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Abstract

The aim of this paper is twofold: Firstly, we try to identify and characterise different types of strategies firms pursue in performing foreign R&D. Secondly, it is analysed whether the types of R&D strategies we identified in the first part differ in terms of their impact on firm productivity. In order to identify foreign R&D strategies we perform, in a first step, a non-hierarchical cluster analysis of data on the firms' motives for investing abroad in R&D. In a second step, we characterise these clusters by use of a large number of variables that, according to the well-known OLI paradigm, determine a firm's FDI in distribution, manufacturing and R&D. In this way, we can check whether the clusters identified by applying a (purely) statistical classification procedure effectively may be interpreted as "types of foreign R&D strategies". We end up with four types of strategies, which significantly differ in terms of characteristics that are important according to the OLI approach. In the second part we estimate a production function where the standard factor inputs are complemented by domestic R&D and strategy-specific foreign R&D. It turns out that only one of the four strategies exerts a positive influence on firm productivity. However, it cannot be excluded that some of the other strategies have, in the longer run, a positive productivity effect as well. The paper also finds that foreign and domestic R&D, on balance, are complements.

Keywords: Internationalisation of R&D; outward FDI in R&D; motives for foreign R&D; types of foreign R&D strategies; foreign R&D and productivity; substitution vs. complementarity of foreign and domestic R&D.

JEL classification: F21, F23, O3

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1. Introduction

Over the last twenty years internationalisation of Swiss firms strongly increased. In a first phase, this process pertained in particular to 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 (Arvanitis et al., 2005).[1] Similar trends are observed in other countries (Veugelers et al., 2005; Narula and Zanfei, 2005).

As a reaction to these developments, there is increasing concern in the public opinion in Switzerland (and probably in other countries as well) that foreign R&D activities may substitute for domestic ones ("relocation of R&D"), thereby reducing the growth potential of the economy ("substitution hypothesis"). However, it is also argued that the internationalisation of R&D is a means to supporting production and sales activities in foreign markets and to tapping into the world-wide pool of knowledge. In this view, foreign R&D is complementing and augmenting the domestic knowledge base, given that the transfer of knowledge to the (domestic) headquarters works sufficiently well ("complementarity hypothesis"). Internationalisation of R&D is considered as a "natural" further step in the ongoing process of globalisation, a view that would be in accordance with the "stages view of internationalisation" (Johanson and Vahlne, 1977).

Whether the one or the other hypothesis holds true depends on the strategies firms pursue in investing in R&D at foreign locations. According to the classical model of international trade and investment, differences among countries with respect to (relative) costs are the driver of foreign (R&D) investments (see e.g. Mundell, 1957). In this view, reducing costs (increasing efficiency) is the prime motive for performing foreign R&D. In this theoretical setting foreign and domestic R&D are substitutes.

The experience with FDI in the sixties of the last century showed, however, that some R&D at foreign locations often was required for successfully penetrating and developing a foreign market. In this case, foreign R&D (which is mostly D rather than R) is a means to modify products that basically are the result of domestic R&D according to the needs of the local market. This strategy has been stressed by the product cycle model of international trade and investment (see Vernon, 1966). In this model, market-oriented motives are driving foreign R&D activities. Foreign and domestic R&D are thus complements.

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, what fits into the concept of the firm as proposed by evolutionary economics (see the "dynamic capability view of the firm" proposed by Teece and

1 Such a high degree of internationalisation of R&D is quite exceptional (see Benito et al., 2003).

Pisano, 1998). If knowledge is incorporated in specialised personnel that is familiar with specific advanced technologies, knowledge-seeking and the (classical) motive of resource-seeking, to a certain extent, become 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").

The different motives of foreign R&D, as stressed by distinct theoretical models (classical model, product cycle model, evolutionary perspective) are incorporated by Dunning in his well-known (eclectic) OLI paradigm. Its most recent version (Dunning, 2000; see also Cantwell and Narula, 2001), contrary to earlier vintages that primarily dealt with FDI in manufacturing (see e.g. Dunning, 1988), is well-suited to accommodate for FDI in R&D activities. "Ownership-specific advantages" (O) capture market-seeking as well as asset-augmenting foreign R&D. "Location-specific (dis)advantages" (L) represent the classical cost-reducing/efficiency seeking motive. "Internalising advantages" (I), however, are not directly linked to a certain motive for performing R&D at foreign locations. Internalising transactions in imperfect markets for knowledge may explain FDI in R&D, but it can be realised only if a firm disposes of specific O-advantages (e.g. particular expertise in international knowledge management). The relative importance of market-seeking and asset-seeking motives, which both are captured by O-advantages, indicates whether asset-exploiting strategies are more prevalent than asset-augmenting strategies.

In recent years, quite a few empirical studies dealing with "technology sourcing" have been published. They demonstrate the relevance of this type of foreign R&D and/or compare the importance of market-seeking strategies with those reflecting knowledge-seeking/asset-seeking motives (see, for example, Patel and Vega, 1999; Frost, 2001; Le Bas and Sierra, 2002). In these studies the two types of foreign R&D are discussed under the heading of "asset-exploiting" (homebase-exploiting, competence-exploiting) strategies vs. "asset-augmenting" (home-base augmenting, competence-creating) strategies. In two recent studies, Cantwell and Piscitello (2005a and b) 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 (externalities).

We assessed the relative merits of the substitution and the complementarity hypothesis of foreign R&D in two previous studies. In the first one, we analysed econometrically why a firm performs foreign R&D, using the OLI paradigm as theoretical framework (Arvanitis and Hollenstein 2001). In a further study, again based on the OLI framework, we extended the analysis: we estimated an econometric model that explains why a firm engages in foreign R&D and, if it does, how much it invests in this type of activity (Arvanitis and Hollenstein 2007). In both studies, however, we did not distinguish between different R&D strategies.

This paper is a continuation of the two previous studies. We aim, firstly, at identifying a number of strategies firms pursue in investing in R&D at foreign locations, expecting that many firms are driven by a combination of several motives ("multiple strategies"). In contrast, most previous studies assume (implicitly) that a firm pursues only one strategy: Le Bas and Sierra (2002), for example, analyse, in first instance, the relative importance of asset-exploiting and asset-augmenting strategies, or Florida (1997) investigated whether market-seeking is more prevalent as a motive for performing foreign R&D than knowledge-seeking. Secondly, having identified (and validated by drawing on the OLI framework) a set of strategies, we explore whether these strategies differ in terms of their impact on firm productivity. This differentiated view of the matter may shed some more light on the relative merits of the substitution and the complementarity hypothesis.

In order to identify foreign R&D strategies we perform, in a first step, a cluster analysis based on firm-level information of the relevance of a set of motives for foreign R&D investments as assessed by the firms themselves. The various clusters are interpreted as different "types of foreign R&D strategies", representing a specific combination of the underlying motives ("multiple strategies"). In a second step, we characterise the clusters (types of strategies) using a large number of variables that represent the most important aspects of the well-known OLI framework as well as some structural firm characteristics. In this way we can check whether the purely statistical procedure of identifying clusters yields "types of foreign R&D strategies" that clearly differ from each other and are plausible in terms of the theoretical framework.

The second part, as already mentioned, is devoted to explaining the impact of foreign R&D and, in particular, of specific foreign R&D strategies on firm productivity. To this end we econometrically estimate production functions using labour, physical and human capital, domestic R&D and foreign R&D as factor inputs. We use, alternatively, foreign R&D in aggregate form, as well as disaggregated in components reflecting strategy-specific foreign R&D. In this way we hope to find out whether the productivity effects differ by strategy.

The investigation of these topics is based on firm-level data collected in the frame of the Swiss Innovation Survey we conducted in 2002. The survey was based on a sample of firms (at least five employees) stratified by 28 industries and three industry-specific firm size classes (with full coverage of large firms). The sample covers manufacturing as well as the (commercial) service sector.

