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

An Analysis Based on Swiss Panel Micro Data

Spyros Arvanitis

ETH Zurich, KOF Swiss Economic Institute
8092 Zurich, Switzerland
Phone: +41 44 / 632‘51‘68
Fax: +41 44 / 632‘13‘52
E-mail: arvanitis@kof.ethz.ch

Heinz Hollenstein

ETH Zurich, KOF Swiss Economic Institute
8092 Zurich, Switzerland
Phone: +41 44 / 632‘53‘29
Fax: +41 44 / 632‘13‘52
E-mail: hollenstein@kof.ethz.ch

First Draft, December 2009

Abstract

Starting point of our 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 related to different motives with respect (a) to the factors influencing the likelihood of foreign R&D investment as postulated by theory; and (b) to the impact of R&D cooperation on firm innovativeness and firm productivity.

Based on microeconometric analysis of Swiss firm panel data, we found that (a) 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; (b) the relative importance of single factors representing advantages or disadvantages varies significantly among the three different groups of motives for foreign R&D we take into consideration in this paper (knowledge-oriented, market-oriented, and resource-oriented-motives); (c) being engaged in foreign R&D activities primarily driven by *knowledge-oriented* motives is positively correlated to innovation performance; and (d) foreign R&D activities driven by *market-oriented* or *resource-oriented* motives correlate positively with productivity.

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 also in other countries.

Since about fifteen years observers became increasingly aware that foreign R&D often is motivated by additional factors. Florida (1997) and Kuemmerle (1999), for example, showed that firms often perform foreign R&D in the first instance in order to profit from knowledge only available at specific foreign locations ("technology sourcing"). Foreign R&D is thus a means to complement and augment knowledge available at the domestic headquarter. In this case, knowledge-seeking (asset seeking) motives drive foreign R&D. If knowledge is incorporated in personnel that is specialized in specific advanced technologies, knowledge-seeking and the (classical) motive of resource-seeking become to a certain extent congruent. In this perspective, foreign and domestic R&D again are complements, at least if it turns out that knowledge transfer to the domestic headquarter works sufficiently well. Otherwise, it cannot be excluded that technology sourcing may lead to gradual (partial) substitution of domestic R&D by moving the core (or a substantial part) of a firm's R&D to foreign locations. This may be the case if knowledge available from foreign sources is superior to domestic R&D, for example, if the latter is specialised in activities that do not correspond to the needs of recent and future technological trends ("lock-in").

Starting point of our 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 related to different motives with respect (a) to the factors influencing the likelihood of foreign R&D investment as postulated by theory; and (b) to the impact of R&D cooperation on firm innovativeness and firm productivity.

To this end, we utilized data on three different groups of motives for foreign R&D reported by Swiss manufacturing firms in the years 2002, 2005 and 2008, thus covering a period of about ten years. In a first step, based on these data we distributed firms having R&D activities in foreign locations in three groups 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 these three groups of motives. In a second step, we specified based on theoretical literature, primarily the expanded OLI-paradigm, a model of the determining factors of the propensity to invest in R&D in foreign locations comprising primarily variables measuring firms' innovation capabilities in the home country, e.g., R&D cooperation, external R&D (O-advantages of firms operating in the home market); variables measuring innovation obstacles

(L-disadvantages of home market); further variables measuring the intensity of competitive pressures and controls for industry, firm size, firm age and time. The three motive dichotomous variables were the variables to be explained by this model. These three cooperation equations were estimated by multivariate probit techniques in order to take into account the interdependence of the dependent variables due to the fact that firms are driven by more than one motive at the time. In a third step, we specified an innovation equation and a productivity equation respectively that included separately each of the four motive dichotomous variables as right-hand variables. These were estimated by random effect tobit and random effect OLS techniques respectively, after testing for endogeneity for the four motive variables and, if necessary, adapting accordingly the estimation method. We also estimated a foreign R&D equation and the two impact equations for the overall foreign R&D variable ('foreign R&D yes/no') as reference.

New elements of this study are (a) the consideration of several distinctive motives for R&D investment in foreign locations; (b) the investigation of the impact of these different motives on innovation and productivity at the home country; and (c) the consideration of panel firm data (three cross-sections of firms) covering a period of about ten years.

