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Characteristics of Foreign R&D Strategies of Swiss Firms: Implications for Policy

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Abstract

The aim of the paper is, firstly, to identify a number of strategies Swiss firms pursue by performing foreign R&D, expecting that firms, in many instances, are driven by a combination of several motives ("mixed strategies"). Secondly, we ask whether foreign and domestic R&D are substitutes or complements. Thirdly, we draw some policy conclusions based on results for direct and indirect home-country effects of foreign R&D. By applying cluster analysis, we identified four specific patterns of motives of foreign R&D. In a second step, we investigated whether these clusters effectively may be interpreted as specific types of R&D strategies. To this end, the clusters were characterised in terms of a large number of variables, which, according to the OLI paradigm of FDI, determine foreign R&D. We found that the patterns of the four clusters systematically differ with respect to these theory-related variables. Some clusters represent, in terms of motives, broad-based mixed strategies, whereas others are strongly focused. It turns out that foreign R&D strategies that primarily aim at exploiting capabilities of the domestic headquarters dominate, whereas cost-reducing strategies are of very minor importance. In case of the other two strategies knowledge sourcing is a constituent element, in the first one, knowledge sourcing is at the core, in the second case it is an important element in the frame of a broad-based strategy. The relative importance of the four strategies implies that, on balance, foreign and domestic R&D are complements. Notwithstanding this positive result, it is sensible to take policy actions supporting the economy to capitalise even more on outward FDI in R&D. Policy basically should aim at securing the attractiveness of Switzerland as a location for R&D-intensive headquarters of firms performing foreign R&D, and at enhancing knowledge spillovers from headquarter companies to other domestic firms. The five categories of measures we recommend are part of a framework-oriented policy design rather than of a more interventionist concept.

JEL classification: F21, F23, O3;

Keywords: Internationalisation of R&D; Motives of foreign R&D; Foreign R&D strategies; Knowledge spillovers; Home-country effects of outward FDI in R&D;

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1. Introduction

During the last three decades internationalisation of Swiss firms' R&D activities strongly increased. Similar trends are observed in other countries (Narula and Zanfei, 2005; Veugelers et al., 2005). As a reaction there is an increasing concern in Switzerland (and in other countries as well; see Hakanson and Nobel, 1993; OECD, 1998; Veugelers et al., 2005) that foreign R&D activities may substitute for domestic ones. On the other hand, it is argued that foreign R&D is a means to support production and sales activities in foreign markets and to tap into the world-wide pool of knowledge. In this view, foreign R&D complements and augments the domestic knowledge base, given the transfer of knowledge to the headquarter works sufficiently well. Whether the one or the other hypothesis holds true depends to a large extent on the strategies firms pursue by investing abroad in R&D.

According to the classical model of international trade and investment, differences among countries with respect to (relative) costs are the driver of foreign investments (Mundell, 1957). Reducing costs (increasing efficiency) is the prime motive for performing foreign R&D. In this theoretical setting, foreign and domestic R&D are substitutes.

In contrast, the experience with FDI in the sixties of the 20th century showed that some R&D at foreign locations often was required for successfully penetrating and developing local markets. Foreign R&D primarily served to modify products that basically were the result of domestic R&D according to the local needs. This strategy driven by market-oriented (demand-side) motives is emphasised by the product cycle model of international trade and investment (Vernon, 1966). In this case, foreign and domestic R&D are complements.

During the last twenty years observers increasingly became aware of the relevance of supply-side motives of foreign R&D as a growing number of companies started to perform R&D abroad in order to profit from (specialised) knowledge (only) available at foreign locations.[1] Knowledge-seeking as a means to augment a headquarter's knowledge base fits well into the dynamic capability view of the firm proposed by evolutionary economics (see Teece and Pisano, 1998). In this theoretical perspective, foreign and domestic R&D again are complements, at least to the extent that knowledge transfer to the domestic headquarters works sufficiently well.