The paper adds to and complements previous work in several respects: firstly, we apply a promising new methodological approach in order to identify a number of foreign R&D strategies. In particular, the procedure suits to accommodate for "multiple" strategies that are based on a combination of motives for performing foreign R&D. Moreover, by combining a statistical procedure (cluster analysis) with a characterisation of the clusters that is strongly embedded in a theoretical framework (OLI paradigm), it is possible to assess whether the "types of foreign R&D strategies" are plausible. To date, the analysis of multiple strategies is rare; the literature dealing with the role of "lead markets" for foreign R&D, that stresses the interaction of market- and knowledge-seeking motives, may be the only exception (see e.g. Beise 2001). Secondly, we can draw on a rich data base in terms of the number of variables, which allows a differentiated analysis of foreign R&D strategies at the firm-level. We also can show that qualitative data, which are much easier to collect than quantitative information, are very meaningful in such an analysis. Thirdly, the study pertains not only to large MNE's (as almost all studies do) but considers SME's as well (more than 20% of the firms performing foreign R&D have less than 50 employees). Besides, we also take account of the service sector that mostly is neglected. Finally, we explore whether foreign R&D contributes to the productivity of the headquarter firm, and, in particular, whether the impact on productivity differs among the "types of foreign R&D strategies" we identified in the first part of the study.

The set-up of the paper is as follows: In the next section, we shortly describe the database. Section 3 is devoted to the methods we apply in order to identify a number of "types of foreign R&D strategies" and to analyse the productivity effects of foreign R&D as a whole and differentiated by type of R&D strategy. In Section 4 and 5 we present the empirical results for the two topics investigated in this study. Finally, we summarize and draw some conclusions.

2. Data

The data used in this study were collected as part of the Swiss Innovation Survey 2002. The firms were asked to fill in a large questionnaire (downloadable from www.kof.ethz.ch) on their innovative activities. Among many other topics, the survey provided information on a firm's foreign R&D activities (in case a firm was engaged in foreign R&D at all). More specifically, we collected data on the volume of foreign R&D as a percentage of total R&D expenditures in 2001 as well as its change between 1999 and 2001. Moreover, we asked the firms to assess on a five-point Likert scale, ranging from "practically irrelevant" (value 1) up to "very important" (value 5), the importance of seven motives for engaging in foreign R&D or extending such activities (see Table 1 for the list of motives). Finally, we got information on the destination of a firm's foreign R&D investments (four regions).

The data on the motives for performing R&D abroad are used to identify different strategies pursued by Swiss firms in investing in such activities. The survey also provided information on a large number of variables that could be used to characterise the R&D strategies we could identify. Among these we choose a subset containing the variables which, according to the well-known OLI paradigm, are relevant for explaining outward-FDI. Most of the variables refer to the period 1999-2001, some of them to the year 2001.

The Swiss Innovation Survey 2002 was based on a stratified sample of firms with at least five employees (28 industries and three industry-specific firm size classes, with full coverage of large companies). The sample covers manufacturing as well as the commercial part of the service sector. The questionnaire that has been sent to 6524 companies yielded valid data for 2583 firms (response rate 39.6%). 1078 firms (41.7% of the respondents) performed R&D, with every seventh doing so also at foreign locations (156 or 14.5% of all R&D performing companies). Table A.1 in the appendix shows the sectorial and firm size composition of the total sample, of the respondents, the R&D performers and the firms performing R&D abroad.

The industry composition of the dataset containing the responding firms is not very different from the underlying sample, although there is some over-representation of manufacturing at the expense of the "traditional" part of the service sector (column 2 vs. 1 of the upper part of Table A.1).[2] Besides, it turns out that foreign R&D activity is concentrated on (high-tech) manufacturing (column 4 vs. 3). In the service sector, knowledge-intensive firms have a higher propensity to perform foreign R&D than "traditional" services firms, if we take as yardstick the relative frequency among all R&D performing firms (column 4 vs. 3). In sum, it turns out that two thirds of the firms investing abroad in R&D belong to the high-tech manufacturing or knowledge-intensive service sector of the economy, whereas the same proportion is only 50% if all R&D performing firms are considered.

Large firms are engaged in foreign R&D activities to a much higher extent than smaller ones, as can be seen from a comparison of the size composition of firms being active in foreign R&D with that of all R&D performing firms (column 4 vs. column 3 in the lower part of Table A.1). This pattern is no surprise, given the general size-dependence of the process of internationalisation.[3] Nevertheless, as Table A.1 shows, more than 20% of all firms investing abroad in R&D have less than 50 employees. This result is quite surprising and illustrates the high degree of internationalisation of the Swiss economy.

An analysis with survey data has to deal with the problem of non-response. Unit non-response is not a real problem: the structure of the sample and that of respondents is sufficiently similar, and a survey among a sample of non-respondents did not indicate a significant bias (see Arvanitis et al., 2004). More serious is the problem of item non-response, although, among the variables reflecting foreign R&D activities, the volume of R&D invested abroad is the only measure that is not available for all firms. However, since this variable is crucial for the analysis of the impact of foreign R&D strategies on firm performance, we did not substitute imputed for missing data in this case. As a consequence, the investigation of the productivity effects of foreign R&D strategies was based on a smaller dataset than the analysis we performed in order to identify R&D strategies (137 vs. 156 companies). This reduction of observations, however, does not seem to be a serious problem, because the sectorial and the firm size composition of the reduced sample is almost the same as that of the larger sample. The same holds true for the mean values of all other variables used in the "productivity analysis". In contrast, item non-response is highly relevant with regard to most variables we used in this study to characterise the "types of foreign R&D strategies" (see subsection 4.2). Without replacing missing by imputed values, which we created by applying the method of "multiple imputation" proposed by Rubin (1987), we would have lost too many observations.[4]

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2 For the composition by firm size classes such a comparison is not feasible for methodological reasons, (see footnote 1 of Table A.4 in the appendix).

3 For a theoretical analysis of the size-dependence of foreign activities, see Buckley (1989); his main propositions are confirmed in an econometric study based on a large dataset of Swiss firms (see Hollenstein, 2005).

4 As shown by Donzé (2001), multiple imputation yields robust estimates for missing values.

3. Method

In order to identify the strategy a firm pursues by performing R&D at foreign locations we apply a procedure that involves two steps. The first one aims at identifying a number of “types of foreign R&D strategies” based on a cluster analysis of the motives for performing foreign R&D. This analysis is primarily a statistical exercise. In a second step we examine whether the clusters previously identified effectively may be interpreted as different types of foreign R&D strategies. To this end we characterise the clusters based on a large number of variables that are relevant for explaining foreign R&D activities. In the following, the two steps of the procedure are explained in some more detail.

Firstly, we perform a (non-hierarchical) cluster analysis of the seven motives of foreign R&D, whose relevance has been assessed by the firms themselves, in order to group the firms into homogeneous categories with respect to these variables. The seven motives for which we have information capture the most important “pull” and “push” factors that may induce foreign R&D. These reflect different theoretical approaches of explaining FDI (see Dunning, 2000): cost-reducing/efficiency-seeking and resource-seeking motives (neo-classical theory), market-seeking motives (product cycle model) and asset-seeking/knowledge-seeking motives (evolutionary perspective). The motives underlying our analysis are listed in Table 1 in subsection 4.1).

Cluster analysis, however, was not directly applied to these variables. Instead, we started by synthesising the information contained in these measures by means of a factor analysis into a smaller number of variables („factors“). The latter are uncorrelated (standardised) variables containing the information common to the original variables. Then, we performed a (non-hierarchical) cluster analysis of these factors, in order to group the firms into a number of categories which are, with respect to the variables under investigation, as homogenous as possible (small within-cluster variance) and at the same time as different as possible (large between-cluster variance).[5]

Secondly, we characterise the clusters previously identified in an attempt to determine whether these really may be interpreted as different “types of foreign R&D strategies”. To this end we calculate the cluster-specific means for a large number of variables that capture the main determinants of foreign R&D activities as proposed by theory. In doing so, we primarily draw upon the OLI paradigm that covers in an eclectic way the most important (partial) theories of explaining FDI (Dunning, 1988 and 2000; Cantwell and Narula, 2001).[6]

More specifically, we characterise the types of foreign R&D strategies based on six groups of variables:

5 This procedure involves partitioning the sample, allowing observations to move in and out of groups at different stages of the analysis. At the beginning, more or less arbitrary group centres („cluster seeds“) were chosen and individual observations were allocated to the nearest one. An observation was later moved to another group, if it proved to be closer to that group’s centre than to the centre of the initial group. This process, during which close groups were merged and distant ones split, was continued until stability was achieved with a predetermined number of clusters (see Manly, 1986).