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 the model specification and the variable construction. In section 5 we discuss the empirical results. Finally, section 6 contains a summary and 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. 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). 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). Finally, 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 organisation 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 internationalisation that are rooted in different "sub-disciplines" of economics such as industrial organisation, 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; Cantwell and Narula 2001). The "new" extended version stresses more explicitly the strategic aspects of internationalisation based on the "dynamic capability view of the firm" (Teece and Pisano, 1998). In this concept, a firm does not invest abroad only to increase its efficiency (efficiency-seeking motives), to get access to (natural) resources (resource-oriented motives) or to exploit at foreign locations the assets produced at home (market-oriented motives, "asset exploiting" strategy"), but also to complement and enrich domestic assets by tapping into foreign "National Innovation Systems" (NIS). As a consequence of this phenomenon, "asset-seeking" becomes a much more prominent motive of foreign investment ("asset augmenting" strategy) 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 factors determining 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 „internalising advantages" (I)". In accordance with the "dynamic capability view of the firm" (Teece and Pisano 1998), O-advantages refer to firm-specific capabilities and assets that make it 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, organisation, 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 favouring or impeding knowledge creation and use (costs of R&D inputs, R&D-related taxes and subsidies, regulatory framework, etc.). I-advantages can be realised through M&A activities or by forming R&D co-operations and alliances as means to internalise market transactions. In this way, 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 R&D in foreign locations

Recent empirical studies on R&D internationalization investigate "technology sourcing" as driver of R&D investment in R&D in 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; Patel and Vega 1999; Frost 2001; Le Bas and Sierra 2002). In these studies these 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. More specifically, Cantwell and Piscitello (2005) showed that geographic proximity to universities and highly innovative firms, in accordance with the asset-augmenting strategy, offers great opportunities for profiting from knowledge spillovers. Further, in a recent study Hollenstein 2009 analyzed the characteristics of several single motives of foreign R&D based on Swiss firm data.

2.4 Foreign R&D activities and home economic performance

In an earlier study Kotabe (1990) suggested that internationally diversified firms can improve their innovative performance through the utilization of the wider range of resources available globally. Kotabe et al. (2002) advanced and confirmed empirically for USA multinational firms the proposition that that the relationship between innovation and performance is mediated by a firm's degree of internationalization. The main idea in this study was that firms need some degree of internationalization as manifested by the ability to access a broad range of markets in order to take full advantage of their new products and processes. Kafouros et al. (2008) in a recent paper presented a theoretical framework and also empirical evidence from UK manufacturing firms for the proposition that the internationalization of a firm's activities positively influences innovation performance.

However, on the whole empirical evidence on the benefits of parent firm in the origin country from foreign R&D has been mixed. For example, Fors (1997) using Swedish firm data found no significant impact of foreign R&D on parent firms' productivity. Similarly, Iwasa and Odagiri (2004) found that R&D of Japanese firms in the USA had no impact on innovation at home. On the other hand, Todo and Shimizutani (2008) based on firm-level data for Japanese multinational enterprises showed 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 to local conditions in foreign locations) has no such effect.

2.5 Resulting hypotheses

The above discussion of literature leads to the formulation of the following hypotheses for the empirical part of the study:

Hypothesis 1: The likelihood to be 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 (owner-specific advantages in the sense of the OLI approach);

Hypothesis 2: The likelihood to be engaged in R&D activities in foreign locations correlates *negatively* with disadvantages with respect tot innovation activities in the home country (location-specific disadvantages in the sense of the OLI approach);

Hypothesis 3: R&D activities in foreign locations, particularly activities driven by *knowledge-oriented* motives enhance firms' innovation performance (through new or improved products or faster introduction of such new or improved products);

Hypothesis 4: R&D activities in foreign locations, particularly activities driven by *market-oriented* and/or *resource-oriented motives* enhance firms' productivity (through the reduction of innovation costs, and/or the utilization of economies of scale, scope, or learning).

