nine industries and three time periods, but the results are not reported here (see Table 1 for the different industries included).

CHAPTER IV

THE SIMULTANEOUS RELATIONSHIP BETWEEN R&D AND FOREIGN SALES

1. Introduction

In small open economies where firms are dependent on foreign markets for their survival, multinational enterprises (MNEs) often play a pronounced role. In Sweden, for example, MNEs accounted for over 40% of industrial output, around half of overall manufacturing exports and more than 80% of the country's industrial R&D in 1990.

The vast majority of the Swedish multinationals' R&D is undertaken at home, while most of their sales are in foreign markets.[1] This suggests that technologies developed at home to a large extent are exploited abroad. On the other hand, it has been proposed that the expansion in foreign sales by MNEs has enabled the firms to grow large and spend more resources on R&D, and that this has had a positive impact on Sweden's technological base (Håkansson, 1980, and Swedenborg, 1982). Similar arguments have also been raised in the Canadian context by Globerman (1994) and McFetridge (1994). The activities of MNEs may, therefore, be potentially important both for the technological development and international competitiveness of small open economies.

In the theoretical literature on MNEs, a two-way reinforcing relationship between R&D and foreign sales has been suggested by e.g. Caves (1996). Firms with higher R&D outlays, should, *ceteris paribus,* have a technological advantage relative to other firms and, therefore, be more successful in foreign markets. At the same time, an expansion of sales should, in turn, facilitate further R&D investments, since the created knowledge can be utilized to a higher degree.

The only previous empirical study testing the two-way relationship between R&D

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[1]By foreign sales is here understood as the sum of parent company exports and net sales by foreign affiliates. Intra-firm exports from a parent company to its foreign affiliates are excluded.

and foreign sales is Hirschey (1981), who used data on MNEs from the United States. He found evidence of a positive impact of foreign sales on R&D, but not the other way around. However, the US is a country with a large domestic market, and we are interested in testing whether Hirschey's results are applicable to small countries, such as Sweden.

In the present study, the simultaneous relationship between R&D and foreign sales in Swedish MNEs is considered. The analysis is based on detailed firm-level data covering practically all Swedish manufacturing MNEs in 1986 and 1990. Our empirical results suggest a positive and significant effect in both directions.

The chapter is organized as follows: Theoretical aspects and previous empirical literature regarding R&D and foreign operations are discussed in section 2. The data and econometric specification are described in section 3, and the exogenous variables are introduced in section 4. The empirical results are presented in section 5, and the final section concludes.

2. Theoretical background and earlier studies

Possession of firm-specific advantages is generally argued to be required before a firm is able to penetrate foreign markets (e.g. Hymer, 1960 and Caves, 1971). Such advantages are considered necessary to offset the costs of setting up and operating affiliates across geographical, cultural, or legal boundaries. Firm-specific advantages increase the market concentration and can be derived from factors that create barriers to entry for new competitors, e.g. superior technology, human capital, or product differentiation (Lall, 1980).

In particular, firms develop new, and improve existing, products and processes by spending resources on R&D. Successful firms may obtain a technologically based competitive edge relative to competitors, in turn leading to a possible increase in foreign market shares. Several empirical studies have supported such a one-way causal relationship, for example Swedenborg (1982) using Swedish data, Lall (1980) and Kravis and Lipsey (1992) analyzing U.S. data, Greenhalgh (1991) studying U.K. industry data, and Hirsch and Bijaoui (1985) considering an Israeli data set.

Turning to the determinants of R&D expenditures, market structure and factors that create internal or external funds, e.g. profitability, solidity, or cash flow, should be of importance (Caves, 1996). When a firm expands sales, at home or abroad, the R&D-created knowledge can be utilized more extensively, leading to an increased rate of return on each dollar spent on R&D.[2] More internal funds will also be available to finance further R&D projects if the firm earns profits from its foreign operations (Pugel, 1985, and Himmelberg and Petersen, 1994).[3]

A number of studies maintain that there is a positive relationship between R&D activities and firm size, measured as total sales (for a survey, see Cohen and Levin, 1989). These studies argue that large firm size facilitates R&D investment on similar grounds as noted above: higher returns on each R&D dollar spent when the firm has a large volume of sales over which to spread fixed R&D costs (Pakes and Schankerman, 1984). For MNEs in small countries, there is less scope to finance R&D investments by sales in the home market alone. Foreign markets will, thus, be essential for expansion as well as for the financing of R&D activities. If a firm has a large country as its home-base, for instance the United States or Japan, the arguments are weaker.

The study by Hirschey (1981), mentioned above, tested the causal relationship between R&D and foreign sales in a simultaneous model using data on US multinationals. He found no support for a simultaneous relationship between R&D and foreign sales, but only that foreign sales had a positive impact on R&D expenditures.[4]

Foreign markets are either served through exports from the parent company or by production in foreign affiliates. We do not know of any studies directly evaluating what role R&D plays in the choice between exports and foreign production. According to the product cycle theory (Vernon, 1966), the choice depends on the historical phase of the product. Vernon argues that R&D aimed at developing new products and

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[2]Mansfield, *et al.* (1979) reports that MNEs based in the United States expect to earn over 30% of the returns on R&D through utilization of the technology in foreign markets. This percentage is likely to be even higher for firms based in a small open economy.

[3]It has been argued that large firms have greater possibilities to raise external funds for R&D. This capacity should, however, be related to the solidity and profitability of the firm and not to size *per se*.

[4]In a related study (Hughes, 1985), using U.K. industry level data, the simultaneity between R&D and exports was taken into account. The results suggest that R&D has a positive effect on exports. The reverse impact how exports affect R&D activities; however, was not tested.

processes should primarily result in exports from the home country, while R&D aimed at improving existing products and processes should tend to favor foreign production.

3. Data and econometric method

The data on Swedish MNEs used in the empirical analysis has been collected by the Industrial Institute for Economic and Social Research (IUI) in Stockholm. Practically all Swedish-owned firms in manufacturing with more than 50 employees and with at least one majority-owned producing affiliate abroad are included in the data set.[5] Data for 1986 and 1990 are pooled in the analysis, yielding a sample of 202 observations, of which 88 are taken from the 1986 survey and 114 from the 1990 survey. A total of 147 different MNEs are analyzed, of which 55 are included twice, and 92 once, in the sample.

When relating R&D to foreign operations, previous studies have used several different measures. For example, intensities have been compared with absolute levels and foreign operations have often been represented by exports. In the present study, the two main variables are defined as follows:

***RD/TS*:** R&D intensity, which equals the firm's total R&D expenditures, *RD*, divided by total sales, *TS*. This is the standard measure of technological intensity (see e.g. Scherer, 1980).

***FS/TS*:** Share of total sales in foreign markets. Foreign sales, *FS*, is here defined as parent company exports plus net sales by foreign affiliates (intra-firm exports from a parent company to its foreign affiliates are excluded in *FS*). We argue that *FS* is a better measure of the firm's international activities than either exports or affiliate sales taken separately. *FS* is divided by *TS*, to obtain the foreign sales intensity.

The use of intensities controls for historical factors of the MNEs as well as for firm size, and is also a way to reduce heteroscedasticity in the regression analysis. A positive relationship is expected between firm *i*'s R&D intensity, RD_{it}/TS_{it}, and its degree

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[5]It could be argued that the sample should also contain firms without production facilities abroad, but comparable data for non-multinationals were not available. However, many small firms with a single facility abroad, and that have had production abroad for only a few years, are also included in our sample. These small MNEs represent a group of firms with limited foreign operations.

of internationalization, FS_{it}/TS_{it}, at time t.[6] The model characterizing the relationship between these two variables is specified as follows:

$$\frac{FS_{it}}{TS_{it}} = \beta_0 + \beta_1 \frac{RD_{it}^*}{TS_{it}} + Z_1'\beta + \epsilon_{it} , \qquad \textbf{(1)}$$

$$\frac{RD_{it}^*}{TS_{it}} = \gamma_0 + \gamma_1 \frac{FS_{it}}{TS_{it}} + Z_2'\gamma + \mu_{it} , \qquad \textbf{(2a)}$$

$$\frac{RD_{it}}{TS_{it}} = \begin{cases} \dfrac{RD_{it}^*}{TS_{it}} & if \ \dfrac{RD_{it}^*}{TS_{it}} > 0 \\ 0 & if \ \dfrac{RD_{it}^*}{TS_{it}} \leq 0 \end{cases} . \qquad \textbf{(2b)}$$

The residuals are assumed to have the desired properties: $\varepsilon \sim N(0,\sigma_\varepsilon^2)$ and $\mu \sim N(0,\sigma_\mu^2)$, $E(\varepsilon_{it}\varepsilon_{jt})=0$ and $E(\mu_{it}\mu_{jt})=0$ for $i \neq j$.[7] However, $E(\mu_{it}\varepsilon_{it}) \neq 0$, since a simultaneous relationship is expected between *RD/TS* and *FS/TS*. The hypothesis of no simultaneity was tested, and rejected, using a Hausman (1978) test.

