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How Do Different Motives for R&D Investment in Foreign Locations Affect Domestic Firm Performance? An Analysis Based on Swiss Panel Micro Data

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How Do Different Motives for R&D Investment in Foreign Locations Affect Domestic Firm Performance?

An Analysis Based on Swiss Panel Micro Data

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Abstract

The aim of this article is to investigate the differences between specific motives of R&D investment in foreign locations with respect to the factors influencing the likelihood of foreign R&D and to the impact of foreign presence on the parent firms' innovativeness and productivity. An econometric analysis of Swiss firm panel data shows, firstly, that factors related to firm-specific knowledge-oriented advantages are more important for explaining the likelihood of foreign R&D activities than factors reflecting disadvantages related to home location. Secondly, knowledge-oriented motives of foreign R&D are positively correlated to innovation performance of domestic firms, whereas market-oriented and resource-oriented strategies correlate positively with productivity.

Key Words: Research and development (R&D); Foreign R&D; Motives of foreign R&D; Home effects of foreign R&D, Firm performance

JEL Classification: O31, F23

1. Introduction

Over the last twenty years internationalization of Swiss firms strongly increased. In a first phase, this process took place particularly in distribution and manufacturing activities; meanwhile, it increasingly covers R&D as well. This holds true not only in terms of the funds invested abroad (since 1996 Swiss foreign R&D expenditures are higher than domestic ones), but also for the number of firms performing foreign R&D. Similar trends are observed in other countries (OECD, 1998; Veugelers et al., 2005).

As early as in the late 1970s, Ronstadt (1978) noticed that foreign R&D may be motivated, in addition to market or cost considerations, by the intention to gain access to specific knowledge. However, it was only in the 1990s that observers increasingly became aware of the high importance of knowledge-oriented motives as a driver of foreign R&D. Among others, Cantwell (1995), Florida (1997) and Kuemmerle (1999) showed that firms often perform foreign R&D, in the first instance, in order to profit from knowledge only available at certain foreign locations ("technology sourcing"). Moreover, firms increasingly realized that geographic proximity of their foreign affiliates to universities and highly innovative local firms offers great opportunities for profiting from knowledge spillovers (Jaffe et al., 1993; Cantwell and Piscitello, 2005). Foreign R&D serves thus as a means to complement and augment knowledge available at the domestic headquarter. A more specific aspect of knowledge-oriented foreign activities is the search for knowledge incorporated in personnel that is specialized in specific fields of science or advanced technologies. In this case, knowledge-seeking and the (classical) motive of resource-seeking become to a certain extent congruent. In this perspective, foreign R&D and domestic R&D again are complements.

So far, it has been implicitly assumed that knowledge acquired and created at foreign locations is transferred to a sufficient degree to the companies' headquarter. If this is not the case, it cannot be excluded that technology sourcing gradually leads to (some) substitution of domestic R&D by moving (part of) a firm's R&D activities to foreign locations. This may happen if knowledge available from foreign sources is superior to domestic R&D, for example, if the latter is specialized in activities that do not correspond to the needs of recent and future technological trends ("lock-in").

Starting point of the analysis is the empirical fact that firms pursue different goals when getting engaged in foreign R&D, often more than one goal at the same time. Given that firms are driven by different motives for investing abroad in R&D, the aim of this article is to investigate the differences between specific motives with respect to (a) the factors influencing the likelihood of foreign R&D investment as postulated by theory, and (b) the impact of foreign presence in R&D on innovativeness and productivity of the parent company.

To this end, we utilized data on three different groups of motives for foreign R&D, i.e. market-oriented, resource-oriented and knowledge oriented motives, as reported by Swiss manufacturing, construction and services firms in 2002, 2005 and 2008 with reference periods 2000/02, 2003/05 and 2006/08 respectively. Hence, the data cover nearly a decade.

In a first step, we divided the firms that perform R&D at foreign locations into three categories according to the importance for them of each of the three groups of motives for foreign R&D. We constructed a dichotomous variable for each of the three groups of motives. Secondly, we specified a model of the factors determining the propensity to invest abroad in R&D based on theoretical literature. In the first place, we relied on the extended version of the OLI-paradigm (Dunning, 2000; Dunning and Lundan, 2008). The model primarily comprises (a) a set of variables measuring the domestic firms' innovation capabilities such as human capital and R&D intensity, R&D co-operation, use of external knowledge sources, etc. (O-advantages), (b) some measures representing innovation obstacles in the home country (L-disadvantages), and (c) additional variables reflecting the intensity of competitive pressure and controlling for industry affiliation, firm size, firm age, foreign/domestic ownership of the firm and time. The model is used to explain the three dichotomous motive variables. The three equations were estimated by the multivariate probit technique in order to take into account the interdependence of the motive variables due to the fact that firms are driven by more than one motive at the time. For sake of comparison we also estimated an equation that explains whether a firm does or does not perform foreign R&D ("foreign R&D yes/no") without differentiating by motive of the foreign engagement).

Finally, we specified two (independent) performance equations, the first one using as dependent variable a firm's innovativeness ("innovation equation"), the second one its productivity ("productivity equation"). In both equations we used as explanatory variables, in addition to the standard determining factors, separately each of the three dichotomous motive variables. The innovation equation was estimated by applying the random effect tobit model, the productivity equation by using the random effect OLS technique, in both cases after testing for endogeneity of the motive variables and, if necessary, adapting accordingly the estimation method. As a reference, we also estimated the (overall) foreign R&D equation ("foreign R&D yes/no") and the two performance equations based on the overall foreign R&D variable, thus without differentiating among the three groups of motives.

New elements of the study are (a) the identification of the drivers of distinct strategies for investing in foreign R&D using information on several motives for such activities; (b) the investigation of the impact of these motives on the performance of the parent company, which may differ depending on the performance measure used (innovativeness vs. productivity) and the specific motive considered; (c) the estimation of models drawing on a firm panel that covers a period of almost a decade (three cross-sections) and includes not only the manufacturing sector but services as well.

The set-up of the paper is as follows. In Section 2 we present the conceptual framework of the paper and related empirical literature. Section 3 describes the data sources. Section 4 deals with model specification and variable construction. In Section 5 we discuss some methodological problems and present the empirical results. Finally, we summarize and draw some conclusions.

2. Conceptual framework and related empirical literature

2.1 General theoretical background

There are basically three strands of theory to explain international investment of firms. Firstly, the classical theory of international trade stresses the factor endowment of an economy and implies that a firm's investment follows the comparative advantages of different locations (see Mundell, 1957). Secondly, according to the „new trade theory" firms exhibit specific capabilities (technology, marketing, etc.) that can be successfully exploited at home as well as at foreign locations independently from the economic attractiveness of different countries (see, for example, Helpman, 1984; Ethier, 1986). Thirdly, transaction cost theory hypothesizes that a firm tends to engage in FDI whenever the costs of setting up and running a transnational hierarchical or network organization are lower than those arising from external market transactions (Buckley and Casson, 1985). In addition to these basic theoretical approaches, there is a whole number of partial hypotheses to explain specific aspects of internationalization that are rooted in different "sub-disciplines" of economics such as industrial organization, management sciences, evolutionary economics, economic geography or finance (see Dunning, 2000).

In the seventies Dunning argued that no single approach is able to fully explain a firm's international activity. Therefore, he proposed as framework of analysis an eclectic theory of international production, the "OLI paradigm". In his understanding, it covers the most important theories in a way that it is more than just a sum of the constituent hypotheses (Dunning 1988, 1993 and 2000). Originally developed to explain international production, its most recent version can be applied to foreign R&D as well (Dunning, 2000; Dunning and Lundan, 2008; Cantwell and Narula, 2001). The recently extended version of the OLI paradigm stresses more explicitly the strategic aspects of internationalization based on the "dynamic capability view of the firm" (see e.g. Teece and Pisano, 1998). In this concept, a firm does invest abroad not only to increase its efficiency (efficiency-seeking motive), to get access to (natural) resources (resource-oriented motive) or to exploit at foreign locations the assets produced at home (market-oriented motive, "asset exploiting" strategy"), but also to complement and enrich domestic assets by tapping into foreign "National Innovation Systems" (NIS). Consequently, "asset-seeking" ("knowledge-oriented motive; "asset augmenting" strategy) becomes much more prominent as a driver of foreign investment than in the past (Dunning, 2000).

