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How do different drivers of R&D investment in foreign locations affect domestic firm performance? An analysis based on Swiss panel micro data

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The aim of this article is to investigate the differences between specific motives of R&D investment in foreign locations with respect to: (i) the factors influencing the likelihood of foreign R&D and (ii) the impact of foreign presence on the parent firms' innovativeness and productivity. An econometric analysis of Swiss firm panel data (period 2000–2008; 2817 companies) shows, first, 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. Second, knowledge-oriented motives of foreign R&D positively influence the innovation performance of domestic firms, whereas market- and resource-oriented strategies have a positive impact on labor productivity.

JEL classification: O31, F23.

1. Introduction

Over the last 20 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

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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").

However, in view of the specific sectoral structure of foreign R&D of Swiss firms, substitution is rather unlikely for a large part of the economy. In manufacturing, not <63% of firms performing R&D abroad are highly specialized and science-based producers (in particular, electrical and mechanical machinery, fine chemicals, pharmaceuticals, and scientific instruments). Moreover, knowledge-intensive services (financial, computer, R&D, and other business services) account for 64% of all services firms having located part of their R&D activities abroad. Since cost reduction is not a primary motive for foreign R&D investments in these industries, foreign, and domestic R&D, on balance, are complements rather than substitutes. This conclusion is confirmed by studies using cross-country data which also include data from Swiss companies (Cantwell and Janne, 1999; Patel and Vega, 1999; LeBas and Sierra, 2002).

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: (i) the factors influencing the likelihood of foreign R&D investment as postulated by theory and (ii) the impact of foreign presence in R&D on innovativeness and productivity of the parent company.

To this end, we use data on three different groups of motives for foreign R&D, that is market-, resource-, and knowledge-oriented motives, as reported by Swiss manufacturing, construction and services firms in 2002, 2005, and 2008 with reference periods 2000–2002, 2003–2005, and 2006–2008, 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. Second, 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: (i) 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. ["ownership-specific advantages" (O) of the firm], (ii) some measures representing innovation obstacles in the home country ["location-specific disadvantages" (L) of Switzerland], and (iii) "internalizing advantages" (I) of the firm. Moreover, we include some 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 (average) labor 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 GLS 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: (i) the identification of the drivers of distinct strategies for investing in foreign R&D using information on several motives for such activities; (ii) 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 versus productivity) and the specific motive considered; and (iii) 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 arrangement of the article is as follows. In Section 2, we present the conceptual framework of the article 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. First, 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). Second, 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 e.g. Helpman (1984) or Ethier (1986)]. Third, 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 explaining 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 (Dunning, 2000).

In the 1970s, 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, 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 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 *et al.*, (1997)]. 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 ("asset exploiting strategy": market-oriented motive), but also to complement and enrich domestic assets by tapping into foreign "national innovation systems" (NIS). Consequently, "asset-seeking" ("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 *et al.*, 1997) 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 cooperations 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, e.g. 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 versus "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, based on Swiss data, Hollenstein (2009) identified 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 fourth 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)].

2.4.1 Innovativeness

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. Mansfield and Romeo (1984) in their study based on survey data from 29 US MNEs in high-tech industries are quite clear in this respect: almost 50% of the technologies generated by foreign R&D are transferred back to the parent company. Recent studies yielded 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 with a high absorptive capacity gain more than those which are weaker in this respect. This is shown, for example, by Ambos *et al.* (2006), who analysed the impact of 294 knowledge transfers of 66 subsidiaries to the headquarters of 33 European MNEs affiliated to the manufacturing sector and a broad selection of service industries. 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), who scrutinized the patent activity of the most patent-intensive 350 MNEs].

Moreover, the impact on the parent firms' innovativeness depends on the kind of foreign R&D activity. Iwasa and Odagiri (2004) investigated the impact of R&D activities of the US affiliates of 172 Japanese manufacturing firms and found that only research activities had a positive effect on the patent productivity of parent firms, in particular when the affiliates are located in high-tech areas. In contrast, more application-oriented R&D ("development") had no significant influence on innovation performance.