The method used to estimate the interactions between *RD/TS* and *FS/TS* is a variant of 2SLS with limited endogenous variables, outlined in Nelson and Olson (1978). OLS can be used to estimate the reduced and structural form of equation (1). The other endogenous variable, *RD/TS*, is, however, characterized by some concentration of zeroes (about 18%), i.e. the firms with no R&D expenditures. When estimating equation (2) in

[6] Since today's R&D will not yield profits or enhance competitiveness until future time periods, it could be argued that a time lag should be used in the R&D variable. Time lags in the regression variables are, however, always a problem in cross-section analysis. The use of time lags would also have reduced the sample considerably (from 202 to 55 observations). Furthermore, R&D intensities are rather stable in the short or medium term. For example, the Pearson correlation coefficient between firms' R&D intensities in 1986 and 1990, for the 55 MNEs included in both years, was estimated to 0.83.

[7] It should be noted that $E(\mu_{is}\mu_{it}) \neq 0$ and $E(\varepsilon_{is}\varepsilon_{it}) \neq 0$ for $s \neq t$. A firm with a high R&D intensity in time s, is also expected to have a high R&D intensity in time t. Although not taken into account in the estimation procedure, the parameter estimates will not be inconsistent. Most firms are only observed once in the sample, implying that this possible autocorrelation should not be a serious problem.

the first and second stage of 2SLS, the Tobit method is therefore employed.[8]

The latent variable, $(RD/TS)^*$, can be interpreted as an index of R&D intensity, of which *FS/TS* is a function. The *Z*'s are vectors including firm and industry-specific attributes, while the β's and γ's denote parameters or vectors of parameters showing the impact of the explanatory variables on the dependent variable. The simultaneous Tobit method yields consistent parameter estimates, but the asymptotic standard errors of the parameter estimates are underestimated. In order to correct for this, the asymptotic variance-covariance-matrix is derived and the standard errors recalculated according to Amemiya (1979).

The parameters in equation (1) are marginal effects. The estimate of γ_1 in the Tobit equation cannot be interpreted as a marginal effect on the actual dependent variable *RD/TS*, however.[9] Rather, it is a combination of the marginal effect on the R&D intensity and the effect on the probability that the firm will undertake any R&D at all (McDonald and Moffitt, 1980).[10] The parameters β_1 and γ_1 show the direct effect of one intensity on another. The marginal effect of R&D on foreign sales, and vice versa, can be obtained by the following formulas (derived in appendix A);

$$\frac{\partial FS}{\partial RD} = \frac{\beta_1}{1 - A} \text{ , } where\ A = \beta_0 + Z_1'\beta \text{ .} \tag{3}$$

$$\frac{\partial^* RD}{\partial^* FS} = C + \gamma_1 \text{ , } where\ C = \gamma_0 + Z_2'\gamma \text{ .} \tag{4}$$

The ∂^* in equation (4) denotes the marginal *and* probability effect of *FS* on *RD*.

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[8]There may be a separate process determining whether a firm undertakes any R&D from how much R&D the firm does, given that it has a R&D facility. In such case, a Heckman (1976) two-step procedure would be appropriate for equation (2). To our knowledge, no simultaneous Heckman procedure is available.

[9]γ_1 is a marginal effect of *FS/TS* on the latent variable $(RD/TS)^*$.

[10]The marginal effect of *FS/TS* on *RD/TS*, $\partial(RD/TS)/\partial(FS/TS)$, simply equals $F(z)\gamma_1$, where $F(z)$ is the cumulative normal distribution and $z = X'\gamma/\sigma_\mu$. *X* is a vector of explanatory variables and γ is the vector of estimated Tobit parameters. The *z* is calculated around the means of *X*.

4. Exogenous variables

In the following, we present the exogenous variables in the model, their definitions and expected impact on the two dependent variables. The explanatory variables included in equation (1), except for high initial capital costs and the size of the home market, are related to firm-specific advantages. These factors have been investigated in earlier empirical studies (e.g. Lall, 1980 and Swedenborg, 1979 and 1982). The explanatory variables in equation (2) are related to market structure and the possibilities to raise funds for R&D. Table 1 summarizes the explanatory variables included in each equation.[11] The signs (+ or -) show the expected effect on the dependent variable.

HIC: High initial capital costs at the plant level (*HIC*) is defined as the average plant size, measured as the average book value of equipment, tools, and real estate of a MNE's foreign affiliates.[12] We assume that plant level capital costs are partly industry-specific and therefore exogenous in the model. Since *HIC* makes it costly for new firms to enter the market, we expect it to be positively associated with *FS/TS*. However, we do not expect that *HIC* is related to *RD/TS*.[13]

LS: Labor skills. MNEs endowed with human capital in terms of a skilled labor force should have an advantage relative to other firms. *LS* is measured as the average wage in the Swedish operations of the MNEs, and is expected to have a positive influence on *FS/TS*.[14] Even if the wage level to some extent is a choice variable for the firm, we treat *LS* as exogenous in the model, because the wage setting on the Swedish labor market is largely determined by industry-level bargaining. The wage dispersion across firms in a certain job category should therefore be limited. Thus, *LS* rather

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[11]See Table 10 in Appendix B for definitions, means and standard deviations of variables.

[12]This definition is made under the assumption that each affiliate operates at the optimal level of scale. No data is available for the plant size of the MNEs' domestic plants.

[13]We do not know of any empirical evidence of a relationship between the variables *HIC* and *RD/TS*. Firms operating e.g. in basic industries often have high initial capital requirements, but low R&D intensity. On the other hand, certain firms in chemicals may be characterized by high R&D intensity and small plants.

[14]We use the Swedish average wage, since the average wage for the whole MNE is largely influenced by the income levels in the different host countries where the firms operates. Hence, we compare the wage levels of firms in the same country.

reflects the composition of the labor force, which is partly industry specific.

HOME: Size of the home country market. Empirical observations on Swedish and other small-country MNEs indicate that they are more international than MNEs originating from larger countries. *HOME* is included in equation (1), and we expect that a small home market forces firms to locate a large share of their sales in foreign markets. Hence a negative effect is expected on *FS/TS*. The variable *HOME* is measured as total industry sales in million SEK on the Swedish market for the product groups of the MNE.

CONC: World market concentration. Firms operating in concentrated industries are more inclined to compete using strategies other than price, including R&D, advertising, and product differentiation. *CONC* is measured as the sum of the world market shares of the four largest firms in the industry where the MNE's largest division operates.[15] A positive effect of *CONC* on R&D intensity is expected. *CONC* is not included in equation (1) since it is regarded more as an outcome of firm-specific advantages rather than a cause of such advantages. The world market concentration is taken to be exogenous in the empirical model.[16]

PROFIT: gross profit margin, defined as operating income before depreciation and financial items divided by total sales. A higher profit implies a greater ability to raise internal funds to finance R&D projects. We expect *PROFIT* to exert a positive impact on firms' R&D intensity. Again, it can be discussed whether this variable is exogenous in the model. We argue that this is reasonable, considering that a firm's profit level for a certain year will to a large extent be influenced by business cycles and stochastic shocks.[17] The reason to include *PROFIT* is mainly for the fund raising capacity in one point in time, and not the MNEs long term profitability or survival, for example.

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[15]The "world market" defined by the MNEs corresponds to the 5-digit, or more detailed, ISIC industrial classification.

[16]Although the market concentration may be endogenously determined in the long run, it is here regarded as predetermined. The *world market concentration* for a given industry is rather stable, and only to a limited degree affected by the actions of individual firms.

[17]Analysis of individual Swedish firms' profitability over time produces a very irregular pattern.

TABLE 1. EXPLANATORY VARIABLES INCLUDED IN EACH EQUATION AND EXPECTED IMPACT ON THE DEPENDENT VARIABLES

Explanatory variables	*Description*	*Dependent variable* FS/TS Equation (1)	RD/TS Equation (2)
RD/TS	Total R&D / Total sales	+	
FS/TS	Foreign sales / Total sales		+
HIC	High initial capital costs	+	
LS	Labor skill	+	
HOME	Size of home market	-	
CONC	World market concentration		+
PROFIT	Profit margin		+

Note: Definitions and means for the variables are available in Table 10, Appendix B.

With regard to absolute firm size, we argue that size *per se* should not confer a distinct firm-specific advantage, but is rather a consequence of, e.g., scale economies. As mentioned above, some previous studies have claimed that there is a positive relationship between size and R&D intensity. In analyzing the simultaneous relationship between R&D and foreign sales, Hirschey (1982) included firm size in the R&D equation, but found no significant effect. Moreover, Cohen *et al.*, (1987) concluded that overall firm size is not significantly related to R&D intensity. We have therefore not included size in our basic model. However, a variant is estimated, including firm size, measured as total number of employees (*EMP*).[18]

In the empirical analysis we use dummy variables to control for fixed industry and time effects which may influence the levels of *FS/TS* and *RD/TS*.[19] Furthermore, by

[18]Ideally, we should measure firm size as total sales, *TS*, but this variable would partly be endogenous since it includes foreign sales, *FS*.

[19]An additive time dummy for 1986 and additive dummies for the following industries are included in all estimations: food, textile, basic chemicals, pharmaceuticals & advanced chemicals, paper & pulp, iron & steel, metal products, machinery, electronics, transport equipment, and "other industries". Since an

including interaction dummies, we also examine whether the estimated parameters for the endogenous variables, β_1 and γ_1, are different for industries undertaking R&D aimed for *product* and *process* innovations, respectively. We assume that R&D undertaken in the engineering and pharmaceutical industries is primarily oriented toward product innovations, while R&D in iron & steel, paper & pulp, textiles, food, cement, and wood, is assumed to be basically geared towards process innovations.