2.2 OLI paradigm

The OLI paradigm serves in this study as theoretical framework for the specification of the equation used to explain the propensity of firms to invest in R&D abroad. Dunning distinguishes three groups of variables which explain international engagements of a firm: „ownership-specific" advantages (O), „location-specific" advantages (L) and „internalizing advantages" (I)". In accordance with the "dynamic capability view of the firm" (Teece and Pisano, 1998) and the pioneering thinking of Hymer going back to the 1960s (Hymer, 1976; see also Caves, 1982), O-advantages refer to firm-specific capabilities and assets that make a company superior to local competitors irrespective of general location characteristics. Such advantages arise from the availability of (firm-specific) human, physical and knowledge capital as well as specific intangibles related to property rights, marketing, organization, learning, managerial skills, governance and trust, finance, experience with foreign markets, etc. L-advantages represent potential gains a firm can realize by optimizing its activities along the value chain across locations. In the present context, this type of advantage primarily roots in differences among locations with respect to factors favoring or impeding knowledge creation and use (costs of R&D inputs, R&D-related taxes and subsidies, regulatory framework, etc.). I-advantages can be realized through M&A activities or by forming R&D co-operations and alliances as means to internalize market transactions. In this way, the high transaction costs on the imperfect markets for knowledge and technology can be reduced, appropriability problems mitigated and access to knowledge sources facilitated.

2.3 Motives for investing in R&D at foreign locations

Recent empirical studies on R&D internationalization investigate "technology sourcing" as a driver of investments in R&D at foreign locations. They demonstrate the relevance of this type of foreign R&D and/or compare the importance of knowledge-seeking strategies with those reflecting market-seeking motives (see, for example, Cantwell, 1995; Florida, 1997; Kuemmerle, 1999; Patel and Vega, 1999; Frost, 2001; Le Bas and Sierra, 2002). In these studies the two types of foreign R&D are discussed under the heading of "asset-exploiting" (homebase-exploiting, competence-exploiting) strategies vs. "asset-augmenting" (home-base augmenting, competence-creating) strategies. Moreover, it was shown that geographic proximity to universities and highly innovative firms, in accordance with the asset-augmenting strategy, offers great opportunities for profiting from knowledge spillovers (Jaffe et al., 1993; Cantwell and Piscitello, 2005). Further, Hollenstein (2009) identified based on Swiss data four categories of firms ("clusters") characterized by distinct combinations of motives for foreign investments in R&D. Two of the clusters are clearly related to asset-augmenting strategies, the third one to the asset-exploiting strategy, whereas the foreign engagement of firms belonging to the forth category is based primarily on cost considerations. The four "clusters" clearly (and plausibly) differ in terms of the core variables of the OLI paradigm.

2.4 Foreign R&D activities and economic performance of the parent company

We concentrate on the impact of foreign R&D on the parent company's economic performance, leaving aside spillovers to other firms in the home country. More specifically, we report primarily based on firm-level studies some empirical findings on the effect of foreign R&D on firm performance differentiated by the two measures used in this analysis, that is to say the firms' "innovativeness" and their "productivity" (for a recent review of the literature see Veugelers et al., 2005).

The empirical literature dealing with the influence foreign R&D exerts on the "*innovativeness*" of the parent company (R&D activity, patent output, etc) concludes in most instances that this effect is positive. Some older studies such as, for example, Mansfield and Romeo (1984) are quite straight in this respect. More recent studies yield more differentiated results. Asset-augmenting and asset-exploiting foreign R&D affect the investing firm's innovativeness differently. It seems quite obvious that in the first case the impact on a firm's innovativeness is positive, whereas in the second case there is probably no effect or only a small effect. However, this assessment must be further qualified. Not all firms pursuing asset-augmenting strategies benefit to the same extent from knowledge sourcing. Firms endowed with a high absorptive capacity benefit more than those which are weaker in this respect (see, e.g., Ambos et al., 2006). Therefore, it is not surprising that asset-augmenting strategies are most prominent in technologically leading countries and least prevalent in technologically less developed economies (see LeBas and Sierra, 2002).

Moreover, the impact on the parent firms' innovativeness depends on the kind of foreign R&D activity. Iwasa and Odagiri (2004), analyzing R&D activities of Japanese firms in the USA, found that only research activities had a positive effect on the patent productivity of parent firms, whereas more application-oriented R&D ("development") had no significant influence. The literature dealing with the different roles foreign affiliates are playing within a MNE yield additional insights. Ambos et al. (2006) found, using the classification of foreign R&D performing affiliates proposed by Gupta and Govindarajan (1994), that affiliates being "Integrated Players" within the R&D network of a MNE strengthen the innovativeness of the company's headquarter. Such a positive effect is not found for affiliates of type "Local Innovator" and "Implementer" (surprisingly, the same holds true for "Global Innovators"). Finally, Frost (2001) shows that the companies' headquarter gain most from foreign R&D when the subsidiaries are well embedded in both firm-external and firm-internal networks ("dual embeddedness").

The empirical results of studies analyzing the impact of foreign R&D on the parent firms' *productivity* are mixed. Fors (1997), using Swedish firm data, did not find any significant productivity effect. On the other hand, Todo and Shimizutani (2008) showed, based on firm-level data for Japanese multinational enterprises, that overseas "innovative" R&D (aiming at the acquisition of foreign knowledge) raises the parent firms' productivity growth, while "adaptive" overseas R&D (aiming at the adaptation of products/technologies to local conditions in foreign locations) has no such effect. Griffith et al. (2004) identified positive productivity effects of knowledge-sourcing. They found that UK firms could improve total factor productivity as a result of sourcing activities of their R&D labs located in the USA. Moreover, technologically less sophisticated firms benefit more from knowledge sourcing than technologically leading companies (what is somewhat puzzling as high absorptive capacity, as mentioned above, fosters reverse technology transfer). Rammer and Schmiele (2008) drawing on a large sample of German SMEs got mixed results: they identified a positive effect of foreign R&D on employment growth of the parent company, whereas growth of sales were not affected. Moreover, production of innovative products and implementation of new processes by foreign affiliates did not influence sales and employment growth of the parent company.

2.5 Resulting hypotheses

Based on the theoretical literature and the available empirical evidence we formulate the following hypotheses for the empirical part of the study:

Hypothesis 1: The likelihood that a firm is engaged in R&D activities in foreign locations correlates *positively* with a firm's specific advantages with respect to the acquisition of innovation-relevant knowledge (*ownership-specific advantages* in the sense of the OLI approach).

Hypothesis 2: The likelihood that a firm is engaged in R&D activities in foreign locations correlates *positively* with *dis*advantages of the home country with respect to innovation activities (*location-specific disadvantages* in the sense of the OLI approach).

Hypothesis 3: R&D activities in foreign locations, particularly those driven by knowledge-oriented motives, enhance the parent firm's innovation performance ("asset-augmenting" strategy).

Hypothesis 4: R&D activities in foreign locations, particularly those driven by market-oriented and/or resource-oriented motives enhance the parent firm's productivity based on a reduction of innovation costs and/or, economies of scale and scope and/or learning effects (as a further economic consequence of the "asset-exploiting" strategy).

3. Data

The data used in this study were collected in the course of three (postal) surveys among Swiss enterprises in the years 2002, 2005 and 2008 with reference years 2000/02, 2003/05 and 2006/08 respectively. The surveys yielded information on some basic firm characteristics (sales, value added, investments, exports, employment, employees' vocational education, firma age, etc.), several innovation indicators quite similar to those collected by the Innovation Surveys of the European Community (CIS) and on R&D activities at home and abroad (year of first investment in foreign R&D, location of foreign presence, motives for foreign R&D, etc.).[1] The surveys were based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all industries of the (private) business sector (manufacturing, energy, construction, services) as well as firm size classes: 28 industries and three industry-specific firm size classes with full coverage of the class of large firms. We used in this study only data for firms having performed R&D at home in the relevant period.[2] The final data set includes 2817 enterprises from all fields of activity and size classes (see table A.1 in the appendix for the composition of the dataset we used in model estimation, by industry, firm size class and year respectively).[3]

4. Model specification and construction of the variables

4.1 Explaining foreign R&D: overall and by group of motives

4.1.1 Dependent variables

Firstly, we constructed a dichotomous variable taking the value 1 for firms with foreign R&D activities and zero for firms without such activities (RD_FOR). Secondly, we also specified a dichotomous variable for each of the three groups of motives of foreign R&D activities taken into consideration in this study, i.e. knowledge-oriented motives

(M_KNOW), market-oriented motives (M_MARK) and resource-oriented motives (M_RESO).[4] For each of the three variables the value 1 was attributed to firms that reported that at least one of the *single* motives of a specific *group* of motives was "important" for them (value 4 or 5 on a five-point Likert scale). The value zero was assigned, firstly, to firms with foreign R&D activities driven by other motives, and secondly, to the firms that did not perform R&D at a foreign location (see sub-section 5.1 for the justification of this construction).