The literature dealing with the different roles foreign affiliates are playing within a MNE yields 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 firm's headquarter. The other types of affiliates ("local innovators", "implementers" and, surprisingly, "global innovators" as well) did not positively affect the innovation performance of the parent companies.

Finally, Frost (2001) showed, based on all patents issued by US-based greenfield subsidiaries between 1980 and 1990, that the companies' headquarter gain most from foreign R&D when the subsidiaries are well embedded in firm-external as well as firm-internal networks ("dual embeddedness").

2.4.2 Productivity

The empirical results of studies analyzing the impact of foreign R&D on the parent firms' productivity are mixed. Fors (1997), using Swedish data from 75 medium-sized and large MNEs in manufacturing, did not find any significant productivity effect. On the other hand, the more differentiated study of Todo and Shimizutani (2008) concluded, based on firm-level time-series data for more than 2500 Japanese manufacturing MNEs, that overseas "innovative" R&D (aiming at the acquisition of foreign knowledge) raised the parent firms' productivity growth, while "adaptive" overseas R&D (aiming at the adaptation of products/technologies to local conditions in foreign locations) had no such effect. Moreover the positive productivity effect is limited to high-tech industries. Griffith *et al.* (2004) identified positive productivity effects of knowledge sourcing. Using time series of patent data for UK and US multinationals, they found that UK companies 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). Finally, Rammer and Schmiele (2008) drawing on a firm panel of about 1700 German SMEs that covers the whole industrial and (private) service sector for the years 2005–2007 got mixed results. They identified a positive effect of foreign R&D on employment growth of the parent company, whereas growth of sales was not affected. Moreover, neither product nor process innovations generated by foreign affiliates had an impact on 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 is related 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 is related positively with disadvantages 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

3.1 Data structure

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 2000–2002, 2003–2005, and 2006–2008, respectively. The surveys yielded information on some basic firm characteristics (sales, value added, investments, exports, employment, employees' vocational education, firm 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 five 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

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

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 1 for the composition of the dataset we used in model estimation, by industry, firm size class and year, respectively). The resulting panel is unbalanced because not all firms participated in all three waves.

3.2 Sectoral incidence and host regions of foreign R&D

Table 1 presents some important descriptive information about the sectoral incidence of foreign R&D in Switzerland. About 19% of R&D-performing firms reported over the period 2002–2008 R&D investment in foreign locations. Electronics and instruments, chemicals (especially pharmaceuticals), plastics, machinery and electrical machinery show the highest shares of firms with foreign R&D activities. Thus, it is the high-tech sector of manufacturing that invests more heavily in foreign R&D. Service industries are less frequently present with R&D activities in foreign locations. However, ∼23% of R&D-active firms in computer services have invested in R&D activities abroad.

Table 2 contains information about the host regions of Swiss foreign R&D activities in 2008. The European Union, which is also the most important trade partner of the Swiss economy, attracts most frequently Swiss foreign R&D investment. About 90% of firms with foreign R&D activities chose the countries of the European Union as the destination of their R&D investment abroad. The USA (together with Canada), the second most important trade partner, are the second most relevant host region for foreign R&D (∼33% of firms). Not surprisingly, China and India (primarily China) take the third position among the host regions (∼24% of firms). Service firms invest in R&D in "other countries" (primarily Eastern Europe and Lain America) significantly more frequently than manufacturing firms.

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

First, 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). Second, 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, that is knowledge-oriented motives (M_KNOW), market-oriented motives (M_MARK), and resource-oriented

[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.

Table 1 Composition of the data set 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 (NACE 15,16)	171	12.3
Textiles (17)	62	21.0
Clothing, leather (18, 19)	12	25.0
Wood processing (20)	54	5.6
Paper (21)	47	12.8
Printing (22)	60	10.0
Chemicals (23, 24)	206	27.7
Plastics, rubber (25)	90	26.7
Glass, stone, clay (26)	59	17.0
Metal (27)	38	18.4
Metal working (28)	212	14.2
Machinery (29)	452	27.4
Electrical machinery (31)	128	26.6
Electronics, instruments (30, 32, 331–334)	294	28.2
Vehicles (34, 35)	68	8.8
Watches (335)	32	15.6
Other manufacturing (36, 37)	61	11.5
Energy, water (40, 41)	26	3.9
Construction (45)	98	8.2
Wholesale trade (50, 51)	115	18.3
Retail trade (52)	49	2.0
Hotels, catering (55)	44	4.6
Transport, telecommunication (60–64)	80	10.0
Banks, insurance (65–7)	113	15.9
Real estate, leasing (70, 71)	5	0.0
Computer services (72, 73)	96	22.9
Business services (74)	138	13.8
Personal services (93)	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 2 Host regions of R&D investment of Swiss firms in foreign locations 2008