Finally, with regard to exogenous variables, a few comments on the issue of rival R&D are appropriate, even if we have not included any such explicit variable. Theoretically, the issue of competitors' R&D interaction is not fully settled. Depending on whether the firms' R&D are substitutes or complements, and if spillovers are important, a rival's R&D may either increase, decrease or have no effect on the R&D expenditures of a firm. In addition, an empirical application would require detailed data on rival R&D, which is not available. Most of the Swedish MNEs have their major competitors abroad, and only in a handful cases can we identify firms which are close rivals. An interesting observation is that rivals tend to have approximately the same R&D intensities.[20] By means of the industry dummies discussed above, we have to some extent taken into account rival R&D, even if a more detailed analyis of this issue would have been interesting.

5. Empirical results

The results of the simultaneous estimation are provided in Tables 2 and 3 below. As shown in Table 2, the estimated parameters of *RD/TS* and *FS/TS* in equations (1) and (2), respectively, are both positive, and significantly different from zero at the 1% level, using a two tailed t-test.[21]

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individual firm is never included more than twice in the pooled sample, it is not possible to analyze firm-specific effects.

[20]There are around 10 cases in the data set where two or more firms are close rivals, e.g. pharmaceuticals, transport equipment, paper, pulp and wood products, machinery, textile, and cement.

[21]In the main econometric model we do not decompose foreign sales into parent exports and affiliate net sales. Estimations including parent exports (*EXP*) and affiliate net sales (*FQ*) were also undertaken. Equation (1) was estimated twice with *EXP/TS* and *FQ/TS*, respectively, as dependent variables. The results were not satisfactory since multicollinearity arose in equation (2) in the second stage of 2SLS.

TABLE 2. RESULTS FROM SIMULTANEOUS TOBIT ESTIMATIONS

	Dependent variable	
Explanatory variables	*FS/TS* Equation (1)	*RD/TS* Equation (2)
RD/TS	5.18*** (1.31)	--
FS/TS	--	0.083*** (0.033)
HIC	6.54 E-4** (3.08 E-4)	--
LS	-0.394 (0.485)	--
HOME	-4.46 E-6 (4.05 E-6)	--
CONC	--	2.29 E-4* (1.39 E-4)
PROFIT	--	0.078** (0.034)
Adjusted R^2	0.35	--
F-value	8.37	--
Log-likelihood ratio	--	118.8
Number of observations	202	202
Left-censored obs.	--	34

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent level, respectively, using a two tailed t-test. Standard errors in parentheses. Intercepts, dummies for time and industries are shown in Table 4, Appendix B. First-stage estimates are shown in Table 5, Appendix B.

By calculating the marginal effects according to equations (3) and (4), the direct effect of an increase in *RD* on *FS*, and vice versa, is obtained. The first row in Table 3 indicates that both $\partial FS/\partial RD$ and $\partial^* RD/\partial^* FS$ are positive and significant at the 1% level. This may suggest that R&D expenditures increase sales in foreign markets and that sales abroad in turn facilitate R&D. Thus, R&D expenditures and foreign sales seem to reinforce each other in accordance with our main hypothesis.

Considering the estimated derivatives for the two groups "product R&D" and "process R&D" in Table 3, we notice that $\partial FS/\partial RD$ is significant at the 1% level in the product-group and at the 5% level in the process group. It is also noted that the difference in the parameter estimate between the two groups is not significant (see Table 6, Appendix B). The difference is, however, significant for $\partial^{*}RD/\partial^{*}FS$. The marginal effect for product R&D is significant at the 1% level, while it is not significant for process R&D, meaning that we cannot tell if a change in *FS* affects *RD* in this group. Hence, the two-way relationship between R&D and foreign sales is only verified in the product R&D group. In the concluding section we discuss possible explanations for this result.

TABLE 3. ESTIMATED DERIVATIVES FOR THE MAIN VARIABLES
TOTAL SAMPLE AND ACROSS INDUSTRIES

	Estimated derivative	
	$\partial FS/\partial RD$ Equation (3)	$\partial^{*}RD/\partial^{*}FS$ Equation (4)
All industries (n=202)	11.14*** (1.87)	0.048*** (0.013)
"Product-R&D" group (n=104)	6.03*** (1.79)	0.044*** (9.26 E-3)
"Process-R&D" group (n=98)	10.35** (5.01)	2.73 E-3 (0.023)
Significant difference between industries?	No	Yes

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent, respectively, using a two tailed t-test. Standard errors in parentheses. The estimated derivative equals the marginal effect in equation (3), but the marginal *and* probability effect in equation (4). The original regressions with industry estimates are available in Tables 6 and 7, Appendix B.

With regard to the exogenous variables in the model (Table 2), we first observe for the foreign sales equation that the variable measuring high initial capital costs, *HIC*, is positively related to *FS/TS*, as expected. The parameter is significant at the 5% level.

The estimated parameters for *LS*, labor skill in the MNE, and *HOME*, size of the home market for the firm's products, are not significant in the foreign sales equation.[22]

Turning to the R&D equation, we see that world market concentration, *CONC*, is positively associated with *RD/TS*. The estimated parameter is, however, only significant at the 10% level. Thus, there is weak evidence that concentration favors competition by R&D. Finally, the parameter of the profit variable, *PROFIT*, also has the expected positive sign, and is significant at the 5% level, indicating that internal fund raising may be important in a firm's decision to undertake R&D.

As discussed above, we also estimate a variant of the model with firm size measured as total number of employees (*EMP*), as an exogenous variable in the R&D equation. However, *EMP* did not turn out to be significant, and did not alter the results for the other variables, as can be seen from Table 8 in Appendix B.

6. Conclusions

This paper analyzed the simultaneous relationship between R&D and foreign sales in Swedish multinationals in manufacturing. Positive and statistically significant effects were found in both directions, supporting the hypothesis of a two-way reinforcing relationship. The only previous study explicitly addressing this issue used data for U.S. manufacturing firms, but did not find evidence of a simultaneous relationship. This may suggest that the link between R&D and foreign sales is stronger for MNEs originating from small home economies, and that the relationship is weaker for firms from countries with large home markets. Industrial firms from small countries have limited growth opportunities in their home markets, and hence are more dependent on foreign sales.

When analyzing product- and process-related R&D separately, proxied by the MNE's industry classification, the two-way relationship is only found for product R&D. The weaker relationship in the process group may be explained in part by the fact that the major R&D investors are found in product industries. Another reason may be that

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[22]One possible explanation for the poor performance of *LS* may be that the average wage is not an appropriate indicator of labor skill; however, no alternative measure was available in our data set. Measurement problems in *HOME* may also have affected the results. First, *HOME* is the only variable in our data that is taken from a source other than the IUI survey. Second, the firms' classification of product groups did not correspond exactly to the official industrial classification system (ISIC).

product innovations are essentially associated with entry into new product markets, while process R&D aims to reduce the costs of producing a given range of products. Moreover, Mansfield (1984) suggests that firms are more hesitant to utilize their process technologies abroad as compared with their product technologies. In a patent context, he argues that once process technologies go abroad, it is difficult to determine whether foreign firms are illegally imitating them.

Since the present study analyzes only what is taking place at the firm level, we are limited in our abilities to draw policy conclusions. However, in the case of small MNE-dependent countries like Sweden, it is plausible that; (i) disadvantages relating to firms' incentives to undertake R&D, such as unfavorable tax treatment of R&D or a limited supply of qualified researchers, may in the long term erode the home country's international competitiveness, while (ii) any eventual regulations constraining firms' foreign expansion could lead to reduced R&D, most of which is undertaken at home, implying the possibility of a slower technological development. Future research should more directly attempt to assess the impact of multinational activity on a home country's international competitiveness and technological development.

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Appendix A

The marginal effect of an increase in *RD* on *FS*, can be derived by first separating total sales, *TS*, in equation (1) into foreign, *FS*, and domestic sales, *DS*

$$\frac{FS}{FS + DS} = A + \beta_1 \frac{RD}{FS + DS} , \tag{A1}$$

$$where \ A = \beta_0 + Z_1'\beta ,$$

$$TS = FS + DS .$$

After that we solve for *FS:*

$$FS = \frac{1}{1 - A} (A \ DS + \beta_1 RD) . \tag{A2}$$

This gives the partial derivative:

$$\frac{\partial FS}{\partial RD} = \frac{\beta_1}{1 - A} . \tag{A3}$$

In a similar way, the effect of *FS* on *RD* can be derived:

$$\frac{\partial^* RD}{\partial^* FS} = C + \gamma_1 , \tag{A4}$$

$$where \ C = \gamma_0 + Z_2'\gamma .$$

In this case, ∂^* indicates the total partial effect (marginal and probability effect). *A* and *C* are calculated around the means of Z_1 and Z_2.