3. Data

The data used in this study were collected in the course of three surveys among Swiss enterprises in the years 2002, 2005 and 2008 using a questionnaire that included besides questions on some basic firm characteristics (sales, exports, employment, investment and employees' vocational education), several innovation indicators quite similar to those in the Innovation Surveys of the European Community (CIS) as well as information on R&D activities at foreign locations (start year of R&D foreign investment, foreign locations, motives, etc.).[1] The survey was based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all relevant industries of the manufacturing sector, the construction sector and selected service industries as well as firm size classes (on the whole 28 industries and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms). We used in this study only data for firms conducting R&D activities 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 structure of the used data set by industry, firm size class and year respectively).[3]

[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 conduct R&D, the results can be interpreted as applicable only to firms investing in R&D.
[3] See Table A.2 for descriptive statistics of the model variables and Table A.6 in the appendix for correlations among the model variables.

4. Model specification and construction of the variables

4.1 Equation for overall R&D activities in foreign locations; motives

4.1.1 Dependent variables

We constructed a dichotomous variable taking the value 1 for firms with foreign R&D activities and the value 0 for firms without such activities. We also constructed a dichotomous variable for the three groups of motives for foreign R&D activities taken into consideration in this study (knowledge-oriented motives (M_KNOW); market-oriented motives (M_MARK); resource-oriented motives (M_RESO)).[4] The value 1 of each of these variables was taken by firms with foreign R&D activities that reported the value 4 or 5 on a five-point Likert scale assessing the importance of a certain motive belonging to a certain group of motives. The value 0 was given to all other firms with foreign R&D activities but different motives as well as firms without such activities (see section 6.1 for the justification of this construction).

4.1.2 Independent variables

We used the same vector of independent variables for all three motive equations and the variable for overall foreign R&D activities (see Table 2 for the exact definition of the variables). For the specification of this vector of explanatory variables the OLI paradigm, emphasizing in this paper the O- and L-factors, served as theoretical guideline (see sub-section 2.1). 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, industry affiliation, foreign ownership, etc..

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 (variable RDPERM) and *high-level* human capital (variable HQUAL) as overall preconditions for knowledge-related O-advantages. Such advantages can be generated by the use of knowledge acquisition strategies such as R&D cooperation (variable RDCOOP) and contract (external) R&D (variable RDEXT) in addition to in-house R&D. The exploitation of science-oriented external knowledge from universities/research institutions and/or patent disclosures (KPATSCIENCE) is a further important form of knowledge sourcing. In case a firm is a member of a company group it is expected that valuable knowledge may come form the parent company and/or sister companies (KGROUP).

Such knowledge-related advantages reflect a high capacity to absorb external knowledge (Cohen and Levinthal 1989) that enables a firm to gain large benefits from knowledge and

[4] See Table 1 for some descriptive statistics with respect to these motive variables and Table 2 for the exact construction of the variables.

technology transfer between foreign and domestic R&D units. Thus, we expect a positive sign for all the above variables (see *hypothesis 1* in section 2).

The sales share of exports (variable EXORTSHARE) is also included as O-variable to capture a firm's experience in doing international business, which according to the "stages view of internationalisation" (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 and R&D activities are usually the final step of this process.[5]

A second group of variables stands for institutional obstacles of innovation activities in Switzerland that may reflect L-disadvantages: excessive regulation of the domestic product market (OBST_REG) and insufficient public support of firm innovation activities (OBST_PROM). We expect a positive sign also for these 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 operating in more concentrated markets have a market power advantage that may enhance their investment in foreign locations. Since the low-concentration segment is the reference group we expect also in this case a positive sign for this variable.

Finally, we control for some (general) firm characteristics that may have an impact on the decision to engage in foreign R&D. Firm size captures some (size-related) factors not explicitly included in the model (variable LEMPL). Some of them may reflect O-advantages, others may be related to I-advantages. For example, large firms are superior to small ones in terms of factors related to I-advantages such as international innovation management (an important instrument for internalising the outcome of foreign R&D activities). Thus, we expect a positive sign for this variable.

Further, it may be the case that foreign-owned firms (FOR) are less likely to perform foreign R&D, since they often operate in the first instance for the Swiss market (expected negative sign). We expect older firms to be more experienced with respect to activities abroad, thus stronger inclined than smaller ones to invest in R&D in foreign locations (expected positive sign for variable LAGE).

---

[5] However, there is evidence for some weakening of the stepwise process of internationalisation, 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 internationalisation" (Coviello and McAuley 1999) and the "Born Global"-approach (Rialp et al. 2005).