Granstrand et al. (1993) reviewed the empirical evidence with respect to the internationalisation of R&D primarily reflecting work done during the eighties and the early nineties. Since then quite a few empirical studies have been published specifically dealing with knowledge-seeking activities, thus the relatively new element of the internationalisation of R&D (see, among others, Cantwell, 1995; Florida, 1997; Kuemmerle, 1999; Patel and Vega, 1999; Frost, 2001; Le Bas and Sierra, 2002). A main objective of this work was to show the growing relevance of this type of foreign R&D ("asset-augmenting") and/or to compare its prevalence with the more traditional market-seeking strategy ("asset-exploiting"). Moreover, this research showed that geographic proximity to universities and highly innovative firms, in accordance with the asset-augmenting strategy, offers great opportunities

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1 For some early evidence see Ronstadt (1978).

for profiting from knowledge spillovers in various forms (access to specific human capital, exploiting local high-tech networks, etc.; see e.g. Cantwell and Piscitello, 2005). Besides it was shown empirically that some foreign affiliates upgraded their market-oriented R&D activities by using locally available firm-internal and firm-external knowledge for creating new products not only for the local but for the world market as well. This extended market-oriented role of foreign affiliates has been documented in various studies (see, among others, Pearce (1992, 1999); Pearce and Papanastassiou, 1999).[2]

The different motives of foreign R&D, as stressed by distinct theoretical models, were incorporated by Dunning in his well-known OLI paradigm. Its most recent version (Dunning, 2000; Cantwell and Narula, 2001; see also Dunning, 1994) is well-suited to accommodate for FDI in R&D activities. "Ownership-specific advantages" (O) capture market-seeking as well as knowledge-seeking foreign R&D. "Location-specific advantages" (L) represent the classical cost-reducing/efficiency-seeking motive. "Internalising advantages" (I) are not directly linked to a certain motive for performing R&D abroad. 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 and firm-internal knowledge transfer).

In this paper we aim, firstly, at identifying a number of specific strategies firms pursue by investing in R&D at foreign locations, expecting that firms mostly are driven by a combination of several motives ("mixed strategies"). Secondly, we ask whether foreign and domestic R&D are substitutes or complements. Thirdly**,** we discuss some policy implications.

In order to identify foreign R&D strategies of Swiss firms, 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 four clusters resulting from this exercise represent specific combinations of the underlying motives and are thus interpreted as different types of foreign R&D strategies ("mixed strategies"). In a second step, we characterise the clusters based on a large number of variables that, in the first place, represent the most important aspects of the OLI paradigm. In this way we can check whether the statistical classification procedure of the first step effectively yields types of foreign R&D strategies that clearly differ from each other and are consistent with the OLI framework. The analysis is based on firm-level data stemming from the Swiss Innovation Survey conducted in 2002.

The relative importance of the different R&D strategies enables us to assess whether foreign R&D, on balance, substitutes domestic R&D, or whether these two components of R&D are complements. By discussing the direct home-country effects of the various strategies and also considering indirect effects (knowledge spillovers to domestic firms) we get additional evidence on the relative merits of

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2 Some indication of the evolution of R&D activities of foreign affiliates from product adaptation for the local market to product development for other markets is already documented in Hakanson (1981).

the two hypotheses. Based on these results we derive some policy implications and discuss what type of policies are required to maximise the benefit of foreign R&D for the Swiss economy.

The paper complements (and adds to) previous work in several respects: firstly, we apply a methodological approach for identifying specific foreign R&D strategies, which, to our knowledge, has been employed so far only in one study (Hakanson and Nobel, 1993). This approach is particularly suited to accommodate for “mixed” strategies that are based on a combination of motives for foreign R&D. By combining a statistical classification procedure (cluster analysis) with a theory-based characterisation of the clusters (variables representing the OLI paradigm) we are quite confident that the clusters effectively represent specific types of foreign R&D strategies. Secondly, as the database contains a large number of variables suitable to characterise different R&D strategies it allows a more differentiated analysis of foreign R&D strategies at the firm-level than it is usually the case, what also holds compared to the above-mentioned study using the same approach. Moreover, our database includes SMEs and service sector firms, which, in most studies dealing with foreign R&D are not considered. Thirdly, the study contributes to the analysis of the home-country effects of foreign R&D, which have not gained much attention till the early nineties (Granstrand et al., 1993) and still remain a question not clearly answered to date (Veugelers et al., 2005). Fourthly, the policy analysis takes into account the specificities of foreign R&D strategies what usually is not the case. Finally, an analysis of the Swiss case may be of special interest as the process of the internationalisation of R&D has progressed very far in this country.