6 For the Swiss case, we confirmed the relevance of the core ingredients of the eclectic approach in some earlier work (Arvanitis and Hollenstein, 2001 and 2007; Hollenstein, 2005).

1. The variables we used in the cluster analysis itself, i.e. seven motives for performing foreign R&D;
2. "Ownership-specific advantages" (O): a) a number of characteristics of innovation activity based on firm-internal and -external factors, b) supply- and demand-side determinants of a firm's innovation performance, c) firm size and productivity (capturing not explicitly specified O-advantages);
3. "Location-specific (dis)advantages" (L): obstacles to innovation;
4. "Internalising advantages" (I): R&D co-operation and firm size (which also reflects O-advantages not explicitly specified);
5. Market conditions: demand perspectives, intensity of competition, etc.;
6. A set of structural firm characteristics: size, age, industry affiliation, etc. (with firm size also capturing O- and I-advantages that are not explicitly specified).

One could argue that, in order to identify a number of "types of foreign R&D strategies", one should perform a cluster analysis not only by using the motives for performing R&D at foreign locations but also by including the variables of the categories 2 to 4 (OLI-variables) as well as 5 and 6 (market conditions, firm characteristics). However, applying such a procedure would imply that the "types of foreign R&D" are identified without referring to "external criteria" (variables not used in clustering) that are required to assess the plausibility of the "types of R&D strategies".

Such an "external plausibility check" is necessary as cluster analysis is a purely statistical procedure that does not necessarily lead to an unambiguous solution in terms of the optimal number of clusters. This proposition may be illustrated by the results of a cluster analysis of innovation indictors we performed in order to identify a number of "modes of innovation" (see Hollenstein, 2003). In that case, cluster analysis yielded three "solutions", which, on purely statistical grounds, were more or less of equal quality. However, based on "external criteria", it was quite easy to determine the "optimal" number of clusters. It is important to notice that a reliable evaluation of the results of a cluster analysis requires "external criteria" that are well founded in theory. By using the OLI paradigm this condition is fulfilled in the present case.

4. Foreign R&D Strategies: Identification and Characteristics

4.1 Identifying foreign R&D strategies

The identification of "foreign R&D strategies" is based on seven motives for performing R&D at foreign locations (see Table 1). The motives capture, as already mentioned, the most important "pull" and "push" factors inducing foreign R&D. The first item ("supporting local production and sales" reflects the "market-seeking" motive of foreign R&D (modifying and adapting products to the needs of the local market), which is stressed by the product cycle model of international trade and investment (Vernon, 1966). The next three items ("geographic proximity to leading edge universities" and "highly innovative firms" as well as "knowledge transfer to the headquarter") represent several dimensions of the "asset-seeking/knowledge-seeking" motive. This category of motives is particularly emphasised in the literature dealing with "technology sourcing" (among many others, see Cantwell, 1995; Kuemmerle, 1999; Patel and Vega, 1999; Frost, 2001; Le Bas and Sierra, 2002) and the evolutionary thinking on the nature of the firm (see e.g. Teece and Pisano, 1998). It is generally presumed that this category of motives has become more important over the last fifteen years (see, e.g. the review article of Narula and Zanfei, 2005). The next two motives (profiting from "low R&D costs" and "high government support for R&D investments", both in comparison to the situation in Switzerland) reflect the "cost-reducing/efficiency-seeking" motive, which is strongly rooted in classical trade theory (see e.g. Mundell, 1957). Finally, making use of an "ample supply of R&D personnel" may also indicate a "cost-reducing/efficiency-seeking" behaviour, but it could also reflect "asset/knowledge seeking" (search for embodied (tacit) knowledge). The importance of the seven motives (as assessed by the firms themselves) is measured on an ordinal scale (5-point Likert scale).[7]

As already mentioned, we started with a factor analysis of the seven motives in order to synthesise and standardise the information contained in these variables. The results of this preparatory step were highly satisfactory. The four factors we extracted account for 74% of total variance. The first factor, which captures 30% of total variance, reflects the three components of the cost-reducing motive (low R&D costs, amply supply of R&D personnel and – to a lesser extent – public support of R&D investments). The second factor, which accounts for 17% of the variance, represents two aspects of knowledge-seeking (geographic proximity to innovative firms, knowledge transfer). The third factor (15% of total variance) refers to geographic proximity to top-level universities and – to a much lesser extent – to public support of R&D. The fourth factor (12 % of total variance) exclusively depicts market-seeking (supporting local production/distribution). We conclude that the basic categories of motives for performing foreign R&D as proposed in the literature are nicely displayed in the factor pattern.

Table 1

Next we performed a non-hierarchical cluster analysis based on the scores of the factor analysis. It turned out that solutions with three or four clusters were of similar quality according to the usual statistical criteria (approximate expected overall R^2, cubic clustering criterion, etc.). In order to determine the final number of clusters, we took three criteria into account, namely: a) the statistical properties in terms of the relationship between within-cluster and between-cluster variance, b) the plausibility of the clusters identified („can the clusters convincingly be interpreted as "foreign R&D strategies"?), and c) the number of firms per cluster, which should not be too small; otherwise, the cluster-specific means of the variables used in characterising the foreign R&D strategies are not reliable. Since the last criterion was satisfied by both solutions, we had to rely on the first and the second one. The solution containing three clusters was slightly inferior to that with four categories in

7 Since many variables used in this paper are measured on a nominal or ordinal scale, it might be worth mentioning that we showed in earlier econometric work (e.g. Arvanitis and Hollenstein, 1996) that the information content of such subjective (assessment) measures is high.

terms of criterion a), and it was clearly less convincing with regard to criterion b). Therefore, we choose the four-cluster solution, which is satisfactory in statistical terms; the approximate expected overall R^2 of 0.47 suggests an acceptable fit of the data to the underlying cluster model (criterion a). More importantly, the four clusters can convincingly be interpreted as foreign R&D strategies (criterion b), as will be shown in the next subsection.

4.2 Characteristics of foreign R&D strategies

In step 2, the four “foreign R&D strategies” have to be characterised, firstly, in terms of the motives for foreign R&D that were used in the cluster analysis. Secondly, we characterise the clusters in terms of the other five groups of variables mentioned in Section 3 (methodological section).

In Table 1, we assess the importance of the seven motives for each strategy relative to the other ones and the sample as a whole. The comparison is based on the cluster-specific share of firms for which a certain motive is of high (very) high relevance. It turns out that the first cluster (column 1), in relative terms, contains a particularly high percentage of companies for which profiting from the geographic proximity to universities, from an ample supply of R&D personnel and – to a lesser extent – from high government support for R&D investments are at the core of their strategy; therefore, this cluster gets the label UNIV_HC (universities, human capital). Firms of the second cluster emphasise most frequently geographic proximity to innovative firm networks and the transfer of know-how to the headquarter company (NETWORK). The third cluster highlights market-oriented motives, i.e. “R&D as a means to support local production/distribution” (MARKET), and the fourth one particularly stresses low R&D costs and access to an ample supply of R&D-related human capital (COST_HC).

By taking the sum of the motive-specific frequencies (see the last row of the table) we get some impression of the breadth of the strategy the firms of a specific cluster pursue. It turns out that firms of type UNIV_HC are (by far) most diversified in their strategic orientation as they pursue several objectives in parallel (“multiple strategy”). At the other end of the spectrum, we find the strategy MARKET whose firms almost exclusively are oriented towards market-seeking R&D. For the economy as a whole (last column), market-seeking and resource-seeking (ample supply of human capital) are, on average, the most important motives. From this characterisation we conclude that the four categories of firms generated by the cluster analysis differ systematically in terms of the “motive variables”; therefore, they seem to qualify as specific “types of foreign R&D strategies”.