Table 1 shows that about 19% of the R&D performing firms (sum of the three surveys) did so also at foreign locations. Moreover, it can be seen that knowledge-oriented strategies are most widespread. But the frequencies differ not much among the three groups of motives.

Table 1

4.1.2 Independent variables

The independent variables in the three motive equations and in the equation explaining overall foreign R&D activity are identical. The variables are specified taking the OLI paradigm, particularly the OL-part, as theoretical guideline (see sub-section 2.1 and 2.2). In addition to O- and L-variables, we also take account of a firm's market environment. Further, we include a set of control variables such as firm size, firm age, foreign/domestic ownership of the firm and industry affiliation. In the following we discuss the specification of the explanatory part of the model. The exact definition of the variables is shown in Table 2.

Table 2

A first group of variables represents O-advantages which are expected to be positively related to a firm's international investments in innovation-related knowledge. We consider the existence of *permanent* in-house R&D activities (RDPERM) and the availability of *high-level* human capital (HQUAL) as overall preconditions for knowledge-related O-advantages. Such advantages can also be generated by acquiring knowledge through R&D co-operation (RDCOOP) and external R&D-contracts (RDEXT). The exploitation of science-oriented external knowledge from universities/research institutions and/or patent disclosures (KPATSCIENCE) is another important form of knowledge sourcing. In case a firm is a member of a company group valuable knowledge may come form the parent company and/or sister companies (KGROUP). These knowledge-related advantages reflect a high capacity of the firm to absorb external knowledge (Cohen and Levinthal, 1989), enabling it to substantially benefit from knowledge and technology transfer from foreign to domestic R&D units. We thus expect a positive sign for all the above variables (see *hypothesis 1* in Section 2).

Besides, we include the sales share of exports (EXP) as O-variable to capture a firm's experience in doing international business, which, according to the "stages view of internationalization" (see, e.g. Johanson and Vahlne, 1977), raises the probability of investing at foreign locations. In many cases, going international starts with setting up distribution facilities, followed by the establishment of production sites, with R&D activities mostly being the final step of the international expansion of firms.[5]

A second group of variables stands for (institutional) obstacles to innovation activities in the home country that may drive firms to locate (or expand) their R&D activities abroad (L-disadvantages). This factor is captured by two variables: "excessive regulation of the domestic markets" (OBST_REG) and "insufficient public support of the firms' innovation activities" (OBST_PROM). We expect a positive sign also for these two variables (see *hypothesis 2* in Section 2).

To characterize a firm's market environment we define, based on the number of principal competitors, three dummy variables representing different degrees of market concentration

(NCOMP). We hypothesize that firms doing business in highly concentrated markets have a market power advantage that may enhance their propensity to invest at foreign locations. Since firms operating in markets with low concentration are the reference group, we expect a positive sign in case of more concentrated markets.

Finally, we control for some (general) firm characteristics that may have an impact on the decision to engage in foreign R&D. Firm size (LEMPL) captures some (size-related) factors not explicitly included in the model. Some of them reflect O-advantages (e.g. easier access to capital markets for large firms what facilitates the financing of international activities), others are related to I-advantages (e.g. effective international innovation management in case of large firms, what is an important instrument for internalizing the outcome of foreign R&D activities). We thus expect a positive sign for the firm size variable. Moreover, we expect that foreign-owned firms (FOREIGN) are less likely to perform R&D abroad, since they often produce primarily for the domestic market (expected negative sign). We also expect that older firms are more experienced with respect to international activities and thus stronger inclined than smaller ones to invest abroad in R&D (expected positive sign for LAGE).

4.2 Innovation equation

As dependent variable of the innovation equation we used the sales of "innovative products" (new or considerably modified products) per employee (natural logarithm; LINNL). On the right-hand side of the innovation equation, we included the standard variables of the resource-based approach of innovative activity, i.e. physical and human capital input (LCL, LHQUAL). In addition, a variable for knowledge-sourcing based on user information (KCUST) was also included. The impact of R&D activities at foreign locations on innovation performance was taken into account by inserting *separately* the dichotomous variables for the three motive variables (M_KNOW, M_MARK, M_RESO), and in a reference equation the dummy variable for overall foreign R&D (R&D_FOR).[6] Further, we used as explanatory variables – in addition to the market structure dummies NCOMP – two competition variables measuring the intensity of price and non-price competition respectively (IPC; INPC). Finally, we inserted controls for firm size, firm age, foreign/domestic ownership of the firm, industry affiliation and survey year.

Based on the standard empirical evidence from earlier studies we expect positive effects of physical capital LCL, human capital (LHQUAL), the intensity of non-price competition (INPC) and – to a smaller extent – the intensity of price competition (IPC) as well as of firm size (see Arvanitis, 2008). We also expect a positive effect for LAGE. There is no clear sign expectation with respect to FOREIGN.

According to *hypothesis 3*, we expect that the motives for foreign R&D primarily oriented towards the acquisition of new knowledge (M_KNOW) would have a significant stronger influence on innovation performance than market- and resource-oriented motives (M_MARK; M_RESO).

4.3 Productivity equation

As dependent variable of the productivity equation we used value added per employee (natural logarithm; LQL). The equation contains as explanatory variables the two classical production factors (natural logarithms), i.e. physical capital (capital income per employee; LCL) and human capital (LHQUAL), augmented by a variable measuring the knowledge base created by the firm itself (R&D expenditures per employee; LRDL). We added the same controls we use in the innovation equation (firm size, etc.). The impact of foreign R&D on labor productivity, which is at the core of our interest, is captured by inserting separately the four dichotomous variables representing overall foreign R&D and separately the three groups of motives for foreign R&D.

We expect positive productivity effects of the input of physical and human capital per employee as well as of R&D expenditure per employee (see also Arvanitis, 2008). According to hypothesis 4, we *exp*ect positive productivity effects particularly in case of foreign R&D based on market- and on resource-oriented motives (M_MARK; M_RESO).

5. Empirical results

5.1 Methodological remarks

5.1.1 Sample selection bias

The variables representing the motives of foreign R&D are measured only for firms having actually invested abroad in such activities. This might give rise to a sample selection problem in estimating the three motive equations that cannot be econometrically solved in a panel data setting as easily as it is usually done in cross-section analyses by applying a Heckman correction (Heckman, 1979). Moreover, the interdependence of the motive variables due to the fact that most of the firms reported more than one option on the question of motives (see also Section 3) renders more difficult a Heckman-type solution as it is implemented in most statistical packages.

As an alternative, in a first step, we assign to all firms with *only domestic* R&D activities the value zero for all motive variables.[7] Thus, a zero value of a certain motive dummy variable refers to firms that perform foreign R&D without focusing on that particular motive as well as to firms investing in R&D only at home. This has to be taken into account when the results are interpreted. One may object to this procedure that the differences among firms pursuing foreign R&D for different reasons – the specific topic of this study – could be dominated by the differences between firms with and those without foreign R&D activities. However, a comparison of the results in Table 3 (referring to the dichotomous variable R&D_FOR) and Table 4 (referring to the three types of motives for foreign R&D) show that this not the case.

5.1.2 Interdependence of the motive variables

In a second step, we took into consideration the interdependence among the dichotomous measures of the three groups of motives which are the dependent variables in the motive equations. To this end, we estimated a trivariate probit model, i.e. a simultaneous system of three motive equations, instead of three separate probits. We applied the corresponding procedure implemented in STATA, which is based on the so-called GHK-simulator for multivariate distributions.[8]

5.1.3 Endogeneity of the foreign R&D variables

To estimate the innovation equations based on the truncated (at zero) dependent variable LINNL we applied a random effect tobit estimator. In case of the productivity equation we used a random effect GLS estimator. In both instances we are confronted with the econometric issue of endogeneity since the overall foreign R&D variable and the motive variables are used as right-hand variables.