Although we are are able to investigate the topic of this paper in a differentiated way, there are limitations which should be addressed in future work. Firstly, as the number of observations is rather low, one may suspect that the pattern of foreign R&D strategies we identify is not very stable. Secondly, an analysis based on one single cross section 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, whether R&D strategies significantly change over time? If this is the case, one may wonder whether such strategies evolve in a systematic way? As data from additional cross-sections are becoming available in Switzerland, we shall be able to explore some of these topics.

The set-up of the paper is as follows: In the next two sections we shortly describe the database and the method we apply in order to identify specific foreign R&D strategies. In Section 4 we present the empirical results. Finally, we discuss the implications of the empirical results for economic policy in Switzerland.

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 expenditures. Moreover, the companies were asked to assess on a five-point Likert scale, ranging from “practically irrelevant” (value 1) up to “very important” (value 5), the importance of specific motives for performing R&D abroad. This information is used to identify alternative foreign R&D strategies. The survey also provided data on a large number of variables that we used to characterise these strategies in terms of the well-known OLI paradigm.

The survey was based on a stratified sample of firms with at least five employees (28 manufacturing and services industries; three industry-specific firm size classes, with full coverage of large companies). The questionnaire that has been sent to 6524 companies yielded valid data for 2583 firms (response rate 40%). 1078 firms performed R&D (42% of the respondents), among which 156 (15%) doing so also at foreign locations. Foreign R&D activity is more concentrated than total R&D on high-tech manufacturing and, to a lesser extent, on knowledge-intensive services. Large companies more often perform foreign R&D than smaller ones. Nevertheless, more than 20% of the firms investing abroad in R&D have less than 50 employees.

The industry composition of the dataset of responding firms is quite similar to that of the underlying sample; we only notice some over-representation of manufacturing at the expense of the “traditional” part of the service sector. As the structure of the sample and that of respondents is sufficiently similar, unit non-response is no serious problem, what is confirmed by a survey among a sample of non-respondents (Arvanitis et al., 2004). In contrast, we had to correct for item non-response by replacing missing by imputed values (“multiple imputation”; see Rubin, 1987).

3. Method

In order to identify the strategy a firm pursues by investing abroad in R&D we apply a two-step procedure. Firstly, we perform a non-hierarchical cluster analysis of seven motives of foreign R&D, which capture the most important “pull” and “push” factors that may induce foreign R&D, as proposed by the different theoretical approaches mentioned above. By applying (non-hierarchical) cluster analysis (see Manly, 1986), we classify firms into a number of categories, which, in terms of the combination of motives of foreign R&D, are as homogenous as possible (small within-cluster variance) and at the same time as different as possible (large between-cluster variance). Therefore, we may conclude that firms of a specific category pursue very similar foreign R&D strategies. However, since cluster analysis is a (purely) statistical classification procedure, such an interpretation is preliminary.

Secondly, in order to check whether the clusters identified in the first step really may be interpreted as specific foreign R&D strategies, we compare the cluster-specific means of a large number of variables we did not used in clustering (“external plausibility check”). These variables represent core elements of the OLI paradigm, the firms’ market environment and some structural firm characteristics.

More specifically, we characterise the clusters, in addition to the motives of foreign R&D, based on four groups of variables:

1. “Ownership-specific advantages” (O): a) several types of innovation indicators based on firm-internal and firm-external factors, b) supply-side determinants of innovation performance

(complemented by some demand-side determinants which are only partly related to O-advantages), c) firm size and productivity (capturing not explicitly specified O-advantages);

2. “Location-specific disadvantages” of Switzerland (L): obstacles to innovation;
3. “Internalising advantages” (I): R&D co-operation and firm size (which, as mentioned, also reflects some not explicitly specified O-advantages);
4. Structural firm characteristics such as, for example, firm size, industry affiliation, etc. (with firm size, as mentioned, also capturing some O- and I-advantages).