In a next step, it is necessary to verify this tentative assessment by characterising the clusters (types of strategies) using “external criteria”, i.e. variables not used in the cluster analysis. To this end we proposed to use five categories of variables, three of them related to the OLI paradigm, the other two capturing market conditions and some structural characteristics of the firms (see Section 3 dealing with the methodology).

O-advantages are represented by four sets of variables. Firstly, based on the view that innovation performance of a firm is an important element of its competitive advantage, we used information on fourteen innovation indicators (see Table 2a). We grouped them into four categories that capture different aspects of the innovation process: a) innovation input (R&D and innovation expenditures),

b) innovation output (patent-related indicators), c) market-oriented innovation measures (sales of innovative products), and d) innovations pertaining to some elements of firm strategies at a more general level.

Secondly (Table 2b), we take into account as further elements of O-advantages firm-external knowledge inputs, which have become more important over the last twenty years in the process of increased specialisation in knowledge production (see e.g. Haagedoorn, 1996). These external inputs directly increase firm productivity as well as indirectly by increasing the effectiveness of a firm's internal innovation input (see Arvanitis and Hollenstein, 1998). We have information at our disposal capturing the intensity of use (firms' assessments) of fourteen external sources of knowledge: customers; suppliers of components, of software, of equipment; competitors; firms of the same enterprise group; universities; other research institutions; consultancy firms; institutions promoting technology transfer; patent disclosures; fairs and exhibitions, professional conferences and (scientific) journals; computer-based networks. To simplify the analysis, we synthesised the information contained in these fourteen sources of knowledge by use of a factor analysis, with five factors turning out as the optimal solution. The results of this analysis are presented in the appendix (Table A.2), which shows that this procedure yields convincing results in statistical terms (the five factors account for 63% of total variance) as well as with respect to the interpretation of the five factors: science-related knowledge sources, supplier-related sources, generally accessible sources, sales-related sources and, finally, group-internal knowledge flows.

Thirdly (see Table 2c), we use the most important supply- and demand-side determinants of innovation as considered in the literature.[8] The supply-side variables represent O-advantages, whereas those of the demand-side variables, capturing the market conditions a firm is confronted with, are only partly or indirectly linked to O-advantages. On the supply side, we include as a proxy for technological opportunities, a variable which represents a firm's assessment of the potential to generate novelties in (or around) its field of activity. Moreover, we consider a measure of the appropriability of knowledge (again based on the assessment of the firms themselves). A proxy for human capital is added to this group of variables, since firms that are well-endowed with highly skilled personnel are in a good position to absorb knowledge from other sources (Cohen and Levinthal 1989). On the demand side, we take account of the medium-run demand prospects (growth of a firm's relevant markets in the period 2000-2005), the intensity of price and non price competition on a firm's product markets and market concentration (number of principal competitors). The intensity of non price competition is measured by a composite indicator which captures a firm's assessment of the relevance of eight elements of non price competition (product variety, after-sales services, etc.) by use of a factor analysis (see Table A.3 in the appendix).

Fourthly, we include labour productivity as a proxy for O-advantages we could not explicitly take into account due to a lack of data (e.g. firm-specific skills in technology management, learning

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8 In some earlier work (e.g. Arvanitis and Hollenstein, 1996) we showed, based on firm-level data, that these supply and demand side variables significantly determine the (intensity of) innovative activities of a firm. For a summary of empirical studies, see Cohen (1995).

capacity, etc.). Firm size, among other things, also captures unspecified O-advantages (size-dependent O-advantages such as, for example, high risk-bearing capacity, advantages in international marketing).

Table 2a, 2b, 2c

L-disadvantages of the Swiss location (see Table 2d) are captured by variables representing obstacles to innovation that may drive firms to perform their R&D activities at foreign rather than at domestic locations. We take account of the relevance of ten obstacles (as assessed by the firms themselves): high taxation; insufficient supply of R&D, of other highly qualified personnel; restricted access to the EU market; excessive regulation of domestic markets; entry barriers for foreigners on the Swiss labour market; lack of public research programmes, of R&D subsidies; regulation of environment protection; regulation of land use. In an attempt to simplify the analysis (in the same way as we did for the external sources of knowledge), we synthesised the information contained in the ten obstacles by use of a factor analysis. The results of this exercise, which yielded a solution with three factors, are presented in the appendix (Table A.4). The results again are convincing statistically (the three factors account for 68% of total variance) as well as in terms of the interpretation of the three factors: restrictive regulatory environment, tax- and subsidy-related obstacles, shortage of highly qualified labour.

I-advantages reflect the internalising of market transactions as a means to reduce transaction costs (Buckley and Casson 1985). In the present context such cost may primarily stem from high risks involved in imperfect markets for knowledge and technology (e.g. limited access to (tacit) knowledge or appropriability problems, etc.). At the empirical level, I-advantages are difficult to measure. Since co-operation in R&D is a frequently (and increasingly) used means for internalising knowledge-related market transactions, we use as a proxy the dummy variable “R&D co-operation yes/no” (see Table 2b, last row). Firm size (which we apply to capture some unspecified O-variables) may also be used as an indicator of I-advantages. Large firms are superior to small ones in terms of factors such as, for example, international innovation management within the company, which is an important instrument for internalising knowledge-related market transactions.

Table 2d

Finally, we take account of a set of structural firm characteristics (see Table 2e): a) firm size (four size classes); b) industry affiliation (five sectors, as defined in Table A.1 in the appendix: low-tech industries; pharmaceuticals, chemicals, plastics; mechanical engineering, vehicles; electrical engineering, electronics, scientific instruments; services); c) export orientation (three categories based on the export to sales ratio); d) company status (independent, mother, daughter), e) firm age (two categories) and, finally (see Table 2c), physical capital intensity.

Table 2e

The Tables 2a, 2b and 2c (variables related to O- and I-advantages), Table 2d (variables related to L-disadvantages) and 2e (structural firm characteristics) show in case of quantitative measures and pseudo-quantitative variables (factor scores) the cluster-specific means as well as the mean for the sample as a whole. In case of ordinal measures (5-point Likert scale) the tables show the average share of firms reporting a value 4 or 5 (high or very high importance), and for dummy variables (yes/no) we tabulate the share of firms reporting "yes". For details see the footnotes to the five tables.

In the following we do not comment each table. It might be more sensible to shortly describe each "type of R&D strategy" (cluster) in terms of the variable groups listed in the tables 2a to 2e. In this way we can synthesise the very detailed information so that we get a clear picture of the main characteristics of each cluster, which allows a comparison with the other ones. For more detail, we ask the reader to study the individual tables in the main text and in the appendix.

Strategy 1: *"Firms pursuing a broad-based foreign R&D strategy in terms of motives, with tapping into knowledge available at foreign universities and embodied in specialists as the core elements"* (UNIV_HC)

This cluster consists of 39 companies (25.0% of all firms, 11.0% of total employment). These firms dispose of strong O-advantages. They are very innovative with special emphasis on the generation of world novelties based on high internal R&D and other innovation-related expenditures and extended patenting activities as well as a very intensive use of external knowledge (in particular from science-related sources). Another feature of innovative activities of the firms of this cluster refers to the adaptation of the firms' general strategic orientation (e.g. concentration on core competencies) and the introduction of new management practices. Innovative activities are supported by very favourable supply-side conditions (large technological opportunities, high appropriability of knowledge), while demand-side factors are somewhat less advantageous as the relevant markets (characterised by high non price competition) are only moderately expanding. I-advantages (as measured by R&D co-operation and firm size) are about average. Besides, the firms of this cluster strongly suffer from all kind of L-disadvantages of Switzerland what might increase the propensity to invest in R&D abroad at the expense of domestic locations. Such disadvantages pertain to excessive regulation, unfavourable financial conditions (taxes, public support for R&D) and shortage of highly qualified personnel. This cluster contains an above-average share of highly export-oriented, medium-sized firms (with only very few large firms), which are slightly over-represented in mechanical engineering and services. The share of rather young firms is also above average. Labour productivity is the highest among all clusters, and the same holds – even more accentuated – for physical capital intensity.