4.2 Innovation equation

As dependent variable we used the natural logarithm of the sales of innovative products (new products and considerably modified products; variable LINNL) per employee. The specification of the innovation variable followed the resource-based approach of innovation, thus containing variables for physical capital input (LCL) und human capital input (LHQUAL). The effect of R&D activities in foreign locations on innovation performance was taken into consideration by inserting separately the dichotomous variables for the three motive categories and the variable for overall R&D foreign activities (variable RD_FOR).[6] Further, the innovation equation included two competition measures for price and non-price competition respectively (IPC; INPC) and controls for foreign forms, firm size, firm age, industry affiliation and survey year.

According to standard empirical evidence from earlier studies we expected positive effects of the human capital variable (LHQUAL), the intensity of non-price competition (INPC) and – to a smaller extent – the intensity of price competition (IPC), and firm size (see Arvanitis 2008). We also expected a positive effect for LAGE. The effect of the variable FOREIGN was not a priori clear.

According to *hypothesis 3*, we would expect that particularly the effects of the motives that are more oriented towards the acquisition of new knowledge (M_KNOW) would be significantly larger than the effects of the market- and resource-oriented motives (M_MARK; M_RESO).

4.3 Productivity equation

As independent variable we used the natural logarithm of value added per employee (variable LQL). The productivity equation contained measures for physical capital (natural logarithm of capital income per employee; LCL), human capital (LHQUAL) and R&D (natural logarithm of R&D expenditures per employee; LRDL) as well as controls for foreign firms, firm size, industry affiliation and survey year. The effect of R&D activities in foreign locations on productivity was taken into consideration by inserting separately the respective dichotomous variables.

We expected positive expects for the variables for physical capital per employee, human capital and R&D expenditure per employee (see also Arvanitis 2008). According to *hypothesis 4* we would expect positive effects particularly for the market- and resource-oriented motives (M_MARK; M_ESO).

[6] Due to strong multicollinearity it was not possible to have all seven variables for cooperation motives in the same innovation equation (see Table A.6 in the Appendix).

5. Empirical results

5.1 Methodological remarks

5.1.1 Sample selection bias

The variables for the motives for R&D activities in foreign locations are measured only for the firms that have such activities. This might give rise to a sample selection problem for the estimation of the motive equations that cannot be econometrically solved in a panel data setting as easily as it is usually done in a cross-section setting by applying the methodology proposed by Heckman (1979). Moreover, there is a problem of interdependence of the motive variables due to the fact that most of the firms reported more than one option on the questions of motives (see also section 3) that renders more difficult a Heckman-type solution as it is implemented in most statistical packages. As an alternative, in a first step we set all firms with only domestic R&D activities to zero for all motive variables.[7] Thus, the zero value of the variable for a certain motive refers not only to firms with foreign R&D activities that do not focus on this motive but also to firms with only domestic R&D activities. This has to be taken into account when the results are interpreted. A possible objection to the chosen approach could be that the differences among firms with different motives for foreign R&D – the specific topic of this study – would be dominated by the differences between firms with foreign activities and firms with only domestic R&D activities. The 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 dependent variables

In a second step, we took into consideration the interdependence among the motive variables. To this end, we estimated a multivariate probit model, i.e. a simultaneous system of three cooperation equations for the seven different motives, instead of three separate probits. We applied the 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

A further econometric issue refers to the possibility of endogeneity of the overall foreign R&D variable and the motive variables when used as right-hand variables in the innovation and the productivity equation respectively.

---

[7] See Belderbos et al. (2004a), 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).

We tested endogeneity by applying the procedure by Rivers and Vuong (1988) separately for RD_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 equation and the productivity equations based on the original variables for overall foreign R&D and the three motives respectively. For the estimation of the innovation equations based on the truncated (at zero) dependent variable LINNL we applied a random effect tobit estimator. For the productivity equation we used a random effect GLS estimator.

5.2 Overall R&D activities in foreign locations; motives

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

We find the expected positive signs for all variables related to knowledge-based O-advantages (column 1 in Table 3). The coefficients of the three export dummies are also positive and statistically significant. A t-test shows that the coefficient of the export variable becomes significantly larger with growing export share. The larger the sales share of exports, the larger is also the probability that a firm has R&D activities at foreign destinations.