We tested for endogeneity by applying the procedure by Rivers and Vuong (1988) separately for R&D_FOR and each motive variable. The coefficients of the residuals (predicted instrumented variables minus original variable) were statistically insignificant at the10% test level in both the innovation (LINNL) and the productivity equation (LQL) estimates for all three motive variables as well as for the overall foreign R&D variable.[9] Therefore, we could not find any evidence for endogeneity in our estimates for innovation and productivity. As a consequence, Table 3 (column 2 and 3) and Table 5 show only the estimates of the innovation and the productivity equations based on the *original* variables for overall foreign R&D and the three motives respectively.

5.2 Results I: Equations for foreign R&D: overall and by group of motives

5.2.1 Overall R&D activities at foreign locations yes/no

We find the expected positive signs for all variables related to knowledge-based O-advantages (Table 3, column 1). The coefficients of the three export dummies are also positive and statistically significant. A t-test shows that the coefficient of the three export dummies becomes significantly larger with growing export share; hence, the larger the sales share of exports, the more likely it is that a firm performs R&D abroad. Moreover, again in line with expectations, we obtain statistically significant positive coefficients for the two variables reflecting L-disadvantages. Finally, as in similar empirical studies, there is a non-linear positive relationship between firm size and the propensity for R&D activities in foreign locations (variable LEMPL). Age and foreign/domestic ownership of a firm do not influence the propensity to invest in foreign R&D. In sum, the findings in Table 3 appear to confirm the hypotheses 1 and 2 put forward in Section 2.

Table 3

5.2.2 Foreign R&D differentiated by group of motives

Table 4 shows the trivariate probit estimates for the three categories of motives for foreign R&D activities (knowledge-oriented, market-oriented and resource-oriented motives). We found significant positive correlations between any pair of motive equations. Thus, there is considerable empirical justification for estimating a multivariate probit model.

As can be seen in Table 4, there are similarities but also discernible differences between the estimated parameters of the explanatory variables in the three motive equations. Firms conducting R&D on a permanent basis (RDPERM) are significantly more inclined to invest in foreign R&D than other firms, but this is not the case for firms engaged abroad for one or another specific motive. Firms pursuing resource-oriented motives seem to use more human capital (HQUAL) than those focusing on other motives. This is probably the main reason why they are stronger restrained than other firms from insufficient availability of R&D personnel at the company headquarter.

Table 4

It is not astonishing that the use of external knowledge as reflected by the variables capturing R&D cooperation (RDCOOP), external R&D (RDEXT) and intensive use of science-based knowledge (KPATSCIENE) appears to be a specific characteristic of firms that invest in foreign R&D primarily in order to augment their own know-how (M_KNOW). Science-based knowledge is less important for firms with market-oriented motives (M_MARK) or resource-oriented motives (M_RESO), and external R&D is of no specific relevance for firms pursuing primarily a resource-oriented strategy (M_RESO). The latter category of firms draws least on external knowledge sources. Only in case of knowledge inflow from other parts of the same company group (KGROUP) it does not differ from the other two categories of firms engaged abroad in R&D. In this respect all three types of firms are different from those performing R&D only at home.

Market-oriented or resource-oriented motives are more important for firms with a sales share of exports of 34%-66% and >66% than for firms with smaller export intensity. Above the threshold of 34% the likelihood of being driven by the one or the other of the two motives is positively related to export intensity (as tests on the statistical significance of the difference of the coefficients of the dummy variables for an export intensity of 34%-66% and >66% showed). Hence, a certain level of presence in foreign markets as reflected by export intensity is obviously a precondition for foreign R&D based on a market-oriented or a resource-oriented R&D strategy. In case of knowledge-oriented foreign R&D the threshold of 34% does not exist as the likelihood of this motive rises with increasing export intensity up to 66% (statistically significant difference according to a t-test of the coefficients of the dummy variables for export intensity 1%-33% vs. 34%-66%). For firms with primarily knowledge-oriented motives the incentives for foreign R&D are high even when the export share is less than 34%.

The results with respect to L-disadvantages of the Swiss location differ among the firms driven by different motives. One the one hand, restrictive product market regulation (OBST_REGUL) is a disadvantage for firms with knowledge-oriented or market-oriented motives but not for those pursuing a resource-oriented strategy. For the latter, as mentioned above, insufficient availability of highly qualified personnel (HQUAL) is a more relevant restriction than unsatisfied needs for acquiring (additional) knowledge abroad or a weak presence on foreign product markets. On the other hand, insufficient public support of R&D (OBST_PROM) is an L-disadvantage for firms with market-oriented or resource-oriented motives but not for those motivated to go abroad seeking for additional know-how, indicating the specific character of foreign knowledge (no substitute of domestic know-how).

Pursuing market- or resource-oriented motives is more relevant for larger than for smaller firms (LEMPL); again the size-effect is non-linear. In contrast, focusing on knowledge-oriented motives is independent of firm size. Besides, there is no evidence for the expected positive relationship between firma age (LAGE) and the propensity to be stimulated by a specific motive to invest in foreign R&D. In case of market-oriented R&D strategies we even find, contrary to expectations, that older firms are less inclined than younger ones to perform R&D abroad. Hence, what is surprising, younger firms (if driven by the market-motive) seem more prepared to undertake such risky investments than older ones even if these presumably are more experienced in foreign transactions. Furthermore, foreign-owned firms are less likely than domestic companies to engage in a resource-oriented foreign R&D strategy (FOREIGN). Being themselves affiliates of multinational firms that invested in Switzerland, it is not astonishing that they assess resource-oriented motives as less relevant than domestic firms. There is no difference between domestic and foreign firms with respect to the other two motive categories.

Market structure (NCOMP) appears to be quite unimportant for all motive categories. Only firms operating in market segments with (worldwide) 16 to 50 principal competitors are stronger present among firms pursuing market-oriented or knowledge-oriented motives than companies operating in another market environment. We see no apparent explanation for this finding.

On the whole, the results for the model explaining overall foreign R&D (Table 3) are confirmed, and at the same time differentiated by the findings for the model dealing with three specific foreign R&D strategies reflecting three groups of motives for foreign R&D (Table 4). Both sets of equations largely support the *hypotheses 1 and 2* that primarily represent the OL-part of the OLI paradigm (see Section 2).

5.3 Results II: Performance equations

5.3.1 Innovativeness

Table 3 (column 2) and Table 5 (columns 1 to 3) show the results for the innovation equations. The firms' resource endowment, i.e. the use of physical (LQL) and human capital (LHQUAL), shows the expected positive coefficients in all four innovation equations. The same holds true for the use of customer/user knowledge (KCUST), firm size (LEMPL; non-linear effect) and the intensity of non-price competition (INPC), whereas we do not find a significant effect for the intensity of price-competition (IPC). These results are in accordance with earlier empirical studies (see Arvanitis, 2008). Firms operating in markets with (worldwide) 6 to 15 principal competitors showed a higher sales share of innovative products than firms in more concentrated markets but also than those competing in less concentrated markets (NCOMP) We found no significant effect for firm age (LAGE) and foreign-owned firms (FOREIGN).

In the first place, we are interested in the impact of foreign R&D on innovation (sales share of innovative products), looking both at the overall variable for foreign R&D and at the variables representing the three categories of motives for foreign R&D. The latter were inserted separately in the innovation equation to circumvent multicollinearity problems (see Footnote 6). It turns out that overall foreign R&D is positively related to innovation performance, but the effect is statistically not significant at the 10%-test level. The same holds for the variables representing foreign R&D strategies based on market-oriented and resource-oriented motives (M_MARK and M_RESO respectively). We only found a statistically significant positive effect on innovativeness for knowledge-oriented motives (M_KNOW). These findings are in accordance with *hypothesis 3* (see Section 2).