Strategy 2: *"Firms strongly embedded in networks of highly innovative companies and transferring a substantial part of the knowledge obtained abroad to the domestic headquarter"* (NETWORK)

This cluster consists of 37 firms (23.7% of firms and employment respectively) characterised by strong O-and I-advantages. Innovative activities of these firms, which are endowed with an excellently qualified staff, are strongly research-oriented. Output- and market-oriented measures of innovations (patenting and sales share of innovative products respectively) are below-average. Quite important are innovations at the level of firm strategy (introduction of new management practices and marketing procedures). The use of external knowledge is below average, with the exception of some elements of (generally accessible) science-related sources (patent documents, scientific journals). This pattern of external innovation input quite clearly corresponds with that of internal innovative activities. Similarly, formal R&D co-operation is a widespread practice what (again) is in line with the strongly research-based firm-internal innovation activities. Supply-side conditions for generating novelties (technological opportunities, appropriability), somewhat surprisingly, are not more than average. On the other hand, firms of this cluster profit from excellent demand conditions (high market growth, low intensity of price competition. L-disadvantages of Switzerland are very low for these firms; in other words, they are not pushed to perform R&D abroad but choose foreign locations in order to complement their high O-and I-advantages by knowledge available in foreign networks of highly innovative firms. This cluster contains a large share of very small, often young companies; however, we also find in this cluster four large MNE's of the chemical, pharmaceutical and food industry). Export orientation, reflecting the high share of companies with less than fifty employees, is low. The chemical and pharmaceutical industry as well as, to some extent, services are over-represented in this category of firms. Labour productivity is about average, while physical capital intensity is low.

Strategy 3: *"Firms pursuing a strongly focused strategy, with foreign R&D almost exclusively used as a means to extend local markets"* (MARKET)

This cluster is the largest one and consists of 56 companies (35.9% of all firms, 57.8% of total employment). On the whole, these firms are weaker in terms of O-advantages as compared to the average firm of the total sample and, in particular, the mean of the first two clusters. The innovation capacity is primarily based on development (and not research) expenditures; patent activity is low and sales-oriented innovation measures point to an only average market performance. Firms of this cluster emphasise quite strongly new firm strategies in general (e.g. concentration on core competencies) and the adaptation of organisational structures. The not very strong position with regard to internal innovation activities is not compensated by an intensive use of external knowledge; on the contrary, external knowledge input is much lower than in all other clusters. In view of the only moderate innovation capacity, it is not very surprising that the supply-side environment for innovation is not more than average (technological opportunities) or below-average (appropriability of knowledge). In contrast, the firms profit from operating in strongly growing markets, but price competition is fierce perhaps reflecting the rather low number of competitors (oligopolistic competition). As far as I-advantages are concerned, the firms of this cluster are in a quite good position (if we take R&D co-operation and firm size as indicators). L-disadvantages are quite substantial but restricted to a shortage of highly skilled (R&D) personnel (whereas excessive regulation and deficits with respect to taxation and public support of R&D are irrelevant). This cluster contains a very high proportion of well-established ("old") large firms, which are export-oriented to an extremely high extent (the sales share of exports of more than half of the firms is higher than 75%). The sectorial pattern is quite equilibrated, with some over-representation of the broadly defined machinery sector (i.e. including electronics and instruments). Labour productivity is higher than average, even more so in case of the physical capital intensity.

Strategy 4: *"Firms pursuing, in terms of motives, a rather narrow-based foreign R&D strategy that aims at reducing R&D costs and gaining access to highly skilled personnel"* (COST_HC)

This cluster consists of only 24 companies (15.4% of all firms, 7.5% of total employment). O-advantages of the firms of this cluster are, taken as a whole, slightly below-average. Innovation activities show a specific pattern. The firms are characterised by quite substantial innovation expenditures, reflecting engineering and innovation-related follow-up expenditures rather than R&D investments. As a result, these firms produce, in the first instance, incremental innovations. Moreover, we do not find much innovation at the level of firm strategies (perhaps with the exception of changes in marketing). The supply-side as well as the demand-side environment for generating innovations is unfavourable (weak position with regard to technological opportunities, appropriability and market growth, combined with very intensive price competition). In contrast to the only moderate internal innovation activities, firms draw very substantially on external knowledge available along the value chain (suppliers, competitors, firms of the same group, customers). As far as I-advantages are concerned, companies of this cluster are in a rather weak position. L-disadvantages seem to be no problem, what is somewhat surprising as the firm's foreign R&D activities are motivated by cost-reduction and getting access to human skills. This cluster contains a very high share of small (mostly "old") firms (with only one really big company). There is some over-representation of electrical engineering and electronics. Export orientation is almost the same as in the total sample. Labour productivity as well as physical capital intensity is far lower than in the other clusters.

These four "types of foreign R&D strategies" reflect clearly different (and plausible) patterns in terms of the underlying motives for investing in foreign R&D as well the other five categories of variables we used to characterise them (OLI-variables, market environment, structural firm characteristics). Moreover, it turns out that some of the clusters represent multiple, broad-based foreign R&D strategies, as they are driven by several motives (particularly in case of strategy UNIV_HC), whereas others are basically focused on one single motive (most clearly in case of strategy MARKET). We thus conclude that it is sensible to analyse R&D strategies in terms of a combination of motives rather than investigating them separately.

5 Productivity Effects of Foreign R&D Strategies

In this section, we investigate, firstly, whether foreign R&D contributes to a firm's productivity, and, secondly, whether productivity effects differ among the four strategies identified in the previous section.

According to Table 2c, average labour productivity differs among the four strategies quite substantially. UNIV_HC and MARKET, the two strategies with the highest level of labour productivity, outperform the least productive strategy COST_HC by about 30%. Average labour productivity of strategy NETWORK is similar to the mean of the whole sample.

Such a simple comparison of cluster means, however, does not allow drawing any conclusions with respect to the relative productivity effect of the four foreign R&D strategies, since a firm's labour productivity, in the first instance, is determined by other factors. For example, it is quite obvious that a firm intensively using physical capital exhibits (ceteris paribus) a higher level of labour productivity than a company whose most important input factor is labour (compare in this respect, for example, the strategies UNIV_HC and COST_HC).

As a consequence, instead of comparing average labour productivity among the four strategies, we estimate a production function with the following independent variables: a) physical capital intensity (CL: gross capital income per employee), human capital intensity (HC: employment share of personnel holding tertiary level degrees), domestic knowledge capital intensity (RDDOML: domestic R&D expenditures per employee), b) foreign knowledge capital intensity (RDFORL: foreign R&D expenditures per employee) and c) strategy-specific foreign R&D expenditures per employee (RDUNIVL, RDMARKETL, RDNETWORKL, RDCOSTL). All variables are specified in logarithmic form. We dropped industry and firm size dummies because they turned out to be insignificant in all specifications.

The econometric analysis is based on 137 observations as against 156 in case of the (descriptive) analysis in Section 4. The loss of observations, due to missing quantitative information on foreign R&D expenditures, is not a real problem since the composition of the full and the reduced sample in terms of R&D strategies is nearly the same. Moreover, it turned out that the mean values of the other variables we used in estimating the model (labour productivity, physical and human capital intensity, domestic R&D expenditures) are very similar for the two samples (see Section 2).

The upper part of Table 3 shows the results from estimating a production function taking into account the explanatory variables mentioned above, with the exception of the four variables representing the four strategies of foreign R&D. These are added in the estimates presented in the lower part of the table, with the cost-oriented strategy taken as reference (variable RDCOSTL).

Column 1 (upper part) shows that the basic production function yields satisfactory results in terms of model fit as well as significance of the three variables included. Since human (HC) and (domestic) knowledge capital (RDDOML), not surprisingly, are quite strongly correlated (r = .36), we show in column 2 estimates where human capital is dropped. It turns out that the model fit remains about the same, with the coefficient of (domestic) knowledge capital somewhat increasing.