	Manufacturing	Services	Total
European Union	88.4	88.9	88.7
USA/Canada	33.3	29.6	32.7
Japan	9.3	11.1	10.1
China, India	24.8	22.2	23.9
Other countries	14.7	29.6	17.0
N	129	27	159

Note: Multiple answers are possible.

motives (M_RESO). 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, first, to firms with foreign R&D activities driven by other motives, and second, to the firms that did not perform R&D at a foreign location (see sub-section 5.1 for the justification of this construction).[3]

Table 3 shows that knowledge-oriented strategies are most widespread. But the frequencies differ not much among the three groups of motives over the three surveys.

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-sections 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 4 [see Dosi (1988) for modeling micro-economic aspects of innovation].[4]

[3]See Table 4 for the exact construction of the motive variables. An alternative construction would be to calculate the average score of the single motives constituting a group of motives. In this case, several issues arise with respect to the nature of such average variables (neither metric nor ordinal variables) that would make econometric analysis unnecessarily complicated.

[4]See the Appendix for the descriptive statistics of the model variables (Appendix Table A1) and the corresponding correlation matrix (Appendix Table A5).

Table 3 R&D activities and motives for R&D of Swiss firms at foreign locations

Groups of motives	2002 *N* (%)	2005 *N* (%)	2008 *N* (%)	Total *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: %, percentage of R&D-performing firms pursuing intensively a certain motive; see Table 4 for the construction of the motive variables.

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) [see e.g. Michie and Sheehan (1999), Leiponen (2005), and Piva and Vivarelli (2009)] as overall preconditions for knowledge-related O-advantages. Such advantages can also be generated by acquiring knowledge through R&D co-operation (RDCOOP) [see e.g. Kleinknecht and Reijnen (1992)] and external R&D-contracts (RDEXT) [see e.g. Piga and Vivarelli (2004)]. The exploitation of science-oriented external knowledge from universities/research institutions and/or patent disclosures (KPATSCIENCE) is another important form of knowledge sourcing [see e.g. Klevorick *et al.* (1995) or Cassiman and Veugelers (2002)]. 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 [see 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]

[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

Table 4 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: (i) geographical proximity to leading research universities and/or (ii) highly-innovative firms and/or (iii) transfer of knowledge to the Swiss headquarter (dummy variable based on an originally 5-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 5-point intensity scale: value 1 for 4 or 5; otherwise 0).
M_RESO	Motive for R&D at foreign locations: (i) lower R&D costs and/or (ii) higher government support of R&D investment and/or (iii) ample supply of R&D personnel (dummy variable based on an originally 5-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 5-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 5-point intensity scale: value 1 for 4 or 5; otherwise 0).
KPATSCIENCE	Importance of science-based external knowledge (from universities and/or patent disclosures) (dummy variable based on an originally 5-point intensity scale: value 1 for 4 or 5; otherwise 0).
IPC	Intensity of price competition (dummy variable based on an originally 5-point intensity scale: value 1 for 4 or 5; otherwise 0).
INPC	Intensity of *nonprice* competition (dummy variable based on an originally 5-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 (three dummy variables: 16–50; 6–15; ≤5; reference group: >50).
EXP	Sales share of exports (three dummy variables: 1–33%; 34–66%; >66%); reference group: no exports.

(continued)

Table 4 Continued

Variable	Description
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 5-point intensity scale: value 1 for 4 or 5; otherwise 0).
DEV	Intensity of product-related development input (dummy variable based on an originally 5-point intensity scale: value 1 for 4 or 5; otherwise 0).