Table 5

5.3.2 Productivity

Table 3 (column 3) and Table 5 (columns 4 to 6) show the results for the productivity equations. The basic elements of the production function, i.e. physical capital (LCL), human capital (LHQUAL) and knowledge input (LRDL) show the expected positive effect in all equations. Besides, we found throughout a positive (non-linear) effect for firm size (LEMPL) and foreign ownership of the firms (FOREIGN).

We focus on the findings for the overall variable for foreign R&D and the variables representing the three categories of motives for foreign R&D that were inserted separately in the productivity equation. We found a positive and statistically significant productivity effect for overall foreign R&D as well as for the foreign R&D strategies based on market-oriented or resource-oriented motives (M_MARK and M_RESO). In contrast, no significant effect on productivity could be detected for knowledge-oriented motives. These findings are consistent with *hypothesis 4* (see Section 2).

6. Summary and discussion

Starting point of the analysis is the empirical fact that firms pursue different goals when getting engaged in foreign R&D, often more than one goal at the same time. Given that firms are driven by different motives for foreign R&D investment, the aim of this article is to investigate the differences between specific motives with respect to (a) the factors influencing the likelihood of foreign R&D investments as postulated by theory, and (b) the impact of foreign presence, differentiated by the motivation of foreign R&D, on a firm's innovativeness and productivity.

Based on an econometric analysis of Swiss firm panel data for nearly a decade covering the whole business sector (i.e. including services), we found that (a) factors related to firm-specific knowledge-based advantages (O-advantages) as well as variables reflecting disadvantages of the home location (L-disadvantages) are as hypothesized important for explaining the likelihood of foreign R&D activities, but the influence of O-advantages is stronger than that of L-disadvantages; (b) the relative importance of single factors representing such advantages or disadvantages varies significantly among the three different groups of motives for foreign R&D we take into consideration (knowledge-oriented, market-oriented and resource-oriented motives); (c) knowledge-oriented motives of foreign R&D activities are positively correlated to innovation performance, whereas (d) market-oriented or resource-oriented motives correlate positively with productivity. On the whole, the results support the four hypotheses put forward in Section 2.

How do these results compare with those of other investigations related to the Swiss economy? Two earlier studies dealing with the topic based on cross-section and panel data for Swiss manufacturing showed similar results with respect to conclusion (a), i.e. the factors explaining the likelihood to get engaged in R&D activities in foreign locations (Arvanitis and Hollenstein, 2001; Arvanitis and Hollenstein, 2007). The findings of the two studies also imply that foreign R&D and domestic R&D are complements. This result is confirmed by another recent study, which, in addition, shows that a considerable proportion of Swiss firms pursue knowledge-oriented foreign R&D strategies (Hollenstein, 2009).

The importance of this specific strategy is emphasized by four cross-country studies which comprise also Switzerland. Three papers are based on the analysis of patent data of MNEs. Patel and Vega (1999), who investigated the relative importance of several R&D strategies, concluded that in the Swiss case, "asset exploiting" and "asset augmenting" are the dominant strategies, whereas there are hardly any Swiss MNEs characterized by "(pure) technology sourcing" (i.e. sourcing combined with a weak domestic knowledge base). According to this study, "asset augmenting" is by far the most important strategy. Le Bas and Sierra (2002), who used the same approach but disposed of a broader database, concluded that "asset exploiting" and "asset augmenting" are much more relevant than other strategies for Swiss MNEs, both strategies being almost equally relevant for them. Cantwell and Janne (1999), who looked at the ranking of countries in terms of technological performance in selected industry groups, obtained the same result. Particularly, they found that "asset augmenting" is the dominant strategy in the Swiss pharmaceutical and chemical industry, whereas "asset exploiting" is characteristic for the Swiss metal and machinery sector. Since the share of these two industry groups in overall Swiss foreign R&D expenditures is almost equal, we conclude that the two strategies are of similar importance. Furthermore, Driffield and Love (2005), using data for FDI in the UK by country of origin showed that firms from technologically leading countries (such as Switzerland) benefit most from the knowledge base of the UK, in particular in case of spatial clusters of R&D intensive firms. Hence, the evidence from these cross-country analyses, in accordance with the studies using Swiss data only, supports, firstly, the hypothesis that foreign and domestic R&D are complements and, secondly, that asset-augmenting strategies play an important role. Although none of these studies explicitly relates the asset-augmenting strategy (reflecting knowledge-oriented motives) with innovativeness, one may presume based on sub-section 2.4 that this type of foreign R&D positively affects the innovation performance of the parent company (what would be in line with conclusion (c).[10]

According to conclusion (d), market- and resource-oriented motives for foreign R&D are positively correlated with the productivity of the parent company, what does not apply in case of knowledge-oriented strategies. This result seems to be at odds with some of the (few) empirical studies for other countries (see sub-section 2.4). However, the evidence on the effects of foreign R&D on domestic productivity remains mixed and inconclusive.

Finally, the results of the present study show that it is valuable to differentiate the analysis of R&D activities at foreign locations by distinguishing distinct motives for a foreign presence. This holds true for the analysis of the determinants of foreign R&D (that differ significantly among the motives considered in this paper) as well as the impact on the performance of the parent company which shows a clear pattern depending on the type of foreign R&D strategy (motives) and on the performance measure considered (innovativeness vs. productivity). To our knowledge, this study is the first one differentiating the analysis along all these lines. Moreover, as the service sector is gaining in importance in general but also in terms of the internationalization of activities, it is necessary to include this segment of the economy as well. The present study is contributing to empirical literature also in this respect.

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Footnotes

1 Versions of the questionnaire in German, French and Italian are available at www.kof.ethz.ch.

2 Since we did not correct for a possible sample selection bias for firms that did not perform R&D the results can be interpreted as applicable only to firms investing in R&D

3 See the Appendix for the descriptive statistics of the model variables (Table A.2) and the corresponding correlation matrix (Table A6).

4 See Table 1 for some descriptive statistics of the motive variables and Table 2 for the exact construction of the variables.

5 However, there is evidence for some weakening of the stepwise process of internationalization, in particular in case of (small- and medium-sized) high-tech and knowledge-intensive firms; see the review of the literature based on the "network perspective of internationalization" (Coviello and McAuley, 1999) and the "Born Global"-approach (Rialp et al., 2005).

6 Due to strong multicollinearity it was not possible to include in the innovation equation the three motive variables at once (see Table A.6 in the Appendix).

7 See Belderbos et al. (2004), Capron and Cincera (2004) and Schmidt (2007) for a similar approach regarding the analysis of motives for R&D cooperation. See also the discussion on this issue in Mohnen and Hoareau (2003) and Schmidt (2007).

8 The STATA procedure 'mprobit' estimates M-equation probit models by the method of simulated maximum likelihood. The Geweke-Hajivassiliou-Keane (GHK)-simulator is applied to evaluate the M-dimensional Normal integrals in the likelihood function (for a description of the GHK-simulator see Greene (2003)).

9 See Table A.3 and Table A.4 in the appendix for the endogeneity tests with respect to the R&D_FOR and the three motive variables in the innovation and the productivity

equation. Table A.5 in the appendix shows the estimates of the underlying instrument equations.

10 A positive relationship between foreign and domestic R&D of Swiss firms is also found by Ben Hamida and Piscitello (2008), but these authors do not take account of different motivations of foreign R&D.

TABLES

Table 1: R&D activities and motives for R&D at foreign locations

Groups of motives	2002		2005		2008		Total	
	N	%	N	%	N	%	N	%
M_KNOW *Knowledge-oriented motives*	94	8.7	112	11.5	101	13.2	307	10.9
M_MARK *Market-oriented*	62	5.8	92	9.5	90	9.1	224	7.8
M_RESO *Resource-oriented motives*	73	6.8	94	9.7	66	8.6	233	8.3
R&D_FOR *R&D activities at foreign locations*	156	14.5	207	21.3	177	23.0	540	19.2

Note: See table 2 for the construction of the motive variables.