In column 3, we take account of foreign knowledge capital (RDFORL). We interpret a positive coefficient of this variable as an indication of a productivity-enhancing knowledge transfer from the foreign location to the domestic headquarter. It turns out that the inclusion of foreign R&D expenditures hardly changes the model fit (column 3 vs. 1) and that the coefficients of RDDOML and RDFORL become insignificant. This finding reflects the high correlation between these two components of R&D expenditures (r = .66). Therefore, it is hardly possible to disentangle the two influences. Against this background, we show in column 4 the results of an estimation of a specification where only foreign R&D is included. It is no surprise that RDFORL exhibits a statistically significant impact on labour productivity, whereas the model fit remains much the same as in column 3 or 1. The fact that the coefficient of RDFORL (column 4) is distinctly smaller than that for RDDOML (column 1) indicates that domestic knowledge influences labour productivity of the headquarter firm to a higher extent (and more directly) than foreign R&D. In view of the collinearity of RDDOML and RDFORL we also estimate a model where the two components of R&D expenditures are added up (RDTOTL). The results are very similar to those we got for model that only relied on domestic R&D expenditures (see column 1). Given the fact that, for most companies, the volume of domestic R&D is much larger than that of foreign R&D this finding is no surprise.

Table 3

The lower part of Table 3 shows estimates of models where the explanatory variables used in the upper part are complemented by variables depicting strategy-specific foreign R&D expenditures. We include the variables RDUNIVL, RDMARKETL and RDNETWORKL, with RDCOSTL used as the redundant variable. Estimation of this extended model yields a consistent pattern across all specifications. R&D expenditures at foreign locations positively influence a firm's labour productivity only if their strategic orientation is on market-seeking. It is remarkable that the market-seeking R&D strategy has a positive impact on productivity even if the general level of foreign R&D expenditures (RDFORL) is taken into account (column 4). In other words: a market-oriented foreign R&D strategy adds to the general productivity effect of foreign R&D expenditures.

The two R&D strategies that stress, among other objectives, technology sourcing (UNIV_HC represented by RDUNIVL, and NETWORK captured by variable RDNETWORKL) do not have an additional impact on productivity. Moreover, some further estimates (not reported here) where RDMARKETL is used as the redundant variable show, that RDCOSTL is negatively correlated with a firm's labour productivity, in some specifications statistically significant at the 10%-level. In other words, the positive productivity effect of aggregate foreign R&D (i.e. not taking account of the specific strategies pursued) is not matched in case of a cost-oriented R&D strategy (COST_HC).

The results with respect to the relative effectiveness of the four strategies of foreign R&D are quite plausible. It is not surprising that a market-oriented foreign R&D strategy (MARKET) is more directly linked to the productivity of the headquarter company than the other strategies. In this case, foreign R&D primarily serves to adapting and designing products for the local market in order to increase sales at that location. These activities foster productivity at the domestic headquarter even if the products sold abroad stem from production at foreign locations, at least as long as these products are primarily based on domestic R&D (asset-exploiting strategy). In these circumstances, the headquarter company may increase deliveries of intermediate goods to their affiliates, what contributes to cover its fixed costs (among which R&D expenditures is a quite substantial element).

It also seems plausible that we cannot detect a productivity effect for the two R&D strategies that are primarily based on technology sourcing (strategies UNIV_HC and NETWORK). The benefits of technology sourcing, in most cases, are not directly linked with productivity at the headquarter. In the first place, these strategies augment a company's knowledge base. It is only in the medium and long run that they might contribute to productivity growth. It is impossible to identify such lagged effects in a cross-section analysis, and I might be difficult to do so even in a longitudinal analysis, since the time-lags between technology sourcing, knowledge transfer and technology use and productivity might be long and variable. Finally, it is not surprising that a cost-oriented foreign R&D strategy (COST_HC) contributes least to the productivity of the headquarter firm, since, in many instances, it often substitutes for domestic R&D.

6 Summary and Conclusions

The literature distinguishes several motives for performing foreign R&D, which are related to specific theoretical (partial) models explaining FDI in R&D activities (classical model, product cycle model, evolutionary perspective). To date, the relevance of these motives in most instances are investigated separately, with analyses dealing with the relative importance of market-seeking (demand side) and knowledge-/technology-seeking (supply side) motives as the dominant theme. In contrast, we presumed that a firm investing in foreign R&D usually pursues several objectives at once ("multiple strategy").

By applying cluster analysis to a set of motives for performing R&D at foreign locations, we identified four clusters. We characterised the four categories of firms by using several groups of variables that represent the main ingredients of the OLI paradigm as well as market conditions and some structural firm characteristics. In view of the distinct patterns of the four clusters in terms of the underlying motives and the large number of characterising variables, the clusters can be interpreted as specific „types of foreign R&D strategies":

- *Strategy 1*: Firms pursuing a broad-based foreign R&D strategy in terms of motives, with tapping into knowledge available at foreign universities and embodied in specialists as the core elements;
- *Strategy 2*: Firms strongly embedded in networks of highly innovative companies and transferring a substantial part of the knowledge obtained abroad to the domestic headquarter;
- *Strategy 3*: Firms pursuing a strongly focused strategy, with foreign R&D almost exclusively used as a means to extend local markets;
- *Strategy 4*: Firms pursuing, in terms of motives, a rather narrow-based foreign R&D strategy that aims at reducing R&D costs and gaining access to highly skilled personnel.

The clusters partly reflect "multiple strategies" (to the highest extent in case of strategy 1), whereas others (particularly strategy 3) are characterised by focusing almost exclusively on one single motive. This variety indicates that it is sensible to allow for "multiple strategies" although not all firms adhere to broad-based strategies. Cluster analysis (combined with a theory-based characterisation of the clusters), which, to our knowledge, is applied in the present context for the first time, proves to be a suitable methodology.

The relative importance of the four clusters in terms of the number of firms and the employment share yields an indication of the relevance of the two competing hypotheses with respect to the home-country effects of foreign R&D activities. Foreign R&D of type 3 clearly complements domestic R&D. The same might be true for type 2 as the transfer of knowledge from foreign locations to the domestic headquarter is an important feature of this strategy. In contrast, many firms pursuing strategy 4 tend to substitute foreign for domestic R&D. There is no definite answer in case of type 1. Consequently, we conclude that foreign R&D complements domestic R&D in case of 60 % of firms that employ 81% of total workforce (strategies 2 and 3), whereas we find a substitutive relationship only for 15% of firms (8% of total employment). The remaining 25% of firms (11% of employment), representing strategy 1, cannot be definitely associated with one of the conflicting hypothesis. Since the sample of firms to which our questionnaire has been sent is largely representative, we may conclude that in case of the Swiss economy foreign and domestic R&D, on balance, are complements. This result confirms the findings of our earlier work where we applied a different methodology.

From the relative size of the four clusters, we can draw another interesting conclusion. Foreign R&D still is based to a very significant extent on the traditional efficiency- and market-seeking motives: clusters 3 and 4, which primarily reflect these types of motives, dominate foreign R&D activities, at least in terms of employment (65% of employment). However, knowledge-seeking, which is a core ingredient of the other two foreign R&D strategies, has become a very important driver of the internationalisation of R&D in the Swiss economy: 51% of firms (although only 35% of employment) pursue these two types of foreign R&D strategies. We conclude that the Swiss economy is not only highly internationalised in terms of distribution and manufacturing (as it is since decades) but it also is strongly embedded in the worldwide system of knowledge production.

The analysis of the impact on firm productivity of foreign R&D in general as well as of specific foreign R&D strategies yielded highly plausible results. Among the four strategies, we only could find a positive effect on firm productivity for strategy 3 (strong focus on foreign R&D as a means for developing local markets). Since technology sourcing plays an important role in case of strategy 1 and 2, it is not very surprising that we could not find a positive productivity effect. These strategies, in the first place, contribute to increase a firm's knowledge base; the impact on productivity might be distributed over many years. These effects cannot be detected based on a cross-section dataset. However, we strongly doubt whether one succeeds to do so even in a longitudinal analysis, since the time-lags between foreign R&D and its impact on productivity may be long and variable.

Although we were able to investigate the topic of this paper in a differentiated way, there are limitations which should be addressed in future work. Firstly, the number of observations underlying our analysis is rather low. Therefore, one may suspect that the pattern of foreign R&D strategies we identified is not very stable. Secondly, an analysis based on cross-section data (like the present one) is not able to uncover the dynamics of foreign R&D strategies. Based on longitudinal data one would like to find answers on questions such as, for example, the following: are there significant changes of R&D strategies over time, and if this is the case, do such strategies evolve in a systematic way? How and to what extent do short- and long-run effects of foreign R&D strategies on domestic productivity differ? As data from additional cross-sections become available in Switzerland in the near future, we shall be able to explore some of these topics.