4. Empirical results

4.1 Identifying foreign R&D strategies

The identification of foreign R&D strategies is based on the seven motives for performing R&D at foreign locations shown in Table 1. These reflect the various theories of international trade and investment as integrated in the OLI paradigm. The first item (“supporting local production and sales”) reflects market-seeking motives of foreign R&D. The next three items (“proximity to leading edge universities”; “proximity to highly innovative firms”; “knowledge transfer to the headquarter”) represent several dimensions of knowledge-seeking**.** Exploiting “low R&D costs” and “high government support for R&D investments”, both as compared to Switzerland, reflect the motive of cost-reduction. Finally, making use of an “ample supply of R&D personnel” at foreign locations may represent cost-reducing but also knowledge-seeking motives (access to specific human capital). The importance of the seven motives, as assessed by the firms themselves, is measured on a 5-point Likert scale.

Table 1

The cluster analysis based on these “motive variables” yielded four clusters. The statistical properties of the classification (relationship between within-cluster and between-cluster variance) is satisfactory in statistical terms. The value of the approximate expected overall R^2 of 0.47 suggests an acceptable fit of the data to the underlying cluster model.

Table 1 shows for the whole sample and the four clusters the share of firms for which a specific motive is highly relevant. It turns out that the first cluster (column 1) contains a particularly high percentage of companies for which profiting from 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; hence, this cluster is labelled UNIV_HC (universities, human capital). Firms of the second cluster emphasise geographic proximity to innovative firm networks and the knowledge transfer to the headquarter (NETWORK). The third cluster highlights R&D as a means to support local production and sales (MARKET), and the fourth one stresses low R&D costs and access to an ample supply of R&D-related human capital (COST_HC). We conclude that the four clusters systematically differ in terms of the seven “motive variables”.

By taking the sum of the motive-specific frequencies (see the last row of the table) we get some idea of the breadth of the strategy the firms of a specific cluster pursue. It turns out that firms of type

UNIV_HC by far are most diversified in their strategic orientation as they pursue several objectives in parallel (strongly “mixed strategy”). At the other end, we find the firms of the cluster MARKET whose strategy is very focused on one motive (market-seeking R&D).

4.2 Characteristics of the foreign R&D strategies

In order to check the appropriateness of the classification resulting from cluster analysis (step 1 of the procedure), the four clusters are characterised and compared in terms of the variables not used in clustering. To this end we refer to a large number of variables representing the OLI paradigm and the firms’ market environment, as well as to some structural firm characteristics. In so doing, it will turn out whether the clusters effectively represent specific foreign R&D strategies.

O-advantages are represented by three sets of variables. Firstly (see Table 2a), based on the view that innovation performance is an important element of a firm’s competitive advantage, we use information on fourteen innovation indicators. These capture different aspects of the innovation process: a) innovation input (R&D and innovation expenditures), b) innovation output (patent-related indicators), and c) market-oriented innovation measures (sales of innovative products).

A second category of O-advantages pertains to firm-external knowledge inputs that have become more important in the process of increased specialisation in knowledge production (Haagedoorn, 1996). External knowledge inputs have a direct (positive) impact on firm productivity and also increases indirectly the effectiveness of a firm’s internal innovation input (Arvanitis and Hollenstein, 1998). We dispose of information capturing the intensity of use of fourteen external sources of knowledge (see Table 2b): 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/exhibitions, professional conferences/(scientific) journals; computer-based networks. We synthesised the information contained in the fourteen sources of knowledge by use of factor analysis, with five factors turning out as the optimal solution. The resulting factor pattern is convincing in statistical terms (the five factors account for 63% of total variance) as well as with respect to the interpretation of the factors: science-related knowledge sources, supplier-related sources, generally accessible sources, market-related sources and, finally, group-internal knowledge flows.

As a third group of O-advantages (Table 2c), we include some supply- and demand-side determinants of innovation as considered in the literature (see e.g. Cohen, 1995). On the supply side, technological opportunity is proxied by the firms’ assessment of the potential of novelties to be generated in and around its field of activity. Besides, we consider a measure of the appropriability of knowledge (again as assessed by the firms themselves). Human capital intensity (share of highly qualified personnel) is used to capture a firm’s capacity to absorb knowledge from outside the firm. These supply-side variables are complemented by four demand-side determinants of a firm’s innovation performance, which are only partly related to O-advantages: medium-run market 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, finally, the number of principal competitors (market concentration). The intensity of non price competition is measured by a composite indicator (based on factor analysis) of the relevance of eight elements of non price competition (firm assessments) such as product quality, product differentiation, after-sales services, etc.