Table 2: Definition of variables

Variable	Description
LQL	Natural logarithm of value added per employee; industry level: at constant prices
LINNL	Natural logarithm of the sales of 'innovative products' (new products + significantly modified existing products) per employee ('innovative sales productivity')
R&D_FOR	R&D activities at foreign locations yes/no (dummy variable)
M_KNOW	Motive for R&D at foreign locations: (a) geographical proximity to leading research universities *and/or* (b) highly-innovative firms *and/or* (c) transfer of knowledge to the Swiss headquarter (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
M_MARK	Motive for R&D at foreign locations: supporting production and sales at foreign locations (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
M_RESO	Motive for R&D at foreign locations: (a) lower R&D costs *and/or* (b) higher government support of R&D investment *and/or* (c) ample supply of R&D personnel (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
LEMPL	Natural logarithm of the number of employees (in full-time equivalents)
LCL	Natural logarithm of gross investment per employee
LRDL	Natural logarithm of R&D expenditures per employee
LHQUAL	Natural logarithm of employment share of employees with tertiary-level education
HQUAL	Employment share of employees with tertiary-level education
KCUST	Importance of customers as external innovation-relevant knowledge source (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
KGROUP	Importance of other firms of an enterprise group as external innovation-relevant knowledge source (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
KPATSCIENCE	Importance of science-based external knowledge (from universities and/or patent disclosures) (five-level ordinal variable)
IPC	Intensity of *price* competition (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
INPC	Intensity of *non-price* competition (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
NCOMP	Number of main competitors in a firm's most important (worldwide) product market (3 dummy variables: 16-50; 6-15; <= 5 ; reference group: > 50)
EXP	Sales share of exports (3 dummy variables: 1%-33%; 34%-66%; > 66%); reference group: no exports
FOREIGN	Foreign-owned firm yes/no (dummy variable)s
LAGE	Logarithm of firm age in years

RDPERM	Permanent R&D activities yes/no (dummy variable)
RDCOOP	R&D cooperation yes/no (dummy variable)
RDEXT	Contract (external) R&D yes/no (dummy variable)
OBST_REG	Obstacle to innovation: excessive regulation of the domestic product market (five-level ordinal variable)
OBST_PROM	Obstacle to innovation: insufficient public support of firm innovation activities (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)
DEXP	Intensity of product-related development input (dummy variable based on an originally five-point intensity scale: value 1 for 4 or 5; otherwise 0)

Table 3: R&D activities at foreign locations (RD_FOR): determinants; relationship to innovation and productivity

Explanatory variables	R&D_FOR RE PROBIT	LINNL RE TOBIT	LQL RE OLS
RDPERM	0.208* (0.109)		
HQUAL	0.005* (0.003)		
RDCOOP	0.387*** (0.102)		
RDEXT	0.596*** (0.112)		
KCUST		0.535** (0.217)	
KPATSCIENCE	0.106** (0.050)		
KGROUP	0.439*** (0.116)		
EXP			
1%-33%	0.509*** (0.176)		
34%-66%	0.772*** (0.194)		
> 66%)	1.151*** (0.196)		
OBST_REG	0.090* (0.052)		
OBST_PROM	0.535*** (0.186)		
NCOMP:			
16-50	0.231 (0.168)	0.390 (0.355)	
6-15	-0.176 (0.163)	0.727** (0.336)	
<= 5	0.128 (0.111)	0.079 (0.249)	
IPC		0.229 (0.242)	
INPC		0.553** (0.217)	
LCL		0.195* (0.102)	0.118*** (0.007)
LHQUAL		0.507*** (0.128)	0.031*** (0.010)
LRDL			0.042*** (0.005)
LEMPL	0.174*** (0.043)	0.166** (0.083)	0.022*** (0.006)

LAGE	-0.075	-0.198	
	(0.080)	(0.160)	
FOREIGN	-0.094	0.315	0.148***
	(0.135)	(0.287)	(0.023)
R&D_FOR		0.392	0.043**
		(0.282)	(0.020)
Const.	-3.969***	4.163***	10.206***
	(0.499)	(1.419)	(0.097)
N	2153	2405	2667
Left-censored		412	
Wald Chi2	140.3***	173.5***	820.5***
Log likelihood	-935.6	-6588.6	
R-sq. within			0.0805
R-sq. between			0.313
R-sq. overall			0.281
Rho	0.554***		0.540

Note: Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level. Rho: share of variance that can be traced back to heterogeneity.

Table 4: Determinants of R&D at foreign locations based on three different types of motives; multivariate probit estimates

Explanatory variables	M_KNOW	M_RESO	M_MARK
RDPERM	0.088	0.090	0.075
	(0.091)	(0.104)	(0.099)
HQUAL	0.003	0.007***	0.003
	(0.002)	(0.002)	(0.002)
RDCOOP	0.404***	0.226***	0.236***
	(0.079)	(0.085)	(0.084)
RDEXT	0.354***	0.142	0.491***
	(0.087)	(0.093)	(0.096)
KPATSCIENCE	0.190***	0.068	0.043
	(0.038)	(0.041)	(0.040)
KGROUP	0.261***	0.213**	0.207**
	(0.086)	(0.091)	(0.090)
EXPORTSHARE:			
1%-33%	0.337**	0.148	0.234
	(0.141)	(0.159)	(0.151)
34%-66%	0.600***	0.277*	0.378**
	(0.149)	(0.168)	(0.162)
> 66%)	0.619***	0.569***	0.665***
	(0.144)	(0.156)	(0.150)
OBST_REG	0.107***	0.063	0.091**
	(0.039)	(0.044)	(0.042)
OBST_PROM	0.133	0.313**	0.430***
	(0.139)	(0.146)	(0.136)
NCOMP:			
16-50	0.257**	0.014	0.289**
	(0.127)	(0.141)	(0.133)
6-15	-0.098	-0.139	-0.180
	(0.131)	(0.141)	(0.144)
<= 5	0.125	-0.011	0.042
	(0.087)	(0.093)	(0.092)
LEMPL	0.030	0.195***	0.104***
	(0.030)	(0.032)	(0.031)
LAGE	0.010	-0.013	-0.128**
	(0.055)	(0.059)	(0.058)
FOREIGN	-0.121	-0.216**	0.083
	(0.098)	(0.105)	(0.100)
Const.	-3.244***	-3.543***	-2.821***
	(0.344)	(0.377)	(0.361)
N		2153	
Log likelihood		-1643.4	
Wald chi2		410.7***	
Rho21		0.577***	
Rho31		0.655***	
Rho32		0.602***	
LR test of rho21 =		410.3***	

rho31 = rho32 = 0			

Note: Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level. Rho: share of variance that can be traced back to heterogeneity.

Table 5: Innovation, productivity and motives for R&D at foreign locations; random effects Tobit and OLS estimates resp.

Explanatory variables	LINNL	LINNL	LINNL	LQL	LQL	LQL
LCL	0.194*	0.197*	0.200**	0.118***	0.119***	0.118***
	(0.101)	(0.102)	(0.102)	(0.031)	(0.007)	(0.007)
LHQUAL	0.504***	0.508***	0.519***	0.031***	0.031***	0.031***
	(0.128)	(0.128)	(0.128)	(0.010)	(0.010)	(0.010)
LRDL				0.042***	0.042***	0.042***
				(0.005)	(0.005)	(0.005)
KCUST	0.538**	0.517**	0.530**			
	(0.217)	(0.218)	(0.218)			
NCOMP:						
16-50	0.373	0.404	0.396			
	(0.356)	(0.355)	(0.356)			
6-15	0.719**	0.733**	0.713**			
	(0.336)	(0.336)	(0.336)			
<= 5	0.069	0.093	0.084			
	(0.249)	(0.249)	(0.249)			
IPC	0.243	0.229	0.232			
	(0.242)	(0.242)	(0.242)			
INPC	0.539**	0.561***	0.556***			
	(0.217)	(0.217)	(0.217)			
LEMPL	0.172**	0.164**	0.184**	0.024***	0.023***	0.023***
	(0.082)	(0.083)	(0.082)	(0.006)	(0.003)	(0.006)
LAGE	-0.200	-0.201	-0.201			
	(0.159)	(0.160)	(0.160)			
FOREIGN	0.323	0.335	0.320	0.148***	0.149***	0.147***
	(0.287)	(0.287)	(0.287)	(0.023)	(0.023)	(0.023)
M_KNOW	0.603*			0.034		
	(0.347)			(0.024)		
M_MARK		0.618			0.049*	
		(0.402)			(0.028)	
M_RESO			0.114			0.071***
			(0.394)			(0.027)
Const.	4.153***	4.170***	4.033	10.192***	10.195***	10.202***
	(1.417)	(1.418)	(1.417)	(0.097)	(0.096)	(0.096)
N	2405	2405	2405	2667	2667	2667
Left-censored	412	412	412			
Log likelihood	-6588.0	-6588.4	-6589.5			
Wald Chi2	174.7***	173.8***	171.3***	816.7***	818.6***	823.8**
R-sq within				0.080	0.079	0.081
R-sq between				0.311	0.313	0.313
R-sq overall				0.280	0.281	0.282
Rho				0.540	0.539	0.539

Note: Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level. Rho: share of variance that can be traced back to heterogeneity.