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Table 1: Motives for Performing R&D at Foreign Locations by Type of R&D Strategy
(Percentage share of firms assessing a specific motive as (highly) important (score 4 or 5 on a 5-point Likert scale))

Motives	R&D strategy UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	All firms N =156
Supporting local production and sales	26	30	61	29	40
Geographic proximity to leading edge universities	67	5	21	0	26
Geographic proximity to highly innovative firms (networks)	44	59	16	29	35
Transfer of knowledge/technology to the domestic headquarter	28	59	13	0	26
Low R&D costs	38	14	4	79	26
High government support for R&D investments	26	0	9	13	12
Ample supply of R&D personnel	64	30	11	71	38
Sum of percentage shares (columns)	*293*	*197*	*135*	*221*	*203*

[1] The labels of the four clusters reflect the dominant motives (on which cluster analysis is based) and is more or less self-evident in view of the relative importance of the seven motives.

Source: Swiss Innovation Survey 2002.

Table 2a: Innovative Activities

Innovation Indicators	R&D Strategies (Cluster Means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	Sample Mean N =156
a) Input-oriented measures					
- Qualitative measures [1]					
Research expenditures	36	41	21	29	31
Development expenditures	82	70	68	67	72
- Quantitative measures					
Sales share of innovation expenditures (%)	7.6	5.2	5.3	8.9	6.4
Sales share of R&D expenditures (%)	5.5	5.0	3.4	2.9	4.2
Employment share of R&D personnel (%)	13.8	11.8	9.7	9.0	11.1
b) Output-oriented measures					
Share of firms with patent applications (%)	59	43	57	54	54
Number of patent applications per employee	.058	.033	.023	.024	.034
c) Market-oriented measures					
- Sales share of innovative products (%)					
World-wide novelties	9.0	4.3	6.7	6.8	6.7
Fundamentally new products	20	17	18	21	19
Significantly improved products	43	35	36	41	38
d) Introduction of new elements of firm strategies [2]					
- Strategy (e.g. concentration on core competencies)	59	51	59	42	54
- Management (e.g. supply-chain management)	54	51	45	29	46
- Organisation (e.g. flattening of hierarchical structures)	51	59	63	50	57
- Marketing (e.g. introduction of E-commerce)	46	59	57	54	54

[1] Percentage share of firms assessing expenditures for research and development respectively as (very) high (score 4 or 5 on a 5-point Likert scale).

[2] Percentage share of firms having introduced specific elements of firm strategies in the reference period (2000-2002).

Source: Swiss Innovation Survey 2002.

Table 2b: Sources of External Knowledge and R&D Co-operation

External Knowledge Sources / R&D Co-operation	R&D Strategies (Cluster Means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	Sample Mean N =156
a) Use of external knowledge sources [1]					
Users	51	54	59	83	60
Suppliers of materials/components	38	54	45	58	47
Suppliers of software	18	24	13	29	19
Suppliers of machinery/equipment	28	19	18	17	21
Competitors	38	43	30	54	39
Firms of the same group	36	35	41	50	40
Universities	59	43	41	21	43
Other research institutions	36	27	18	13	24
Consulting firms	15	8	7	0	8
Technology transfer organisations	10	8	4	8	7
Patent documents	23	32	25	25	26
Fairs/exhibitions	51	43	29	75	45
Scientific and trade journals, conferences	54	57	32	46	46
Computer networks	38	46	21	29	33
b) Aggregate measure of the use of external knowledge sources (mean of factor scores) [2]					
SCIENCE	.34	-.13	-.03	-.18	0
SUPPLIER	.01	.05	-.10	.13	0
GENERAL	.17	.18	-.28	.10	0
MARKET	.02	-.14	-.13	.49	0
GROUP	.03	-.15	.06	.04	0
Sum of the five mean scores	*.57*	*-.19*	*-.48*	*.48*	*0*
c) R&D co-operation					
Share of firms co-operating in R&D with other firms or research institutions (%)	41	49	48	33	44

[1] Percentage share of firms assessing the input of external knowledge as (very) high (score 4 or 5 on a 5-point Likert scale).

[2] Factor scores based on a principal component analysis of the use of the fourteen external knowledge sources listed in the upper part of the table (five-factor solution). The table shows the mean scores by cluster and for the full sample (which is zero as a result of standardisation). In addition we show the sum of the mean scores across the five categories of knowledge sources as a measure of the total input of external knowledge.

For the detailed results of the factor analysis (factor pattern, etc.) see *Table A.2* in the Appendix.

Source: Swiss Innovation Survey 2002.

Table 2c: Other Innovation-related Characteristics, Factor Input and Productivity

Indicators	R&D Strategies (Cluster Means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	Sample Mean N =156
a) Supply-side determinants of innovation					
Technological opportunities [1]	56	51	48	33	49
Appropriability [1]	46	41	30	42	38
b) Demand-side determinants of innovation					
Demand trend 2000/05 [1]	36	46	45	33	41
Intensity of price competition [1]	74	65	82	79	76
Intensity of non price competition [2]	.19	.00	-.16	.07	0
c) Market concentration (number of principal competitors)					
0 – 4	26	32	39	21	32
5 – 10	33	32	29	21	29
11 – 15	15	6	16	21	14
16 and more	26	30	16	37	25
d) Factor input and productivity					
Human capital intensity (employment share of highly qualified personnel, %)	25.9	31.1	25.5	29.0	27.5
Physical capital intensity (gross capital income per employee)[3]	117	87	106	72	99
Labour productivity (value added per employee)[3]	203	189	200	157	192

[1] Percentage share of firms assessing technological opportunities, appropriability and demand growth, respectively, as (very) high (score 4 or 5 on a 5-point Likert scale).

[2] Factor scores based on a principal component analysis (one-factor solution) of eight dimensions of non price competition. The table shows the mean scores by cluster and for the full sample (which is zero as a result of standardisation). See *Table A2* in the appendix for the set of the non price instruments of competition as well as for the detailed results of the factor analysis (factor pattern, etc.).

[4] Mio. SFR.

Source: Swiss Innovation Survey 2002.

Table 2d: Obstacles to Innovation

(Percentage share of firms assessing a specific obstacle as (highly) important (value 4 or 5 on a 5-point Likert scale))

Obstacles	R&D Strategies (Cluster Means) UNIV_HC N = 39	 NETWORK N = 37	 MARKET N =56	 COST_HC N =24	Sample Mean N =156
a) Obstacles [1]					
High taxation	31	13	13	11	17
Insufficient availability of R&D personnel	69	50	63	41	54
Insufficient availability of qualified employees in general	64	39	58	35	47
Restricted access to the EU market	33	14	38	27	26
Excessive regulation of the domestic product market	23	13	13	19	17
Restrictive access of foreigners to the domestic labour market	31	18	46	22	26
Lack of public research programmes	28	18	25	19	22
Lack of R&D subsidies	28	14	17	11	17
Environmental regulations	33	13	17	27	22
Regulation of land use/construction	31	13	25	22	21
b) Aggregate measure of the importance of ten obstacles to innovation (mean of factor scores) [2]					
REGULATION	0.26	*-0.29*	0.08	0.12	0
SUPPORT	0.32	-0.11	-0.08	-0.12	0
LABOUR	0.19	-0.12	0.45	*-0.31*	0
Sum of the three mean scores	0.77	-0.52	0.45	*-0.31*	0

[1] Percentage share of firms assessing the obstacles as (very) important (score 4 or 5 on a 5-point Likert scale).

[2] Factor scores based on a principal component analysis of the ten obstacles to innovation listed in the upper part of the table (three-factor solution). The table shows the mean scores by cluster and for the full sample (which is zero as a result of standardisation). In addition, we show the sum of the mean scores across the three categories of obstacles to innovation as a measure of the total level of hindrances. For the detailed results of the factor analysis (factor pattern, etc.) see *Table A.4* in the appendix.