The standard error of $\partial FS/\partial RD$ is then calculated, using a first-order linear approximation, according to Blom (1980):

$$\sigma_{\partial FS \,/\, \partial RD} = \sqrt{Var\left(\frac{\beta_1}{1 - A}\right)} = \sqrt{Var\left(g\left(\beta_0, \beta_1, ..., \beta_k\right)\right)} = \tag{A5}$$

$$= \sqrt{\sum_{i=0}^{k} Var(\beta_i) \left(\frac{\partial g}{\partial \beta_i}\right)^2 + 2 \sum_{i=0,\, i<j}^{k} Cov(\beta_i, \beta_j) \left(\frac{\partial g}{\partial \beta_i}\right) \left(\frac{\partial g}{\partial \beta_j}\right)} \; ,$$

where

$$\frac{\partial g}{\partial \beta_1} = \frac{1}{1 - A} \; ,$$

$$\left.\frac{\partial g}{\partial \beta_i}\right|_{i \neq 1} = \frac{\beta_1}{(1 - A)^2} X_i \; .$$

The standard error of $\partial^* RD / \partial^* FS$ is calculated in a similar manner:

$$\sigma_{\partial^* RD \,/\, \partial^* FS} = \sqrt{\sum_{i=0}^{k} Var(\gamma_i) \left(\frac{\partial h}{\partial \gamma_i}\right)^2 + 2 \sum_{i=0,\, i<j}^{k} Cov(\gamma_i, \gamma_j) \left(\frac{\partial h}{\partial \gamma_i}\right) \left(\frac{\partial h}{\partial \gamma_j}\right)} \; , \qquad \textbf{(A6)}$$

where

$$h = h\,(\gamma_0, \gamma_1, \ldots, \gamma_k) \; ,$$

$$\frac{\partial h}{\partial \gamma_1} = 1 \; ,$$

$$\left.\frac{\partial h}{\partial \gamma_i}\right|_{i \neq 1} = X_i \; .$$

Appendix B

TABLE 4. SUPPLEMENT TO TABLE 2. SECOND-STAGE ESTIMATES OF DUMMY VARIABLES FOR TIME AND INDUSTRIES

Dummy variables	Dependent variable	
	FS/TS Equation (1)	*RD/TS* Equation (2)
Intercept	0.650*** (0.090)	-0.060*** (0.016)
Dummy 1986	0.026 (0.037)	6.25 E-4 (4.51 E-3)
Dummy food industry	-0.281*** (0.077)	0.024* (0.014)
Dummy textiles	-0.048 (0.082)	6.44 E-3 (0.011)
Dummy basic chemicals	-0.035 (0.071)	5.10 E-3 (9.10 E-3)
Dummy pharmaceuticals & advanced chemicals	-0.178** (0.073)	0.032*** (7.85 E-3)
Dummy non-electrical machinery	0.094* (0.055)	-3.42 E-3 (8.01 E-3)
Dummy electrical machinery	-0.114* (0.073)	0.020** (8.99 E-3)
Dummy transport equipment	-0.140 (0.122)	0.038*** (0.012)
Dummy paper & pulp	-9.51 E-3 (0.070)	-1.59 E-4 (8.12 E-3)
Dummy iron & steel	-0.052 (0.108)	6.84 E-3 (0.013)
Dummy other industries	-0.128** (0.060)	0.014 (9.31 E-3)

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. Standard errors in parentheses. The metal products industry is the reference group for the industry dummies.

TABLE 5. SUPPLEMENT TO TABLE 2. FIRST STAGE ESTIMATES

Explanatory variables	*Dependent variable*	
	FS/TS Equation (1)	*RD/TS* Equation (2)
Intercept	0.448***	-0.040***
	(0.072)	(0.010)
HIC	1.06 E-3***	7.10 E-5**
	(2.43 E-4)	(3.20 E-5)
LS	0.294	0.124**
	(0.371)	(0.050)
HOME	-2.64 E-6	1.84 E-7
	(3.60 E-6)	(4.79 E-7)
CONC	2.96 E-3***	4.70 E-4***
	(6.09 E-4)	(8.11 E-5)
PROFIT	0.021	0.071**
	(0.213)	(0.031)
Dummy 1986	0.071**	7.71 E-3*
	(0.030)	(4.08 E-3)
Dummy food industry	-0.305***	-2.43 E-3
	(0.067)	(9.01 E-3)
Dummy textiles	-0.052	1.97 E-3
	(0.071)	(9.99 E-3)
Dummy basic chemicals	-0.039	1.31 E-4
	(0.062)	(8.21 E-3)
Dummy pharmaceuticals &	-0.017	0.029***
advanced chemicals	(0.053)	(7.09 E-3)
Dummy non-electrical	0.102**	4.43 E-3
machinery	(0.048)	(6.39 E-3)
Dummy electrical machinery	-0.030	0.019**
	(0.060)	(8.09 E-3)
Dummy transport equipment	0.042	0.034***
	(0.093)	(0.013)
Dummy paper & pulp	-0.044	-6.25 E-3
	(0.058)	(8.17 E-3)
Dummy iron & steel	-0.086	-7.62 E-3
	(0.094)	(0.013)
Dummy other industries	-0.074	9.28 E-3
	(0.052	(6.96 E-3)
Adjusted R^2	0.36	--
F-value	8.12	--
Log-likelihood ratio	--	126.72
Number of observations	202	202
Left-censored obs.	--	34

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. Standard errors in parentheses. The metal products industry is the reference group for the industry dummies.

TABLE 6. RESULTS FROM SIMULTANEOUS ESTIMATIONS FOR PRODUCT AND PROCESS INDUSTRIES. SECOND STAGE ESTIMATES

	Dependent variable			
	FS/TS Equation (1)		*RD/TS* Equation (2)	
Explanatory variables	Parameter	Std. error	Parameter	Std.error
RD/TS	2.56***	0.940	--	--
(*RD/TS*)×Dummy Process	2.23	2.95	--	--
FS/TS	--	--	0.071***	0.025
(*FS/TS*)×Dummy Process	--	--	-0.116***	0.017
HIC	9.40 E-4***	3.05 E-4	--	--
LS	0.291	0.477	--	--
HOME	-5.36 E-6	4.47 E-6	--	--
CONC	--	--	2.53 E-4**	1.11 E-4
PROFIT	--	--	0.051*	0.029
Intercept	0.540***	0.090	-0.050***	0.013
Dummy 1986	0.056	0.037	3.04 E-3	3.79 E-3
Dummy food industry	-0.302***	0.080	0.056***	0.012
Dummy textiles	-0.056	0.083	0.063***	0.013
Dummy basic chemicals	-0.017	0.084	0.076***	0.014
Dummy pharm. & adv. chemicals	-0.148*	0.084	0.082***	9.45 E-3
Dummy non-electrical machinery	0.122**	0.056	-2.82 E-3	6.60 E-3
Dummy electrical machinery	-0.067	0.073	0.019**	7.57 E-3
Dummy transport equipment	-0.025	0.121	0.037***	9.80 E-3
Dummy paper & pulp	-0.063	0.071	0.072***	0.013
Dummy iron & steel	-0.072	0.126	0.066***	0.014
Dummy other industries	-0.130	0.072	0.074***	0.011
Adjusted R^2	0.32		--	
F-value	6.84		--	
Log-likelihood ratio	--		152.40	
Number of observations	202		202	
Left-censored obs.	--		34	

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. First-stage estimates are shown in Table 7. The metal products industry is the reference group for the industry dummies.

TABLE 7. SUPPLEMENT TO TABLE 6. FIRST STAGE ESTIMATES

	Dependent variable			
	FS/TS Equation (1)		*RD/TS* Equation (2)	
Explanatory variables	Parameter	Std. error	Parameter	Std.error
HIC	1.29 E-3***	4.26 E-4	1.67 E-5	4.50 E-5
HIC×Dummy Process	-3.38 E-4	5.21 E-4	1.53 E-5	5.51 E-5
LS	0.059	0.469	0.236***	0.050
LS×Dummy Process	0.214	0.535	-0.297***	0.058
HOME	-5.92 E-6	5.37 E-6	2.01 E-6***	5.62 E-7
HOME×Dummy Process	3.87 E-6	7.11 E-6	-2.58 E-6***	7.55 E-7
CONC	3.84 E-3***	8.55 E-4	3.10 E-4***	9.21 E-5
CONC×Dummy Process	-1.89 E-3	1.23 E-3	-6.43 E-5	1.31 E-4
PROFIT	4.27 E-3	0.268	0.076**	0.034
PROFIT×Dummy Process	-0.048	0.437	-0.060	0.050
Intercept	0.474***	0.080	-0.060***	8.81 E-3
Dummy 1986	0.070**	0.031	4.81 E-3	3.29 E-3
Dummy food industry	-0.298***	0.102	0.067***	0.011
Dummy textiles	-0.059	0.103	0.065***	0.011
Dummy basic chemicals	0.020	0.104	0.073***	0.011
Dummy pharm. & adv. chemicals	-0.045	0.079	0.082***	8.37 E-3
Dummy non-electrical machinery	0.077	0.051	0.010*	5.43 E-3
Dummy electrical machinery	-0.041	0.061	0.022**	6.58 E-3
Dummy transport equipment	0.035	0.114	9.59 E-3	0.012
Dummy paper & pulp	-0.043	0.101	0.071***	0.011
Dummy iron & steel	-0.076	0.142	0.081***	0.015
Dummy other industries	-0.067	0.090	0.075***	9.56 E-3
Adjusted R^2	0.36		--	
F-value	6.34		--	
Log-likelihood ratio	--		152.40	
Number of observations	202		202	
Left-censored obs.	--		34	

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. The metal products industry is the reference group for the industry dummies.