APPENDIX

Table A.1: Composition of the dataset by industry, firm size class and year

	Number of firms with R&D activities	Firms with R&D activities at foreign locations (%)
Industry:		
Food, beverage, tobacco	171	12.3
Textiles	62	21.0
Clothing, leather	12	25.0
Wood processing	54	5.6
Paper	47	12.8
Printing	60	10.0
Chemicals	206	27.7
Plastics, rubber	90	26.7
Glass, stone, clay	59	17.0
Metal	38	18.4
Metal working	212	14.2
Machinery	452	27.4
Electrical machinery	128	26.6
Electronics, instruments	294	28.2
Vehicles	68	8.8
Watches	32	15.6
Other manufacturing	61	11.5
Energy, water	26	3.9
Construction	98	8.2
Wholesale trade	115	18.3
Retail trade	49	2.0
Hotels, catering	44	4.6
Transport, telecommunication	80	10.0
Banks, insurance	113	15.9
Real estate, leasing	5	0.0
Computer services	96	22.9
Business services	138	13.8
Personal services	7	14.3
Firm size:		
5-19 employees	459	12.2
20-49 employees	579	10.4
50-99 employees	496	16.7
100-199 employees	540	22.0
200-499 employees	470	24.3
500-999 employees	141	36.2
1000 employees and more	132	43.2
Year:		
2002	1075	14.5
2005	974	21.3
2008	768	23.1
Total	2817	19.2

Table A.2: Descriptive statistics

Variable	N	Mean	Std. Dev.	Min	Max
R&D_FOR	2817	0.191	0.394	0	1
M_KNOW	2817	0.109	0.312	0	1
M_MARK	2817	0.080	0.271	0	1
M_RESO	2817	0.083	0.275	0	1
LINNS	2784	3.139	1.301	0	4.615
LQL	2776	11.941	0.466	10.835	13.809
LCL	2720	9.804	1.392	0.125	13.342
LHQUAL	2817	2.848	0.941	0	4.615
LRDL	2815	8.092	1.707	0	12.372
LEMPL	2817	4.426	1.474	1.386	11.002
LAGE	2742	3.901	0.735	1.099	5.864
HQUAL	2817	23.702	20.392	0	100
KCUST	2817	0.520	0.500	0	1
KPATSCIENCE	2817	0.231	0.330	0	1
KGROUP	2817	0.243	0.429	0	1
IPC	2817	0.717	0.451	0	1
INPC	2817	0.415	0.493	0	1
NCOMP: 16-50	2817	0.115	0.319	0	1
NCOMP: 6-15	2817	0.129	0.335	0	1
NCOMP: <= 5	2817	0.302	0.459	0	1
EXP: 1%-33%	2795	0.277	0.447	0	1
EXP: 34%-66%	2795	0.161	0.368	0	1
EXP: > 66%	2795	0.297	0.457	0	1
FOREIGN	2790	0.181	0.385	0	1
RDPERM	2237	0.570	0.495	0	1
RDCOOP	2812	0.336	0.472	0	1
RDEXT	2817	0.531	0.499	0	1
OBST_REG	2817	0.082	0.320	0	1
OBST_PROM	2817	0.070	0.256	0	1
DEXP	2491	0.285	0.452	0	1

Table A.3: Test on endogeneity; R&D activities at foreign locations; random effects Tobit and OLS estimates; bootstrapping

Explanatory variables	LINNL	LQL
LCL	0.093	0.111***
	(0.144)	(0.016)
LHQUAL	0.143	0.027
	(0.204)	(0.017)
LRDL		0.044***
		(0.009)
KCUST	0.536*	
	(0.323)	
NCOMP:		
16-50	0.325	
	(0.517)	
6-15	0.809*	
	(0.425)	
<= 5	0.035	
	(0.383)	
IPC	0.281	
	(0.367)	
INPC	0.401	
	(0.250)	
LEMPL	0.139	0.021**
	(0.127)	(0.009)
LAGE	-0.115	
	(0.187)	
FOREIGN	0.456	0.130***
	(0.391)	(0.030)
R&D_FOR	0.662*	0.034
	(0.378)	(0.034)
RES_R&D_FOR	-0.259	-0.009
	(0.217)	(0.015)
Const.	6.565***	10.330***
	(2.050)	(0.211)
N	1917	2064
Left-censored	323	
R-sq within		0.093
R-sq between		0.285
R-sq overall		0.263
Log likelihood	-5256.0	
Wald Chi2	263.7***	596.0***
Rho		0.564

Note: Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level. Rho: share of variance that can be traced back to heterogeneity.

Table A.4: Test on endogeneity; motives of R&D at foreign locations; random effects Tobit and OLS estimates; bootstrapping

Explanatory variables	LINNL	LINNL	LINNL	LQL	LQL	LQL
LCL	0.145	0.102	0.099	0.112***	0.112***	0.111***
	(0.155)	(0.132)	(0.142)	(0.016)	(0.016)	(0.016)
LHQUAL	0.190	0.129	0.161	0.029*	0.027	0.026*
	(0.211)	(0.208)	(0.226)	(0.017)	(0.017)	(0.16)
LRDL				0.046***	0.045***	0.044***
				(0.008)	(0.008)	(0.008)
KCUST	0.539*	0.525*	0.530*			
	(0.305)	(0.273)	(0.282)			
NCOMP:						
16-50	0.223	0.390	0.259			
	(0.512)	(0.515)	(0.458)			
6-15	0.813**	0.815**	0.829*			
	(0.406)	(0.397)	(0.493)			
<= 5	0.042	0.088	0.038			
	(0.393)	(0.335)	(0.302)			
IPC	0.101	0.284	0.285			
	(0.347)	(0.349)	(0.338)			
INPC	0.368	0.417	0.404			
	(0.348)	(0.296)	(0.287)			
LEMPL	0.179	0.115	0.164	0.025***	0.021*	0.021***
	(0.119)	(0.182)	(0.111)	(0.007)	(0.012)	(0.008)
LAGE	-0.147	-0.120	-0.070			
	(0.270)	(0.242)	(0.255)			
FOREIGN	0.625	0.558	0.425	0.132***	0.134***	0.127***
	(0.430)	(0.361)	(0.338)	(0.032)	(0.033)	(0.033)
M_KNOW	0.858*			0.002		
	(0.493)			(0.032)		
RES_M_KNOW	-0.101			-0.000		
	(0.304)			(0.019)		
M_MARK		0.827			0.045	
		(0.602)			(0.047)	
RES_M_MARK		-0.309			-0.008	
		(0.423)			(0.025)	
M_RESO			0.355			0.061*
			(0.592)			(0.037)
RES_M_RESO			-0.328			-0.017
			(0.279)			(0.018)
Const.	5.649***	6.933***	6.506***	10.271***	10.324***	10.363***
	(2.615)	(2.555)	(1.999)	(0.207)	(0.226)	(0.199)
N	1917	1917	1917	2064	2064	2064
Left-censored	323	323	323			
R-sq within				0.094	0.092	0.093
R-sq between				0.284	0.286	0.286
R-sq overall				0.267	0.262	0.263

Log likelihood	-4502.3	-5256.8	-5257.2			
Wald Chi2	253.2***	191.5***	195.8***	549.1***	664.2***	545.4***
Rho				0.566	0.565	0.563

Note: Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level. Rho: share of variance that can be traced back to heterogeneity.