The independent variables KCUST, KGROUP, KPATSCIENCE, IPC, and INPC were transformed to binary variables for two reasons: (i) to avoid the methodological problems associated with the use of qualitative ordinal variables as metric variables (Ronning and Kukuk, 1990) and (ii) to achieve a higher variability of these variables.

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 [see, e.g. Aghion *et al.* (2005)]. 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

review of the literature based on the "network perspective of internationalization" (Coviello and McAuley, 1999) and the "born global"-approach (Rialp *et al.*, 2005).

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 [see e.g. Arvanitis (1997)]. 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) [see e.g. Huergo and Jaumandreu (2004)].

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, that is 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 and 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 nonprice 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).

[6]Due to strong multicollinearity, it was not possible to include in the innovation equation the three motive variables at once (see Appendix Table A5).

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), that is 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 expect 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 [see 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

[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).

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 5 (referring to the dichotomous variable R&D_FOR) and Table 6 (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 that is a simultaneous system of three motive equations, instead of three separate probits.

Table 5 R&D activities at foreign locations (RD_FOR): determinants; relationship to innovation and productivity; random effects probit, tobit, and GLS estimate, respectively

Explanatory variables	R&D_FOR	LINNL	LQL
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)		

(continued)

Table 5 Continued

Explanatory variables	R&D_FOR	LINNL	LQL
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)
Constant	−3.969***	4.163***	10.206***
	(0.499)	(1.419)	(0.097)
N	2153	2405	2667
Left-censored		412	
Wald χ^2	140.3***	173.5***	820.5***
Log likelihood	−935.6	−6588.6	
R^2 within			0.0805
R^2 between			0.313
R^2 overall			0.281
ρ	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.

ρ: share of variance that can be traced back to heterogeneity.

Table 6 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)
Constant	−3.244***	−3.543***	−2.821***
	(0.344)	(0.377)	(0.361)
N		2153	

(continued)

Table 6 Continued

Explanatory variables	M_KNOW	M_RESO	M_MARK
Log likelihood		−1643.4	
Wald χ^2		410.7***	
Rho21		0.577***	
Rho31		0.655***	
Rho32		0.602***	
LR test of rho21 = rho31 = rho32 = 0		410.3***	

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.

ρ: share of variance that can be traced back to heterogeneity.

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 the 10% 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 5 (columns 2 and 3) and Table 7 show only the estimates of the innovation and the productivity

[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 Appendix Tables A2 and A3 for the endogeneity tests with respect to R&D_FOR and the three motive variables in the innovation and the productivity equation. Appendix Table A4 shows the estimates of the underlying instrument equations.

Table 7 Innovation, productivity and motives for R&D at foreign locations; random effects Tobit and GLS estimates, respectively

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)
Constant	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 χ^2	174.7***	173.8***	171.3***	816.7***	818.6***	823.8***
R^2 within				0.080	0.079	0.081
R^2 between				0.311	0.313	0.313
R^2 overall				0.280	0.281	0.282
ρ				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. ρ: share of variance that can be traced back to heterogeneity.

equations based on the *original* variables for overall foreign R&D and the three motives, respectively.

5.1.4 The goodness of fit of the estimated models
In general the goodness of fit of the estimated models is satisfactory, given the character of the used data: survey data contain mostly relatively much noise. More concrete, the "R^2 overall" measures of the productivity equations of ~0.28 (column 3 in Table 5; columns 4–6 in Table 7) point to satisfactory model fitting. For the estimates for which no R^2 measure is available the Wald χ^2 tests show that the models are on the whole statistically valid (columns 1 and 2 in Table 5; columns 1–3 in Table 7). Finally, the Wald χ^2 test for the multivariate probit estimates in Table 6 also indicates validity of the estimated model.

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 5, 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 nonlinear 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 5 appear to confirm the Hypotheses 1 and 2 put forward in Section 2.

5.2.2 Foreign R&D differentiated by group of motives
Table 6 shows the trivariate probit estimates for the three categories of motives for foreign R&D activities (knowledge-, market-, 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 6, 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.