TABLE 8. RESULTS FROM SIMULTANEOUS ESTIMATIONS WHEN FIRM SIZE (*EMP*) IS INCLUDED IN EQUATION (2). SECOND-STAGE ESTIMATES.

	Dependent variable			
	FS/TS Equation (1)		*RD/TS* Equation (2)	
Explanatory variables	Parameter	Std.error	Parameter	Std.error
RD/TS	5.31***	1.291	--	--
FS/TS	--	--	0.084*	0.044
HIC	6.39 E-4**	3.10 E-4	--	--
LS	-0.417	0.485	--	--
HOME	-4.39 E-6	4.07 E-6	--	--
CONC	--	--	2.26 E-4	1.63 E-4
PROFIT	--	--	0.079**	0.035
EMP	--	--	-2.20 E-8	1.76 E-7
Intercept	0.653***	0.089	-0.060***	0.225
Dummy 1986	0.025	0.037	5.80 E-4	4.66 E-3
Dummy food industry	-0.281***	0.077	0.024	0.016
Dummy textiles	-0.047	0.081	6.53 E-3	0.011
Dummy basic chemicals	-0.036	0.072	5.07 E-3	9.06 E-3
Dummy pharm. & adv. chemicals	-0.182**	0.073	0.032***	7.85 E-3
Dummy non-electrical machinery	0.093*	0.055	-3.49 E-3	8.43 E-3
Dummy electrical machinery	-0.116	0.072	0.020*	0.011
Dummy transport equipment	-0.146	0.123	0.039***	0.013
Dummy paper & pulp	-7.92 E-3	0.069	7.69 E-5	8.15 E-3
Dummy iron & steel	-0.053	0.108	6.94 E-3	0.013
Dummy other industries	-0.129**	0.061	0.014*	8.48 E-3
Adjusted R^2	0.36		--	
F-value	6.52		--	
Log-likelihood ratio	--		146.46	
Number of observations	202		202	
Left-censored obs.	--		34	

	Estimated derivative		Estimated derivative	
	Parameter	Std.error	Parameter	Std.error
$\partial FS/\partial RD$	11.36***	1.89	--	--
$\partial^* RD/\partial^* FS$	--	--	0.049***	0.017

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. First-stage estimates are shown in Table 9. The metal products industry is the reference group for the industry dummies.

TABLE 9. SUPPLEMENT TO TABLE 8. FIRST STAGE ESTIMATES

	Dependent variable			
	FS/TS Equation (1)		*RD/TS* Equation (2)	
Explanatory variables	Parameter	Std. error	Parameter	Std.error
HIC	8.71 E-4***	2.66 E-4	5.95 E-5*	3.48 E-5
LS	0.282	0.370	0.123***	0.050
HOME	-3.42 E-6	3.62 E-6	1.34 E-7	4.83 E-7
CONC	2.89 E-3***	6.08 E-4	4.66 E-4***	8.09 E-5
PROFIT	0.018	0.212	0.071**	0.031
EMP	1.58 E-6	9.64 E-7	9.67 E-8	1.26 E-7
Intercept	0.458***	0.072	-0.039***	9.99 E-3
Dummy 1986	0.068**	0.030	7.54 E-3*	4.08 E-3
Dummy food industry	-0.300***	0.067	-2.09 E-3	9.00 E-3
Dummy textiles	-0.051	0.070	2.02 E-3	9.98 E-3
Dummy basic chemicals	-0.033	0.062	5.33 E-4	8.22 E-3
Dummy pharm. & adv. chemicals	-0.014	0.053	0.030***	7.09 E-3
Dummy non-electrical machinery	0.096**	0.048	4.08 E-3	6.40 E-3
Dummy electrical machinery	-0.072	0.065	0.016*	8.86 E-3
Dummy transport equipment	-0.021	0.098	0.032**	0.013
Dummy paper & pulp	-0.038	0.058	-5.83 E-3	8.16 E-3
Dummy iron & steel	-0.075	0.094	-6.96 E-3	0.013
Dummy other industries	-0.074	0.052	9.27 E-3	6.95 E-3
Adjusted R^2	0.37		--	
F-value	7.88		--	
Log-likelihood ratio	--		152.40	
Number of observations	202		202	
Left-censored obs.	--		34	

Notes: ***, ** and * indicate significance at 1, 5 and 10 percent level respectively. The metal products industry is the reference group for the industry dummies.

TABLE 10. DEFINITIONS AND MEANS OF VARIABLES

Variable	*Definition*	Mean	Std. deviation
RD/TS	R&D intensity: Total R&D expenditures divided by total sales. *RD* and *TS* are expressed in nominal SEK.	0.020	0.029
FS/TS	Foreign sales intensity: Foreign sales divided by total sales. Foreign sales is defined as the sum of parent company exports and foreign affiliate net sales (intra-firm exports from a parent company to its foreign affiliates are excluded in *FS*). *FS* and *TS* are expressed in nominal SEK.	0.621	0.244
HIC	High initial capital costs: Average plant level book value of equipment, tools and real estate in a MNE's foreign plants. Expressed in 1990 SEK (million).	35.53	65.92
LS	Average wage level in the parent company. Expressed in 1990 SEK (million).	0.170	0.041
HOME	Size of the Swedish home market for the firm's product groups, measured by industry sales. Expressed in 1990 SEK (million). *Source*: Statistics Sweden 1986 and 1990).	6760	6313
CONC	Concentration. Sum of world market concentration for the four largest firms in the industry in which the firm's largest division operates (percent).	32.19	26.52
PROFIT	Gross profit margin. Operating income before depreciation and financial items divided by total sales. Operating income and *TS* are expressed in nominal SEK.	0.103	0.072

CHAPTER V

OVERSEAS R&D IN FOREIGN CENTERS OF EXCELLENCE

1. Introduction

To a large extent, overseas R&D by multinational enterprises (MNEs) is explained by the need to adapt products and processes to foreign markets. It has also been suggested that overseas R&D is undertaken to gain access to knowledge in foreign "centers of excellence", and to benefit from localized R&D spillovers. This motive behind the location of R&D has been pointed out as potentially important e.g. by Behrman and Fischer (1980), but the issue has not yet been subjected to a more systematic empirical investigation. The aim of this chapter is to fill part of this gap.

Multinational enterprises still perform the major part of their R&D at home, because of scale economies in R&D, proximity to the company headquarters, and maintaining the secrecy of firms' technologies, to name a few of the main reasons. Yet, a trend of increased internationalization of their R&D activities has been observed over time.[1]

A number of factors underlying the decision to decentralize R&D outside the home country have been identified in the empirical literature. Production in foreign affiliates, the size of the host country market, and the technological intensity of the MNE have been shown to be positively related to the internationalization of R&D (Mansfield *et al.*, 1979, Lall, 1980, and Zejan, 1990). These factors essentially capture the overseas R&D undertaken to adapt the MNEs' technologies to the conditions and requirements prevailing in the host countries where the firms operate. Adaptive overseas R&D is here taken to encompass: direct adaptation of products and processes, technical support to production activities taking place in foreign affiliates, and R&D to facilitate technology transfer from the parent company to foreign affiliates.

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[1]Swedish MNEs in manufacturing located around 18% of their R&D expenditures overseas in 1990. The corresponding figure was 9% for 1970, and 13-14% for the years 1974, 1978 and 1986 (Fors and Svensson, 1994). A trend of increased internationalization of R&D has been observed for MNEs from other countries as well (see Caves, 1996).

Even if the adaptation argument is likely to remain important, there may be other explanations for why firms locate R&D abroad. The present study analyzes whether Swedish MNEs in manufacturing locate overseas R&D activities according to the relative technological specialization of host countries. The question we ask is whether Swedish firms locate overseas R&D to foreign "centers of excellence" in their particular industry. To answer this question we use data for 1978 and 1990 on Swedish firms' overseas production and R&D activities in different OECD countries together with indices of the host countries' technological specialization in terms of R&D in a number of manufacturing industries.

The chapter is organized as follows: Determinants of overseas R&D are discussed in section 2. Data and variables are introduced in section 3, and the econometric method is described in section 4. Empirical results are presented in section 5, and the final section concludes.

2. Determinants of overseas R&D

Three factors which mainly relate to the adaptation motive of overseas R&D have been examined in the literature. First, *production in affiliates* requires overseas R&D to adapt a MNE's products and processes to local conditions. Consequently, overseas R&D to a large extent will be found where overseas production is taking place. Adaptation is pointed to as the most important motive for overseas R&D in the case studies by Ronstadt (1978) and Behrman and Fisher (1980). In the econometric studies by Mansfield, *et al.* (1979), Lall (1980), Hirschey and Caves (1981), and Pearce (1989), who all examine data on US firms, production in foreign affiliates turns out to be the most powerful determinant of overseas R&D. Pearce and Singh (1992), employing a patent based proxy for internationalization of R&D, obtain a positive association between this proxy and the share of production abroad for European-based MNEs as well.

These empirical studies use "share of total R&D undertaken abroad" as the dependent variable in the regressions, and do not separate overseas R&D by host county. Lack of detailed data on the R&D undertaken in different host countries has generally prevented the earlier literature to examine host country determinants.