Table A.5: Instrument equations; random effects Probit estimates

Explanatory variables	M_KNOW/ LINNL	M_KNOW/ LQL	M_RESO	M_MARK	R&D_FOR
DEXP	0.296***				
	(0.112)				
OBST_REG	0.150***	0.132***	0.093	0.099	0.090*
	(0.053)	(0.048)	(0.059)	(0.063)	(0.052)
OBST_PROM	0.076	0.188	0.613***	0.399*	0.535***
	(0.187)	(0.172)	(0.200)	(0.212)	(0.185)
RDPERM	0.159	0.143	0.127	0.100	0.208*
	(0.120)	(0.108)	(0.131)	(0.141)	(0.109)
HQUAL	0.003	0.004	0.003	0.009***	0.005*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
RDCOOP	0.503***	0.470***	0.248**	0.263**	0.387***
	(0.198)	(0.098)	(0.116)	(0.121)	(0.102)
RDEXT	0.493***	0.437***	0.666***	0.212	0.569***
	(0.122)	(0.109)	(0.140)	(0.130)	(0.112)
KPATSCIENCE	0.208***	0.215***	0.063	0.076	0.106**
	(0.052)	(0.048)	(0.057)	(0.060)	(0.050)
KGROUP	0.254**	0.278***	0.218*	0.226*	0.439***
	(0.118)	(0.108)	(0.128)	(0.131)	(0.116)
EXP:					
1%-33%	0.451**	0.423**	0.319	0.184	0.509***
	(0.192)	(0.173)	(0.211)	(0.225)	(0.176)
34%-66%	0.685***	0.700***	0.480**	0.346	0.772***
	(0.207)	(0.187)	(0.231)	(0.240)	(0.194)
> 66%)	0.792***	0.771***	0.891***	0.738***	1.151***
	(0.206)	(0.184)	(0.223)	(0.230)	(0.196)
NCOMP:					
16-50	0.322*	0.283*	0.425**	0.046	0.231
	(0.170)	(0.156)	(0.185)	(0.199)	(0.168)
6-15	-0.093	-0.147	-0.265	-0.172	-0.176
	(0.176)	(0.161)	(0.204)	(0.200)	(0.163)
<= 5	0.170	0.138	0.109	-0.001	0.128
	(0.118)	(0.107)	(0.127)	(0.132)	(0.111)
LEMPL	0.018	0.029	0.137***	0.280***	0.174***
	(0.042)	(0.037)	(0.047)	(0.054)	(0.043)
LAGE	0.004	0.000	-0.209**	-0.054	-0.075
	(0.078)	(0.070)	(0.085)	(0.087)	(0.077)
FOREIGN	-0.027	-0.083	0.095	-0.269*	-0.094
	(0.138)	(0.124)	(0.147)	(0.158)	(0.135)
Const.	-3.924***	-3.744***	-3.432***	-4.685***	-3.969***
	(0.514)	(0.465)	(0.547)	(0.563)	(0.499)
N	1839	2153	2153	2513	2153
Log likelihood	-606.4	-690.6	-568.5	-555.9	-935.6
Wald chi2	108.3***	125.0***	92.7***	85.3***	140.3***

Note: Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies. ***, **, * denote statistical significance at the 1%, 5% and 10% test level.

Table A.6: Correlations

	R&D_ FOR	M_ KNOW	M_ MARK	M_ RESO	LCL	LHQU AL	HQUA L	LRDL	LAGE	KCUST	KGROU P	KPATSCI ENCE	IPC	INPC
R&D_FOR	1.000													
M_KNOW	0.706	1.000												
M_MARK	0.599	0.393	1.000											
M_RESO	0.615	0.502	0.381	1.000										
LCL	0.010	0.018	0.004	-0.001	1.000									
LHQUAL	0.124	0.117	0.111	0.112	-0.049	1.000								
HQUAL	0.105	0.077	0.094	0.101	-0.077	0.864	1.000							
LRDL	0.203	0.138	0.165	0.157	0.128	0.326	0.318	1.000						
LAGE	-0.007	0.004	0.015	-0.066	0.081	-0.125	-0.188	-0.141	1.000					
KCUST	0.032	0.011	0.060	0.025	0.040	0.068	0.052	0.046	-0.062	1.000				
KGROUP	0.144	0.097	0.096	0.081	0.074	0.060	0.046	0.058	0.015	0.086	1.000			
KPATSCIENCE	0.202	0.229	0.145	0.143	0.074	0.211	0.175	0.154	0.042	0.101	0.129	1.000		
IPC	0.002	-0.030	0.014	-0.009	0.005	-0.035	-0.077	-0.037	0.092	0.027	0.058	0.041	1.000	
INPC	0.021	0.063	0.002	0.017	0.071	0.025	0.022	0.077	0.015	0.084	0.016	0.108	-0.063	1.000
NCOMP:	0.015	0.035	-0.006	0.034	0.030	0.003	-0.007	-0.031	0.017	-0.033	-0.044	0.019	0.057	-0.022
NCOMP:	-0.060	-0.043	-0.044	-0.054	0.011	-0.060	-0.050	-0.043	0.027	-0.016	-0.027	-0.062	0.056	-0.045
NCOMP:	0.046	0.044	0.019	0.031	0.002	-0.022	-0.045	0.026	0.036	0.077	0.026	0.035	0.045	0.023
FOREIGN	0.076	0.035	0.023	0.098	0.010	-0.132	0.111	0.120	-0.068	0.044	0.304	0.097	0.015	0.014
LEMPL	0.196	0.1115	0.196	0.110	0.100	0.046	-0.055	0.010	0.282	0.064	0.220	0.265	0.118	0.094
RDPERM	0.103	0.064	0.072	0.052	-0.192	0.034	0.033	0.102	-0.028	0.015	0.020	0.036	-0.017	0.029
RDCOOP	0.187	0.186	0.123	0.130	0.009	0.159	0.145	0.156	0.022	0.030	0.064	0.210	0.004	0.017
RDEXT	0.208	0.170	0.117	0.172	0.027	0.135	0.085	0.151	0.047	0.046	0.047	0.250	0.017	0.063
EXP:	-0.087	-0.057	-0.083	-0.083	-0.006	-0.023	0.003	-0.132	0.063	-0.026	-0.044	-0.054	0.001	0.026
EXP:	0.008	0.027	-0.013	-0.015	0.042	-0.016	-0.041	0.008	0.037	0.017	0.056	0.034	0.006	0.041
EXP:	0.228	0.134	0.188	0.180	-0.005	0.166	0.112	0.325	-0.054	0.092	0.045	0.142	0.013	0.044
OBST_REG	0.016	0.051	0.012	0.029	0.000	0.018	0.011	-0.032	-0.027	0.015	0.032	0.074	-0.019	0.000
OBST_PROM	0.084	0.054	0.046	0.094	-0.027	0.028	0.066	0.027	-0.092	0.012	0.005	0.051	-0.007	0.004
DEXP	0.064	0.104	0.073	0.079	0.185	0.079	0.077	0.226	-0.024	0.048	0.045	0.148	0.010	0.107

	NCOMP:	NCOMP:	NCOMP:	FOREIGN	LEMPL	RDPERM	RDCOOP	RDEXT	EXP:	EXP:	EXP:	OBS_ REG	OBS_ PROM	DEXP
NCOMP:	1.000													
NCOMP:	-0.138	1.000												
NCOMP:	-0.233	-0.253	1.000											
FOREIGN	-0.070	-0.038	0.090	1.000										
LEMPL	-0.033	-0.036	0.057	0.099	1.000									
RDPERM	-0.043	-0.029	0.004	0.013	0.070	1.000								
RDCOOP	0.019	-0.040	0.040	0.037	0.132	0.065	1.000							
RDEXT	-0.062	-0.026	0.035	0.044	0.211	0.032	0.173	1.000						
EXP:	0.032	0.030	-0.048	-0.123	-0.013	-0.046	-0.060	-0.058	1.000					
EXP:	0.003	0.006	0.046	0.022	0.045	-0.016	-0.040	-0.019	-0.284	1.000				
EXP:	-0.063	-0.075	0.071	0.220	0.125	0.099	0.149	0.166	-0.442	-0.327	1.000			
OBS_REG	0.042	0.019	-0.042	-0.061	-0.071	0.010	-0.082	-0.018	0.097	-0.006	-0.162	1.000		
OBS_PROM	0.048	-0.010	-0.004	-0.16	-0.098	-0.002	0.060	0.013	0.005	-0.018	0.008	0.192	1.000	
DEXP	0.006	-0.038	0.011	0.005	0.057	-0.049	0.043	0.052	-0.555	0.024	0.105	0.023	0.086	1.000