We obtain the expected positive and statistically significant coefficients also for the two variables reflecting L-disadvantages.

Finally, as in similar empirical studies there is a non-linear positive relationship between firm size (measured by the number of employees) and the propensity for R&D activities in foreign destinations (variable LEMPL). Firm age show no effect on the propensity to invest in foreign R&D, the same holds also for a firm being in foreign ownership.

In sum, the findings in Table 3 appear to confirm both hypotheses 1 and 2 in section 2.

5.2.2 Motive equations

Table 4 shows the multivariate probit estimates for the three motives for foreign R&D activities. We found significant positive correlations between any pair of motive equations. Thus, there is considerable empirical justification for estimating a multivariate probit model. There are similarities but also discernible differences among the estimates based on different cooperation motives as to the determining factors.

[9] See Table A.3 and Table A.4 in the appendix for the endogeneity tests with respect to the RD_FOR and the three motive variables in the innovation and the productivity equation. Table A.5 also in the appendix shows the estimates of the underlying instrument equations.

Conducting permanently R&D (RDPERM) is a characteristic that distinguishes firms with foreign R&D activities from those with only domestic R&D activities (see Table 3) but not firms pursuing one or another specific motive for foreign R&D. Firms pursuing resource-oriented motives seem to have a higher human capital endowment than firms focussing on other motives, this is probably the main reason why they are stronger restrained than other firms as to the availability of domestic R&D personnel. The use of knowledge from other firms of the same group is also a specific characteristic of all firms with foreign R&D activities independent of the kind of motives for such activities.

It is not astonishing that the use of external innovation-relevant knowledge as reflected by the variables for 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 primarily in order to expand their own know-how through the exploitation of foreign knowledge networks (motive M_KNOW). Science-based knowledge is less important for firms with market-oriented motives (M_MARK) or resource-oriented motives (M_RESO); external R&D is of no specific relevance for firms pursuing primarily resource-oriented motives (M_RESO).

Acquiring external knowledge from other firms of the same group (KGROUP) is equally important for all three motive categories.

Market-oriented or resource-oriented motives are more important for firms with a sales share of exports of at least 34% than for firms with smaller export intensity. Also above the threshold of 34% the likelihood of one of these 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 export intensity (34%-66% vs. > 66%) showed. A certain level of engagement in foreign markets as reflected by export intensity is obviously a precondition for foreign R&D pursuing one of these two motives. The threshold of 34% does not hold for primarily knowledge-motivated foreign R&D, even if also in this case the likelihood of this motive increases with increasing export intensity up to 66%, as tests on the statistical significance of the difference of the coefficients of the dummy variables for export intensity (1%-33% vs. 34%-66%) showed. For firms with primarily knowledge-oriented motives the incentives for foreign R&D are high even when the engagement in foreign markets is not so large.

Product market regulation (OBST_REGUL) is a location disadvantage for firms with knowledge-oriented or market-oriented motives but not for those with resource-oriented motives that assess input restrictions as more important than the acquisition of additional knowledge abroad or the strong presence on foreign product markets. On the other hand, in sufficient public support of R&D (OBST_PROM) is a location disadvantage for firms with market-oriented or resource-oriented motives but not for firms with knowledge-oriented motives seeking for additional know-how.

Focusing on knowledge-oriented motives is independent of firm size (LEMPL), pursuing market- or resource-oriented motives is more relevant for larger firms, the relation between the likelihood to pursue one of these two motive categories being positively but non-linearly related to firm size.

We did not find the expected positive relationship between the propensity to a certain motive for foreign activities and firm age (LAGE). Moreover, contrary to expectations we found a negative coefficient for the estimate for M-Mark, meaning that the older firms are less inclined than younger firms to invest in R&D abroad driven by the market motive. It seems that younger firms are stronger inclined to undertake such risky investments (primarily driven by the market motive) than older firms, even if the latter would presumably be more experienced as to foreign activities.