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- 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- 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% versus 34–66%). For firms with primarily knowledge-oriented motives, the incentives for foreign R&D are high even when the export share is <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- 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- 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 nonlinear. In contrast, focusing on knowledge-oriented motives is independent of firm size. Besides, there is no evidence for the expected positive relationship between firm 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) 16–50 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 5) 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 6). 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

Tables 5 (column 2) and 7 (columns 1–3) show the results for the innovation equations. The firms' resource endowment, that is 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 INPC, whereas we do not find a significant effect for the IPC. These results are in accordance with earlier empirical studies (Arvanitis, 2008). Firms operating in markets with (worldwide) 6–15 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 note 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- 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 (Section 2).

5.3.2 Productivity

Tables 5 (column 3) and 7 (columns 4–6) show the results for the productivity equations. The basic elements of the production function, that is physical capital (LCL), human capital (LHQUAL), and knowledge input (LRDL) show the expected positive effect in all equations. Besides, we found throughout a positive (nonlinear) 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- 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 (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: (i) the factors influencing the likelihood of foreign R&D investments as postulated by theory, and (ii) 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 (i) 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; (ii) 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-, market-, and resource-oriented motives); (iii) knowledge-oriented motives of foreign R&D activities appear to influence positively innovation performance, whereas (iv) market- or resource-oriented motives have a positive impact on 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 (i), that is the factors explaining the likelihood to get engaged in R&D activities in foreign locations (Arvanitis and Hollenstein, 2001, 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 [see 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, first, the hypothesis that foreign and domestic R&D are complements and, second, 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 (iii) above].[10]

According to conclusion (iv), market- and resource-oriented motives for foreign R&D exercise a positive influence on 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 from other studies on the effects of foreign R&D on domestic productivity is on the whole 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 versus productivity). To our knowledge, this study is the first one differentiating the analysis along all these lines. Moreover, as the service sector is gaining an 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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Appendix A

Table A1 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
DEV	2491	0.285 (0.452)	0	1

Table A2 Test on endogeneity; R&D activities at foreign locations; random effects Tobit and GLS 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)
Constant	6.565***	10.330***
	(2.050)	(0.211)
N	1917	2064
Left-censored	323	
R^2 within		0.093
R^2 between		0.285
R^2 overall		0.263
Log likelihood	−5256.0	
Wald χ^2	263.7***	596.0***
ρ		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.

ρ: share of variance that can be traced back to heterogeneity.

Table A3 Test on endogeneity; motives of R&D at foreign locations; random effects Tobit, and GLS 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)
Constant	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^2 within				0.094	0.092	0.093
R^2 between				0.284	0.286	0.286
R^2 overall				0.267	0.262	0.263
Log likelihood	−4502.3	−5256.8	−5257.2			
Wald χ^2	253.2***	191.5***	195.8***	549.1***	664.2***	545.4***
ρ				0.566	0.565	0.563

Note: Control variables: 27 industry dummies (reference industry: food, beverage, tobacco) and 2 year dummies.

***, **, * denotes statistical significance at the 1%, 5%, and 10% test level.

ρ: share of variance that can be traced back to heterogeneity.

Table A4 Instrument equations; random effects Probit estimates

Explanatory variables	M_KNOW/ LINNL	M_KNOW/ LQL	M_RESO	M_MARK	R&D_FOR
DEV	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)
Constant	−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 χ^2	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 A5 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: 16–50	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: 6–15	−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: ≤5	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: 1–33%	−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: 34–66%	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: >66%	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
DEV	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

(continued)

Table A5 Continued

	NCOMP: 16–50	NCOMP: 6–15	NCOMP: ≤5	FOREIGN	LEMPL	RDPERM	RDCOOP	RDEXT	EXP: 1–33%	EXP: 34–66%	EXP: >66%	OBS_REG	OBS_PROM
NCOMP: 16–50	1.000												
NCOMP: 6–15	−0.138	1.000											
NCOMP: ≤5	−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: 1–33%	0.032	0.030	−0.048	−0.123	−0.013	−0.046	−0.060	−0.058	1.000				
EXP: 34–6%	0.003	0.006	0.046	0.022	0.045	−0.016	−0.040	−0.019	−0.284	1.000			
EXP: >66%	−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