Second, a positive relationship is expected between *market size of the host country* and overseas R&D. A larger market should provide incentives to perform overseas R&D

for the purposes of adapting products and processes to local conditions, which may not be worthwhile in a small host country. Zejan (1990) finds a positive association between the R&D intensity of Swedish foreign affiliates and the host country GDP. It could be argued that market size is already accounted for in a measure of affiliate production since there should be incentives to locate more production to larger countries.[2] Yet, a large market size, given the location of production, may have a separate positive effect on the location of R&D, e.g. to adapt products in view of an expected higher future potential in a larger market.

Third, firms with *more technologically advanced products or processes* should have a greater need to undertake overseas R&D for adaptation. Lall (1980) reports a positive and significant influence of R&D intensity on the share of R&D located abroad for US firms. Empirical analysis of Swedish firms by Zejan (1990) suggests a positive relationship between parent company and affiliate R&D intensity. However, Pearce and Singh (1992), using a patent-based intensity measure and a proxy for overseas R&D, could not verify this result.

In addition to the above factors relating mainly to adaptive R&D, it has been shown that MNEs locate overseas R&D facilities to countries with a highly skilled workforce (Pearce and Singh, 1992). Figures reported in OECD (1994) for Japanese firms and in Åkerblom (1994) for Finnish MNEs point in the same direction, although the effect of a skilled workforce on the decision as to where to locate R&D appears to be of second order importance in the Japanese and Finnish firms. We argue that a high skill level should attract technology sourcing R&D as well as adaptive R&D, since firms undertaking both kinds of R&D will need to recruit qualified personnel locally.

Another motive for MNEs to undertake overseas R&D may be to source technology in foreign countries and benefit from localized spillovers. We argue that MNEs can more efficiently appropriate R&D spillovers if they undertake their own R&D near the sources of the spillovers.[3] Two sets of empirical findings support this view:

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[2]For Swedish MNEs, Braunerhjelm and Svensson (1996) found a positive relationship between affiliate production and market size of the host country.

[3]Marshall (1920) provides three reasons why industries cluster spatially: a pooled market for labor with specialized knowledge, development of specialized inputs and services, and the possibility to benefit from knowledge spillovers. In a survey of empirical studies, Griliches (1992) concludes that knowledge spillovers are both prevalent and important for economic growth in general.

Knowledge spillovers appear to increase with proximity. Jaffe, *et al.* (1993) compare patent citations with the origins of the cited patents and conclude that citations to domestic patents tend to be domestic, and that citations are more likely to come from the same state within the US as the origin of the patent. Analyzing innovation data across US states, Audretsch and Feldman (1996) find that the propensity for innovative activity to agglomerate spatially is higher in industries where the creation of new knowledge and spillovers is more important. The authors take this as a sign of localized spillovers.

R&D spillovers have also been argued to increase if the potential recipient of the spillover undertakes own R&D. Cohen and Levinthal (1989) propose two functions for R&D: to generate innovations and to absorb spillovers from other firms, and they present evidence for both. Jaffe (1986) concludes that the payoff in terms of patents, profits, or market value to a firm's own R&D is higher in technological areas where there is much R&D undertaken by other firms. Furthermore, Levin, *et al.* (1987) find that independent R&D is the most effective method of "learning" about other firms' products and processes, compared with licensing, patent disclosures, hiring competitors' R&D employees and reverse engineering.

The following hypothesis comes out of the above arguments: MNEs may locate overseas R&D activities to countries that are technologically specialized in their industry in order to benefit from localized spillovers.[4]

From the literature concerning the *location of production* by MNEs, some empirical results have suggested that firms locate production activities to host countries to source technology. Results reported by Kogut and Chang (1991) indicate that Japanese investments in the United States are attracted to industries that are relatively R&D intensive. Cantwell (1989) finds that US and German firms establish production in foreign "centers of excellence" in their respective technological fields. Furthermore, Braunerhjelm and Svensson (1996) present evidence that Swedish MNEs in high-tech industries tend to locate production facilities to industrial clusters abroad. But these studies on the location of production do not evaluate the role of overseas R&D in sourcing technology in host

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[4]Such a knowledge-seeking strategy should potentially benefit the entire MNE, and not merely the units abroad performing the overseas R&D. These units are to be seen as an MNE's interface with technological knowledge in the host country.

countries, which is the focus of the current paper.

To the best of our knowledge, the only empirical study that directly attempts to address the above hypothesis is Cantwell and Hodson (1991).[5] Their findings indicate that the distribution of aggregate overseas R&D across countries is positively related to the overall pattern of innovation. However, the empirical results were only significant for some countries and periods. Moreover, they did not control for the location of overseas production. This is of major importance, since overseas R&D for adaptation is basically located where overseas production is taking place. Hence, to test if the location of overseas R&D is directly related to host countries' R&D specialization, the location of production must be controlled for.

3. Data and variables

The firm-level data set used in the estimations has been collected by the Industrial Institute for Economic and Social Research (IUI), of Stockholm, Sweden. All Swedish MNEs in the manufacturing sector having more than 50 employees and at least one majority-owned production affiliate abroad are included. The response rate to the survey exceeds 90%. Information on the firms' production and R&D by host country and data on the MNEs' global operations are included in the data set. Country-specific variables are taken from OECD (1995) and various issues of the *Statistical Yearbook* published by the United Nations. The firm and country data are available for 1978 and 1990 and pooled for these two years to obtain the sample to be analyzed.

The data make it possible to analyze the R&D that takes place in foreign production affiliates in OECD countries. One observation is generated for each location l (country outside Sweden) and industry k where MNE j undertakes production. For Swedish firms only a small part of overseas R&D is undertaken in sales affiliates or "R&D affiliates".[6] In most cases an observation represents an individual foreign affiliate, which commonly

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[5]A few case studies and descriptive papers also give some support to the view that MNEs locate R&D abroad to source technology. These studies include: Behrman and Fischer (1980), which analyzes selected overseas R&D laboratories of a few major US firms, Håkansson and Nobel (1993), which surveys the 20 largest Swedish MNEs, and OECD (1994), which presents information regarding the motives of overseas R&D in Japanese firms.

[6]In 1990, the MNEs in the IUI survey had together less than 400 employees in foreign affiliates classified as "R&D affiliates". Only four large MNEs indicated that they had affiliates solely dealing in R&D.

corresponds to a single production plant. In the instances where a MNE has more than one affiliate in a host country, the data for the MNE's individual affiliates in the country are summarized. Firms that do not perform any R&D in Sweden or abroad are excluded. This is not a serious restriction on the sample size. In 1990, about 20 small MNEs, each with very few establishments abroad, out of the population of 120 MNEs did not record any R&D.[7]

Furthermore, we only include foreign operations established up to ten years prior to the years 1978 and 1990, respectively. This is in accordance with others who have studied the location of economic activities, e.g. Head, *et al.* (1995), who argue that it is likely that there are more unobserved factors behind "older" establishments. The 10-year limitation also implies that no observation occurs twice in the samples, when pooling the data for 1978 and 1990.[8]

With the above constraints applied to the data set, we obtain a sample of 244 observations, of which 107 recorded overseas R&D.[9] The sample contains information on 17 manufacturing industries in 11 OECD countries (see Table A1 in Appendix).[10]

Below we introduce the variables included in the analysis. Table 1 provides a list of the variables and their definitions and sources. Table A2 shows the means of the variables. The dependent variable is:

RSHARE: The share of MNE *j*'s total R&D expenditures performed in industry *k* in country *l*. Since there is a large concentration of zeroes in the sample (the countries where the MNE does not undertake overseas R&D), we also specify a dummy variable;

RKL, which takes the value one if MNE *j* undertakes overseas R&D in industry *k* in country *l*, and zero otherwise.

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[7]The difference in size, in terms of average firm employment, between the following groups of Swedish MNEs is striking; (i) less than 300 employees for firms without R&D, (ii) almost 1.600 for firms only undertaking R&D in Sweden, and (iii) around 11.000 employees for firms recording overseas R&D (Fors and Svensson 1994).

[8]In the empirical analysis we altered the age limitation from 0-5 years to 0-12 years, and obtained basically the same results. Hence, the exact age limit adopted does not appear to have a major impact on the results. An age limit shorter than five years generated a very small sample.

[9]Of the 244 observations, 149 relate to 1990 and 95 to 1978. Of the 107 observations with overseas R&D, 75 relate to 1990 and 32 to 1978.

[10]The 17 industries together comprise the total of manufacturing, with the exception of *Office & Computing Machinery*, *Petroleum Refineries & Products* and *Other Manufacturing not elsewhere classified*, which are relatively unimportant industries in the Swedish MNE context.

The explanatory variables in the empirical model are the following:

PROD: The share of firm *j*'s total value-added accounted for by operations in industry *k* in country *l*. *PROD* captures the overseas R&D geared toward adaptation, and is expected to have a positive influence on the location of overseas R&D. By including *PROD* as a control variable for adaptive R&D, we are able to examine additional motives for undertaking overseas R&D.

GDP: The logarithm of the GDP of country *l*, to take account of the size of the host country market.[11] We expect a positive association between overseas R&D and market size, since there should be more incentives to adapt products and processes to a larger market.