As expected, foreign-owned firms are less inclined than domestic firms to invest in foreign R&D pursuing the resource-oriented motive (variable 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 appears to be of (almost) no importance for all three motive categories (variable NCOMP). Only firms operating in market segments with (worldwide) 16 to 50 main competitors are stronger present among firms pursuing market-oriented or knowledge-oriented motives than firms operating in all other market segments. This is no the case for the primarily resource-oriented motives. We see no apparent explanation for this finding.

On the whole, also the findings in Table 4 seem to support hypothesis 1 as well as hypothesis 2 in section 2.

5.3 Innovation equations

Table 3, column 2 and Table 5, columns 1 to 3 show the results for the innovation equations. The variables for physical capital and human capital show in all four innovation equations the expected positive coefficients. Further, there is a positive effect for the use of customer/user knowledge (KCUST), a positive, non-linear effect for firm size, a positive effect for the intensity of non-price competition and no significant effect for the intensity of price-competition, all of them in accordance to earlier empirical studies (see Arvanitis 2008). We found no significant effect also for firm age and foreign-owned firms. Firms in a market segment with (worldwide) 6 to 15 main competitors showed a higher sales share of innovative products than firms in more but also less concentrated market segments.

We concentrate here to the effects on innovation of the overall variable for foreign R&D and the variables for the three categories of motives for foreign R&D that were inserted separately in the innovation equation. We found a positive but statistically insignificant effect (at the

10%-test level) for the overall variable as well as the variables for the market-oriented (M_MARK) and the resource-oriented motives (M_RESO). A statistically significant positive effect was found only for knowledge-oriented motives (M_KNOW). These findings are is in accordance to hypothesis 3 in section 2.

5.4 Productivity equations

Table 3, column 3 and Table 5, columns 4 to 6 show the results for the productivity equations. The variables for physical capital, human capital and R&D expenditures per employee show also in this case the expected positive effects. Further we found a positive, non-linear effect for firm size and a positive effect for foreign-owned firms. We focus on the findings for the overall variable for foreign R&D and the variables for the three categories of motives for foreign R&D that were inserted separately in the productivity equation. We found a positive and statistically significant effect for the overall variable as well as for the variables for the market-oriented (M_MARK) and the resource-oriented motives (M_RESO). No significant effect could be found for the variable for the knowledge-oriented motives. These findings seem to confirm hypothesis 4 in section 2.

6. Summary and discussion

Starting point of our 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 related to different motives with respect (a) to the factors influencing the likelihood of foreign R&D investment as postulated by theory; and (b) to the impact of R&D cooperation on firm innovativeness and firm productivity.

Based on microeconometric analysis of Swiss firm panel data, we found that (a) 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; (b) the relative importance of single factors representing advantages or disadvantages varies significantly among the three different groups of motives for foreign R&D we take into consideration in this paper (knowledge-oriented, market-oriented, and resource-oriented-motives); (c) being engaged in foreign R&D activities primarily driven by *knowledge-oriented* motives is positively correlated to innovation performance; and (d) foreign R&D activities driven by *market-oriented* or *resource-oriented* motives correlate positively with productivity.

How do these results compare with those of other investigations? Three earlier studies dealing with this topic based on Swiss data up to 2002 showed similar results with respect to the factors explaining the likelihood to get engaged in R&D activities in foreign locations (see

Arvanitis and Hollenstein 2001; Arvanitis et al. 2005; and Arvanitis and Hollenstein 2007). Further, we gain additional insights from four cross-country studies where Switzerland is included. Three of them are based on the analysis of patent data of MNEs. Patel and Vega (1999), who investigated the relative importance of several R&D strategies, conclude that in the Swiss case, "asset exploiting" and "asset augmenting" are the dominant strategies, whereas there are hardly any Swiss MNE's characterised 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"-strategies are dominating in Swiss pharmaceutical/chemicals, whereas "asset exploiting" is characteristic for the Swiss metal and machinery sector (and probably the rest of the manufacturing sector in Switzerland). Since the shares of these two industry groups on overall Swiss foreign R&D expenditures are almost equal, we conclude that the two strategies are of similar importance. Furthermore, Driffield and Love (2003) showed that firms investing in the UK, in the first instance those from technologically leading countries (such as Switzerland), benefit from the host country's knowledge base, in particular in case of spatial clusters of R&D intensive firms ("reverse spillovers").