Source: Swiss Innovation Survey 2002.

Table 2e: Selected Structural Characteristics of Firms

Characteristics	R&D Strategies (Cluster Means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	Sample Mean N =156
a) Firm size (share of firms (%) by size class; number of employees)					
5 – 49	23	43	13	13	22
50 -149	31	24	27	50	31
150 – 499	33	11	32	29	27
500 or more	13	22	28	8	20
b) Industry / sector (share of firms, %)					
Low-tech industries	26	22	27	21	24
Pharmaceuticals, chemicals/plastics	13	26	11	13	15
Mechanical engineering, vehicles	30	14	29	28	27
Electrical engineering, electronics, instruments	10	16	20	25	17
Services	21	22	13	13	17
c) Export orientation (share of firms (%), based on the export to sales ratio)					
1 – 29	18	38	27	29	28
30 – 74	31	30	18	25	25
75 or more	51	32	55	46	47
d) Company status					
Independent	36	43	32	38	37
Mother	28	22	29	29	27
Affiliate	36	35	39	33	36
e) Firm age (number of years)					
1 - 19 years	23	24	7	13	16
20 or more	77	76	93	87	84

Source: Swiss Innovation Survey 2002.

Table 3: Impact of Foreign R&D Strategies on Labour Productivity

Basic model	**Dependent variable: Value added per employee**				
Intercept	6.82***	6.88***	6.83***	6.89***	6.78***
	(.261)	(.261)	(0.260)	(0.259)	(0.262)
CL	.419***	.417***	0.421***	0.430***	0.422***
	(.024)	(.024)	(0.024)	(0.023)	(0.023)
HC	.038*		0.039*	0.049**	0.038*
	(.022)		(0.022)	(0.021)	(0.022)
RDDOML	.047***	.057***	0.030		
	(.017)	(.016)	(0.021)		
RDFORL			0.017	0.029***	
			(0.013)	(0.011)	
RDTOTL					0.047***
					(0.016)
Statistics					
N	137	137	137	137	137
Adjusted R^2	.746	.742	.747	.745	.748
Extended model	**Dependent variable: Value added per employee**				
Intercept	6.91***	6.96***	6.90***	6.96***	6.87***
	(.266)	(.261)	(0.267)	(0.263)	(0.271)
CL	.414***	.412***	0.416***	0.424***	0.418***
	(.024)	(.024)	(0.024)	(0.023)	(0.023)
HC	.040*		0.041*	0.050**	0.041*
	(.022)		(0.022)	(0.021)	(0.022)
RDDOML	.035*	.047***	0.027		
	(.019)	(.016)	(0.022)		
RDFORL			0.010	0.020***	
			(0.014)	(0.013)	
RDTOTL					0.036*
					(0.019)
RDUNIVL	.009	.007	.007	.009	.007
	(.008)	(.008)	(.008)	(.009)	(.009)
RDMARKETL	.015*	.014*	.013	.015*	.013
	(.007)	(.007)	(.008)	(.008)	(.008)
RDNETWORKL	.009	.009	.007	.008	.007
	(.008)	(.008)	(.008)	(.009)	(.009)
Statistics					
N	137	137	137	137	137
Adjusted R^2	.747	.743	.747	.745	.748

APPENDIX

Table A.1: Composition of the Data Set

Sectors	Sample	Respondents	R&D performing	Foreign R&D
		Percentage shares		
Manufacturing	*46.7*	*52.7*	*74.3*	*83.4*
Low-tech manufacturing	26.0	29.9	35.0	24.4
Chemicals, pharmaceuticals	5.4	6.1	10.5	15.4
Machinery, vehicles	8.6	9.5	16.4	26.3
Electrical machinery, electronics, instruments	6.7	7.2	12.4	17.3
Services	*53.3*	*47.3*	*25.7*	*16.6*
"Traditional" services	39.4	34.0	14.7	8.3
Knowledge-intensive services	13.9	13.3	11.0	8.3
TOTAL	100 (N = 6524)	100 (N = 2583)	100 (N = 1078)	100 (N = 156)
Firm size [1] (number of employees)				
5 – 49		52.5	39.8	22.4
50 – 149		25.9	29.2	30.9
150 – 499		15.7	22.7	26.9
500 and more		5.9	8.3	19.8
TOTAL	100 (N = 6524)	100 (N = 2583)	100 (N = 1078)	100 (N = 156)

[1] The overall sample distinguishes three industry-specific firm size classes which are the outcome of an "optimal stratification" of census employment data. Since we prefer a somewhat higher level of disaggregation based on size thresholds which do not vary across industries, there are no comparable figures for the basic sample.

[2] Sector definition: *Low-tech manufacturing*: food, textiles, clothing, wood, paper, printing, non-metallic minerals, metals, metal products, watchmaking, other manufacturing, energy/water; *High-tech manufacturing*: chemicals/pharmaceuticals, plastics, non-electrical machinery, vehicles; c) electrical machinery, electronics, scientific instruments; *"Traditional" services*: wholesale trade, retail trade, hotels/restaurants, transport/telecommunication, personal and other services; *Knowledge-intensive services*: banking/insurance, ICT and R&D services, business services.

Source: Swiss Innovation Survey 2002.

Table A.2: Factor Analysis of External Knowledge Sources

Knowledge Sources	Rotated Factor Pattern (Varimax) [1] (1)	(2)	(3)	(4)	(5)
Other research institutions	.81				
Technology transfer organisations	.77				
Universities	.69				
Consulting firms	.66	.			
Patent documents	.50	.			
Suppliers of materials/components		.80			
Suppliers of software		.77			
Suppliers of machinery and equipment		.64			
Conferences and trade journals			.77		
Computer networks			.75		
Users				.71	
Fairs and exhibitions			.47	.61	
Firms of the same industry, competitors				.55	
Firms of the same group					.94
Statistics					
Number of observations					156
Kaiser's overall measure of sampling adequacy (MSA)					.727
Variance accounted for by the first five factors					.629
Root mean square off-diagonal residuals (RMSE)					.081
Variance accounted for by each factor	2.67	1.86	1.67	1.51	1.10
Final communality estimate (total)					8.81

Characterisation based on the factor pattern

(1) Science-related knowledge (SCIENCE)

(2) Supplier-related knowledge (SUPPLIER)

(3) Generally accessible knowledge (GENERAL)

(4) Sales-related knowledge (MARKET)

(5) Group-internal knowledge (GROUP)

[1] The table only shows factor loadings that are 0.4 or higher.

Table A.3: Factor Analysis of Elements of Non Price Competition

Elements of non price competition	Factor pattern (loadings)
Product quality	.78
Product differentiation (customisation)	.71
Product variety	.67
Frequency of innovations	.65
Technological lead	.59
Flexibility in serving customers	.51
After-sales service	.46
Product design	.40
Statistics	
Number of observations	156
Kaiser's overall measure of sampling adequacy (MSA)	.737
Variance accounted for by the first factor	.37
Root mean square off-diagonal residuals (RMSE)	.134
Final communality estimate (total)	2.95

Table A.4: Factor Analysis of Obstacles to Innovation

Obstacles	Rotated Factor Pattern (Varimax) [1] (1)	(2)	(3)
Restricted access to the EU market	.85		
Environmental regulations	.77		
Regulation of land use / construction	.71		
Excessive regulation of the domestic product market	.69		
Lack of public research programmes		.88	
Lack of R&D subsidies		.88	
High taxation		.70	
Insufficient availability of (highly) qualified employees			.83
Insufficient availability of R&D personnel			.82
Restrictive access of foreigners to the domestic labour market		.40	.46
Statistics			
Number of observations			156
Kaiser's overall measure of sampling adequacy (MSA)			.762
Variance accounted for by the first three factors			.678
Root mean square off-diagonal residuals (RMSE)			.086
Variance accounted for by each factor	2.56	2.49	1.70
Final communality estimate (total)			6.75

Characterisation based on the factor pattern

(1) Restrictive regulatory environment (REGULATION)

(2) Tax and subsidy-related obstacles (SUPPORT)

(3) Deficiency of highly qualified personnel (LABOUR)

[1] The table only shows factor loadings that are 0.4 or higher.