RINT: The technological intensity of MNE *j*, measured as total R&D expenditures divided by total sales of the entire enterprise. A higher technological intensity is expected to increase the need to undertake overseas R&D for adaptation. *RINT* should be positively related to *RKL*, the decision whether to undertake overseas R&D or not, but not necessarily to *RSHARE*, the share of total R&D located to a certain foreign country.

RSPEC: The host country's technological specialization index measured by R&D expenditures. *RSPEC* for industry *k* in country *l* is calculated as

$$RSPEC_{kl} = \frac{RD_{kl} \,/\, \sum_{l} RD_{kl}}{\sum_{k} RD_{kl} \,/\, \sum_{k}\sum_{l} RD_{kl}} ,$$

i.e. country *l*'s share of R&D in industry *k*, divided by country *l*'s share in overall manufacturing R&D. A value exceeding unity indicates that country *l* has a higher technological specialization in industry *k* compared with other countries.[12] As already discussed, MNEs are expected to locate R&D to countries that are technologically specialized.

[11]We take the logarithm of GDP to facilitate the interpretation of the parameter of this variable in the estimations, since the dependent variable and all other explanatory variables are defined as ratios or shares.

[12]This index is similar to the one used by Feldman (1994) to measure the agglomeration of innovation across US states.

TABLE 1. DESCRIPTION OF VARIABLES

Variable name	*Description*	*Source*
RSHARE	Share of firm *j*'s total R&D expenditures performed in industry *k* in country *l*. R&D expenditures are expressed in nominal SEK.	IUI-database
RKL	*RKL* takes the value 1 if firm *j* undertakes R&D in industry *k* in country *l*, zero otherwise.	IUI-database
PROD	Share of firm *j*'s total value-added accounted for by operations in industry *k* in country *l*. (Value-added is measured as wages + operating income before depreciation and financial items). Value-added is expressed in nominal SEK.	IUI-database
GDP	log of GDP in country *l*, expressed in constant US dollars.	United Nations
RINT	R&D intensity of firm *j*, measured as total R&D expenditures divided by total sales. R&D and sales are expressed in nominal SEK.	IUI-database
RSPEC	Index of country *l*'s relative specialization in R&D in industry *k*. *RSPEC* is calculated as country *l*'s share of R&D expenditures in industry *k*, divided by country *l*'s share in overall R&D. (See Table A1 in Appendix for included industries and countries). Calculated from OECD's PPP US$ R&D data set.	OECD (1995)
RSET	Researchers, scientists, engineers and technicians per 1.000 inhabitants in country *l*.	United Nations
D78	Additive dummy 1978. (Reference year: 1990).	
Industry dummies	Additive industry dummies (see Table A1 in Appendix).	

RSET: Relative endowment of high-skilled labor in the host country, defined as the number of researchers, scientists, engineers and technicians per thousand inhabitants in host country *l*. We interpret *RSET* as a proxy for a country's general skill level.

A time dummy is included to control for possible time-specific effects, since the analysis uses a sample based on pooled observations from two years. We know for example that the internationalization of R&D has increased over time. Additive industry dummies are also included in the estimations to take into account industry-specific effects.

To summarize the preceding discussion, we will test the following relationships (expected sign in parentheses):

$$RKL = g[\,(+)PROD\,,\,(+)GDP\,,\,(+)RINT\,,\,(+)RSPEC\,,\,(+)RSET\,]$$

$$RSHARE = h[\,(+)PROD\,,\,(+)GDP\,,\,(+)RSPEC\,,\,(+)RSET\,]$$

A variable proposed to exert a negative impact on the internationalization of R&D is economies of scale in the R&D function. These may arise from indivisibility of the equipment used and the need for a critical mass of researchers. Unfortunately no such variable could be included in the present analysis. First, the variable is not directly available.[13] With mixed results, Mansfield, *et al.* (1979) used the absolute size of the firm as an alternative. However, a measure of absolute firm size turns out to be strongly correlated with the variable *PROD* in our data set.

4. Econometric method

Since the dependent variable *RSHARE* contains a large share of zeroes (56%), we use a selection bias corrected regression method, see e.g., Fomby, *et al.* (1984, ch. 16). The method enables a separation of the probability and marginal effects of the explanatory variables on the location of overseas R&D.[14] First a Probit function is estimated via maximum likelihood procedures for the overall sample to obtain the probability effect

$$Pr(RKL_{jkl}) = F(\alpha_0 + \alpha_1 Z'_{jkl}) \quad , \qquad \textbf{(1)}$$

where F denotes the cumulative standard normal distribution and *RKL* takes the value one if *RSHARE* > 0 and zero if *RSHARE* = 0. Hence, $Pr(RKL_{jkl})$ is the probability that MNE j undertakes overseas R&D in industry k in country l, given the values of the vector of

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[13] Hirschey and Caves (1981) used average plant size as a proxy for the relative efficient scale of R&D units between industries, and found a negative relationship between efficient scale and share of R&D abroad. As many firms in the present sample have several plants in Sweden (and in some cases even in the same host country) we do not have a good measure of plant size.

[14] Alternatively a Tobit model could have been used; however, the disadvantage with such a model is that the interpretation of the probability and marginal effects is less straight forward.

explanatory variables Z. The vector of parameters α_1 indicates the influence of the explanatory variables on $F^{-1}[Pr(RKL_{jkl})]$. Based on the Probit estimates, the sample selection correction variable Heckman's lambda, λ_H, is computed according to

$$\lambda_{Hjkl} = \frac{f(-\alpha_0 - \alpha_1 Z'_{jkl})}{[1 - F(-\alpha_0 - \alpha_1 Z'_{jkl})]} \quad , \tag{2}$$

where f is the standard normal density function, and F is defined as above. In a second step, OLS is applied to observations with $RSHARE > 0$, with the estimated Heckman's lambda included,

$$RSHARE_{jkl} = \beta_0 + \beta_1 Y'_{jkl} + \gamma \hat{\lambda}_{Hjkl} + \nu_{jkl} \quad , \tag{3}$$

where the vector Y denotes another set of explanatory variables (in the present analysis the same as Z with the exception of *RINT*), β_1 denotes the corresponding parameters showing the marginal effect on *RSHARE*, γ is the parameter for Heckman's lambda and ν is the error term. OLS estimation of (3) yields consistent parameter estimates.

5. Empirical results

In this section we report the results from the first stage Probit analysis and the second stage Heckman's lambda corrected OLS regressions. To investigate the stability of the results, four different versions of the model are estimated. We also consider an alternative measure of the technological specialization of host countries.

Table 2 reports the results from the Probit estimations with *RKL* as the dependent variable. We see that the share of a MNE's production accounted for by operations in a certain host country, *PROD*, and the R&D intensity of the MNE, *RINT*, are both positively associated with the probability to undertake R&D in a host country. The estimated parameters for *PROD* and *RINT* are positive and significantly different from zero at the 1% level, using a two-tailed t-test. The results are stable across the four versions. The parameters for *RSPEC* and the other explanatory variables are not significantly different from zero. Hence, there is no significant relationship between the probability to undertake R&D in a host country and the technological specialization of that country.

Additive time and industry dummies were included in the regressions, but only a few of the industry dummies are significant. These results are not reported here, but available on request.

The results from the OLS regression with *RSHARE* as the dependent variable are shown in Table 3. First we note that *PROD* is positive and significantly different from zero at the 5% level. Hence, the higher the share of a firm's production located to a certain host country, the higher the share of the firm's total R&D located to that country. The results from both the Probit and OLS analysis for *PROD* suggest, in accordance with the earlier literature, that adaptation may be an important motive behind undertaking overseas R&D. Host-country market size, measured by *GDP*, turns out not to be significant. This means that we do not find any additional effect of market size on the location of overseas R&D apart from what can be captured by *PROD*. As already noted, *RINT* is not included in the OLS estimations, since the share of total R&D located to a certain country is not expected to be associated with the R&D intensity of the entire MNE.[15]

Turning to the explanatory variable of main interest in this paper, *RSPEC*, the estimated parameter has the expected positive sign in the OLS regression. The results are significant at the 5% level in the first three versions of the regression, and at the 10% level in the last version, and the estimated parameter of *RSPEC* is relatively stable across the different versions. Hence, MNEs appear to locate a larger share of their total R&D expenditures to host countries that are relatively specialized technologically in their particular industries. By use of an interaction dummy variable to take into account possible changes over time, we allowed the slope coefficient for *RSPEC* to vary: however, no significant difference between 1978 and 1990 can be discerned.

The general skill level of host countries, *RSET*, is not significant in any estimations. Finally, the correction variable λ_H and the industry and time dummies do not turn out to be significant in the OLS regressions.

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[15]With regard to the identification of the two equations, it is also desirable that not exactly the same set of variables are used to explain the two dependent variables *RKL* and *RSPEC*, respectively.