Finally, the evidence seems to support the hypothesis of foreign R&D *complementing* domestic R&D. The evidence of recent studies for other countries is mixed (see, e.g., Veugelers et al., 2005). A main message is that the spillovers to the home country crucially depend on the type of R&D activity performed by foreign affiliates. High "research content" of foreign R&D might be most beneficial to the home country, especially when this is characterized by high knowledge absorptive capacity.

References

Arvanitis, S. (2008): Innovation and Labour Productivity in the Swiss Manufacturing Sector: An Analysis based on Firm panel Data, in C. van Beers, A. Kleinknecht, R. Ortt and R. Verburg (eds.), *Determinants of Innovative Behaviour: A Firm's Internal Practices and Its External Environment*, Palgrave, London.

Arvanitis, S. and H. Hollenstein (2001): Technologiestandort Schweiz im Zuge der Globalisierung. Eine explorative Analyse der F&E-Aktivitäten schweizerischer Industrieunternehmen im Ausland, *Schweizerische Zeitschrift für Volkswirtschaft und Statistik,* 137, 129-148.

Arvanitis, S. and H. Hollenstein (2007): Determinants of Swiss Firms' R&D Activities at Foreign Locations: An Empirical Analysis Based on Firm-level Data, in: G.R.G. Benito

and H.R. Greve (Eds.), *Progress in International Business Research*, Elsevier, Amsterdam, pp. 61-90.

Arvanitis, S., Hollenstein, H., Marmet, D. und N. Sydow (2005): *Forschungs- und Technologiestandort Schweiz: Stärken-/Schwächenprofil im internationalen Vergleich*. Reihe Strukturberichterstattung Nr. 32, hrsg. vom Staatssekretariat für Wirtschaft (Seco), Bern.

Belderbos, R., Carree, B., Diederen, B., Lokshin, B. and R. Veugelers (2004): Heterogeneity in R&D Cooperation Strategies, *International Journal of Industrial Organization*, 22(8-9), 1237-1263.

Buckley, P.J. and M.C. Casson (1985): *The Economic Theory of the Multinational Enterprise*, London: McMillan.

Cantwell, J. and O. Janne (1999): Technological Globalisation and Innovative Centres: the Role of Corporate Technological Leadership and Local Hierarchy, *Research Policy*, 28, 119-149.

Cantwell, J. and R. Narula (2001): The Eclectic Paradigm in the Global Economy, *International Journal of the Economics of Business* 8(2), 155-172.

Cantwell, J. and L. Piscitello (2005): Recent Location of Foreign-Owned Research and Development Activities by Large Multinational Corporations in the European Regions: The Role of Spillovers and Externalities, *Regional Studies*, 39, 1-16.

Capron, H. and M. Cincera (2004): Industry-University S&T Transfer: What Can We Learn from Belgium CIS-2 Data?, *CEPR Discussion Paper Series No. 4685*, London.

Coviello, N.E. and A. McAuley (1999): Internationalisation and the Smaller Firm: A Review of Contemporary Empirical Research, *Management International Review* 39(3), 223-256.

Driffield, N. and J.H. Love (2003): Who Learns from Whom? Spillovers, Competition and Technology Sourcing in the Foreign-owned Sector of UK Manufacturing, *Paper Presented at the EUNIP Conference 2003, 18-20 Septembe*r, Porto.

Dunning, J.H. (1988): *Explaining International Production*, London: Unwin Hyman.

Dunning, J.H. (1993): *Multinational Enterprises and the Global Economy*, Workingham: Addison-Wesley.

Dunning, J.H. (2000): The Eclectic Paradigm as an Envelope for Economic and Business Theories of MNE Activity, *International Business Review* 9(2), 163-190.

Ethier, W.J. (1986): The Multinational Firm, *Quarterly Journal of Economics* 101(4), 805-833.

Florida, R. (1997): The Globalization of R&D: Results of a Survey of Foreign-affiliated R&D Laboratories in the USA, *Research Policy*, 26, 85-103.

Fors, G. (1996): R&D and Technology Transfer by Multinational Enterprises, Almqvist & Wiksell International, Stockholm.

Frost, T.S. (2001): The Geographic Sources of Foreign Subsidiaries' Innovations. *Strategic Management Journal,* 22, 101-123.