TABLE 2. ESTIMATION RESULTS PROBIT. DEPENDENT VARIABLE: *RKL*

Explanatory variables	*(i)*	*(ii)*	*(iii)*	*(iv)*
PROD	3.81***	3.73***	3.73***	3.79***
	(0.94)	(0.93)	(0.93)	(0.94)
GDP	0.12	0.11	--	--
	(0.077)	(0.076)		
RINT	24.22***	24.01***	23.39***	23.48***
	(5.91)	(5.87)	(5.81)	(5.83)
RSPEC	-0.11	-0.14	-0.19	-0.17
	(0.12)	(0.12)	(0.12)	(0.12)
RSET	-0.082	--	--	-0.065
	(0.078)			(0.077)
Correct pred.	71%	70%	71%	70%
No. of obs.	244	244	244	244
No. of *RKL*=0	137	137	137	137

Notes: *** indicates significance at the 1% level, using a two tailed t-test. Standard errors in parentheses. The intercept is allowed to vary across different industries and over time (see Table A1), by use of additive dummy variables. The results are not reported here, but available on request.

TABLE 3. ESTIMATION RESULTS OLS. DEPENDENT VARIABLE: *RSHARE*

Explanatory variables	*(i)*	*(ii)*	*(iii)*	*(iv)*
PROD	0.52**	0.52**	0.57**	0.57**
	(0.26)	(0.26)	(0.27)	(0.26)
GDP	0.0073	0.0090	--	--
	(0.011)	(0.011)		
RSPEC	0.055**	0.062**	0.055**	0.049*
	(0.025)	(0.026)	(0.026)	(0.026)
RSET	0.014	--	--	0.014
	(0.0085)			(0.0085)
HECKMAN's λ	-0.028	-0.037	-0.0063	0.0025
	(0.066)	(0.068)	(0.069)	(0.067)
Adj R^2	0.30	0.31	0.31	0.31
F-value	3.44	3.59	3.75	3.62
No. of obs.	107	107	107	107

Notes: ** and * indicate significance at the 5 and 10% level, respectively, using a two tailed t-test. Standard errors in parentheses, are White (1980) Heteroskedasticity consistent. The intercept is allowed to vary across different industries and over time (see Table A1), by use of additive dummy variables. The results are not reported here, but available on request.

RTA as a measure of technological specialization

To check the estimation results obtained with the R&D-based measure of technological specialization, *RSPEC*, we also use an alternative measure which is based on patents, "Revealed Technological Advantage", *RTA*. This index is calculated in the same way as *RSPEC*, but the number of patents granted in the US is inserted into the formula, instead of R&D expenditures. As the US is an important market for most countries, patents granted in the US can be used as an indicator of innovative capacity (Pearce and Singh, 1992). The data on *RTA* are from Cantwell (1989) and they generate a considerably smaller sample than the one analyzed above, since fewer industries are included. The sample comprises 87 observations, of which 35 recorded overseas R&D.[16]

From Table 4, showing the results from the Probit analysis, it is seen that the results for *PROD* and *RINT* are in line with the earlier estimations, although at a lower level of significance. The parameter for *RTA* is not significant when considering the pooled sample of observations from 1978 and 1990. However, when we include an interaction dummy for *RTA* for the year 1978, the parameter for *RTA* is positive and significant at the 5% level for 1990. In Table 4, we only report the estimation results for the model without *GDP* and *RSET*. Inclusion of these two variables did not change the results, and non of the variables turned out significant.

Even if the two samples using *RSPEC* and *RTA*, respectively, differ considerably in size and industry coverage, the empirical results both point in the same direction, although we only find significant effects with *RTA* for 1990. We do not report the results from the OLS, since no significant results were obtained. This is probably explained in part by the small sample considered in the OLS regression when we use the *RTA* measure.

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[16]*RTA* was only available as an average for the period 1963-83. This average is used in connection with firm and other country data from 1978 and 1990, respectively. Since the *RTA* indices are rather stable over time (Cantwell 1989), this should not pose a major problem. For example, the Pearson correlation coefficient between *RSPEC*(1978) and *RSPEC*(1990) is as high as 0.80, indicating little change in the countries' positions over a 12-year period when using the R&D-based measure.

TABLE 4. ESTIMATION RESULTS PROBIT WITH *RTA* AS MEASURE OF TECHNOLOGICAL SPECIALIZATION. DEPENDENT VARIABLE: *RKL*

Explanatory variables	*No interaction dummy for RTA*	*With interaction dummy for RTA Reference group: 1990*
PROD	3.10* (1.58)	3.61** (1.72)
RINT	14.72* (8.55)	18.52** (8.83)
RTA	0.59 (0.48)	1.49** (0.68)
RTAxD78	--	-2.48** (1.18)
Correct pred.	69%	77%
No. of obs.	87	87
No. of *RKL*=0	52	52

Notes: ** and * indicate significance at the 5 and 10% level, respectively, using a two tailed t-test. Standard errors in parentheses. The intercept is allowed to vary across different industries and over time (see Table A1), by use of additive dummy variables. The results are not reported here, but available on request.

6. Concluding remarks

The empirical evidence from this study first suggest that the location of overseas R&D by Swedish multinational enterprises is motivated to a large extent by the need to adapt products and processes to conditions in the foreign markets where the firms operate. This is consistent with the earlier literature on overseas R&D.

When we control for factors related to adaptation, we also find that the Swedish firms locate a higher share of their R&D expenditures to host countries which are relatively specialized technologically in their industry. We measure a country's specialization in a particular industry in terms of R&D expenditures relative to other countries. This finding may suggest that one additional motive to locating R&D abroad is to gain access to knowledge in foreign "centers of excellence" and to benefit from localized spillovers.

Hence, it is possible that the foreign affiliates could be seen as a MNE's interface with technological knowledge in host countries. However, in the present analysis we have only established a positive relationship between the share of R&D located to a certain host country and the country's technological specialization. In future work it would be interesting to analyze the effects of this suggested "technology sourcing strategy" on both the parent company and the foreign affiliates performing the overseas R&D. The important question to answer is whether the technology sourced in a host country will benefit the entire MNE, or only the units located in the foreign country.

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Appendix

TABLE A1. INDUSTRIES AND COUNTRIES INCLUDED IN SAMPLE
NUMBER OF OBSERVATIONS

Industries (*k*)		Countries (*l*)	
Food, Beverages & Tobacco	5	France	24
Textiles, Apparel & Leather	3	Italy	10
Wood products & Furniture	18	Netherlands	18
Paper, Paper prod. & Printing	25	Germany (a)	39
Chemicals excl. Drugs	26	Denmark	28
Drugs & Medicines	6	Finland	22
Rubber & Plastic Products	13	United Kingdom	38
Non-metallic Mineral Prod.	8		
Iron & Steel	10	Japan	4
Non-ferrous Metals	2	USA	45
Metal Products	38	Canada	9
Non-electrical Machinery	52	Australia	7
Elec. Mach. excl. Comm Eq.	21		
Communication Eq. Radio, TV	4		
Motor Vehicles	8		
Other Transport Equipment	1		
Professional Goods	4		
All industries	**244**	**All countries**	**244**

Note: (a) Germany in 1978 refers to West Germany.

TABLE A2. MEANS OF VARIABLES

Variables	*PROBIT (n=244)*	*OLS (n=107)*
RKL	0.44 (0.50)	--
RSHARE	--	0.11 (0.17)
PROD	0.087 (0.12)	0.12 (0.16)
GDP	8.39 (1.29)	8.61 (1.18)
RINT	0.025 (0.024)	--
RSPEC	1.14 (1.15)	1.02 (0.70)
RSET	4.11 (1.18)	4.07 (1.18)
HECKMAN's λ	--	0.73 (0.37)

Note: Standard deviations in parentheses.

TABLE A3. CORRELATION MATRIX FOR SAMPLE USED IN THE PROBIT
PEARSON CORRELATION COEFFICIENTS

Variable	*RKL*	*PROD*	*GDP*	*RINT*	*RSPEC*
PROD	0.25***	--	--	--	--
GDP	0.15**	0.056	--	--	--
RINT	0.24***	-0.044	0.081	--	--
RSPEC	-0.094	0.069	-0.33***	-0.063	--
RSET	-0.030	0.12	0.060	0.056	0.21***

Note: *** and ** indicate significance at the 1 and 5% level, respectively.

TABLE A4. CORRELATION MATRIX FOR SAMPLE USED IN THE OLS
PEARSON CORRELATION COEFFICIENTS

Variable	*RSHARE*	*PROD*	*GDP*	*RSPEC*	*RSET*
PROD	0.58***	--	--	--	--
GDP	0.053	0.088	--	--	--
RSPEC	0.24**	0.17*	-0.22**	--	--
RSET	0.17*	0.15	0.13	0.23**	--
λ_H	-0.26***	-0.53***	-0.31***	0.16	0.080

Note: ***, ** and * indicate significance at the 1, 5 and 10% level, respectively.

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R&D and Technology Transfer by Multinational Enterprises

Gunnar Fors

The existence of multinational enterprises (MNEs) is to a large extent attributed to the creation and utilization of firm-specific intangible assets, such as technological knowledge generated by research and development (R&D). This thesis focusses on two questions related to R&D and technology transfer by MNEs. First, to what extent do firms transfer technology to their affiliates located abroad? Second, what are the motives for undertaking R&D in the foreign affiliates?

These issues are important for a broader understanding of technology transfer between countries, since MNEs perform the bulk of the world's industrial R&D, and are also key actors in the international diffusion of technological knowledge. The empirical analysis is based on detailed data on Swedish MNEs collected by IUI since 1965.

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