Greene, W.H. (2003): Econometric Analysis, Prentice-Hall, New York.

Helpman, E. (1984): A Simple Theory of International Trade with Multinational Corporations, *Journal of Political Economy* 92(3), 451-471.

Hollenstein, H. (2009): Characteristics of Foreign R&D Strategies of Swiss Firms: Implications for Policy, in: D. Foray (Ed.), *The New Economics of Technology Policy*, Edward Elgar, Cheltenham.

Iwasa, T. and H. Odagiri (2004): Overseas R&D, Knowledge Sourcing, and Patenting: An Empirical Study of Japanese R&D Investment in the US, *Research Policy*, 33(5), 807-828.

Kafouros, M.I., Buckley, P.J., Sharp, J.A. and C. Wang (2008): The Role of Internationalization in Explaining Innovation Performance, *Technovation*, 28, 63-74.

Kotabe, M. (1990): The Relationship between Offshore Sourcing and Innovativeness of US Multinational Firms: An Empirical Investigation, *Journal of International Business Studies*, 21(4), 623-638.

Kotabe, M., Srinivasan, S.S. and P.S. Aulakh (2002): Multinationality and Firm Performance: The Moderating Role of R&D and Marketing Capabilities, *Journal of International Business Studies,* 33(1), 79-97.

Kuemmerle, W. (1999b): The Drivers of Foreign Direct Investment into Research and Development: An Empirical Investigation, *Journal of International Business Studies*, 30, 1-24.

Le Bas, C. and C. Sierra (2002): Location versus Home Country Advantages in R&D Activities: Some Further Results on Multinationals Locations Strategies, *Research Policy*, 31, 589-609.

Mohnen, P. and C. Hoareau (2003): What type of Enterprises Forges Close Links with Universities and Government Labs? Evidence from CIS-2 Data, *Managerial & Decision Economics*, 24(2-3), 133-145.

Mundell, R.A. (1957):, International Trade and Factor Mobility, *American Economic Review* 47, 321-347.

Patel, P. and M. Vega (1999): Patterns of Internationalization of Corporate Technology: Location vs. Home Country Advantages, *Research Policy*, 28, 145-155.

Rialp, A., Rialp, J. and G.A. Knight (2005): The Phenomenon of Early Internationalizing Firms: What Do we Know After a Decade (1993-2003) of Scientific Inquiry?, *International Business Review*, 14, 147-166.

Schmidt, T. (2007): Motives for Innovation Cooperation – Evidence from the Canadian Survey of Innovation, *ZEW Working Paper No. 07-018*, Mannheim.

Teece, D.J. and G. Pisano (1998): The Dynamic Capabilities of Firms, in: G. Dosi, D.J. Teece and J. Chytry (eds.), *Technology, Organisation, and Competitiveness. Perspectives on Industrial and Corporate Change*, Oxford: Oxford University Press, pp. 193-212.

Veugelers, R., Dachs, B., Mahroum, S., Nones, B., Schibany, K, and R. Falk (2005): *Internationalisation of R&D: Trends, Issues and Implications for S&T Policies. A Review of the Literature*, Background Report Presented at the Forum on the Internationalisation of R&D, Brussels, Brussels, 29-30 March.

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

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: geographical proximity to leading research universities *and/or* highly-innovative firms *and/or* 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: lower R&D costs *and/or* higher government support of R&D investment *and/or* 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
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)		
EXPORTSHARE:			
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	0.390	
	(0.168)	(0.355)	
6-15	-0.176	0.727**	
	(0.163)	(0.336)	
<= 5	0.128	0.079	
	(0.111)	(0.249)	
IPC		0.229	
		(0.242)	
INPC		0.553**	
		(0.217)	
LCL		0.195*	0.118***
		(0.102)	(0.007)
LHQUAL		0.507***	0.031***
		(0.128)	(0.010)
LRDL			0.042***
			(0.005)
LEMPL	0.174***	0.166**	0.022***
	(0.043)	(0.083)	(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)
EXPORTSHARE:					
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***

Table A.6: Correlations

	R&D_FOR	M_KNOW	M_MARK	M_RESO	LCL	LHQUAL	HQUAL	LRDL	LAGE	KCUST	KGROUP	KPATSCIENCE	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