Finally, in order to take account of O-advantages we could not explicitly specify, we use labour productivity and firm size. The latter (among other things) may capture size-dependent O-advantages (e.g. advantages of large firms in international marketing), whereas the former should represent not explicitly specified O-advantages in general (high learning capacity, etc.).

Tables 2a, 2b, 2c

L-disadvantages of Swiss locations are captured by a set of variables representing obstacles to innovation that may drive firms to perform R&D at foreign rather than at domestic locations. We take account of the relevance of ten obstacles as assessed by the firms themselves (see Table 2d): high taxation; insufficient supply of R&D personnel, of other highly qualified workers; 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; environment protection; restrictive regulation of land use. Again we synthesised the information by use of a factor analysis, with three-factors turning out as the optimal solution. The factor pattern is convincing in statistical terms (the three factors account for 68% of total variance) as well as with regard to the interpretation of the three factors: restrictive regulatory conditions, tax-/subsidy-related obstacles, shortage of highly qualified labour.

Table 2d

I-advantages reflect gains a firm may realise by internalising market relationships in order to reduce transaction costs (Buckley and Casson, 1985). In the present context such costs may primarily stem from high risks involved in imperfect markets for knowledge and technology (e.g. limited access to tacit knowledge). I-advantages, however, are difficult to measure. Since co-operation in R&D is an 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 above). As another indicator of I-advantages, we include firm size (which also is used to capture some unspecified O-variables). Large firms are likely to be superior to small ones, for example, with regard to international innovation management, which is an important instrument for internalising knowledge-related market transactions.

Finally, we include a set of structural firm characteristics: firm size and age, industry affiliation, degree of export orientation and company status (Table 2e).

Table 2e

In the following we do not comment each table. It is more sensible to shortly describe each cluster in terms of the groups of variables shown 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 the four strategies. For more details, we ask the reader to study the individual tables.

4.3 A portrait of the four 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* (UNIV_HC)

This cluster consists of 39 companies (25.0% of firms, 11.0% of 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, extended patenting activities as well as a very intensive use of external knowledge (in particular science-related sources).**.** 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 are only moderately expanding. I-advantages (R&D co-operation, firm size) are about average. The firms of this cluster 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, insufficient financial incentives (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 excellent staff, are strongly research-oriented. Output- and market-oriented measures of innovations (patents, sales share of innovative products) are below-average. The same holds true for the use of external knowledge, with the exception of some elements of (generally accessible) science-related sources (patent documents, scientific journals). This pattern and the widespread practice of formal R&D co-operation are in line with the strongly research-based firm-internal innovative activities. Supply-side conditions for generating novelties (technological opportunities, appropriability), somewhat surprisingly, are not better than average. On the other hand, firms of this cluster benefit from excellent demand conditions (high market growth, low intensity of price competition). L-disadvantages of Switzerland are very low; in other words, these firms are not pushed to perform R&D abroad but choose foreign locations in order to complement their capabilities 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 MNEs of the chemical, pharmaceutical and food industry. Export orientation is low, reflecting the high share of small companies. Among the sectors, the chemical and pharmaceutical industry and, to a lesser extent, services are over-represented. 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 firms, 57.8% of employment). In terms of O-advantages, these firms are weaker than the average firm, and, in particular, the average company of the first two clusters. Innovation capacity primarily is based on development expenditures; patent activity is low and market-oriented innovation measures point to only average innovation content of sales. The moderate intensity of internal innovation activities is not matched by an intensive use of external knowledge. Therefore, it is not very surprising that the supply-side conditions for innovation are not more than average (technological opportunities) or even below-average (appropriability). In contrast, the firms benefit from operating in strongly growing markets, where non price competition is low; price competition, however, 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 good position. L-disadvantages are concentrated on shortages of highly skilled personnel. This cluster contains a very high proportion of large, well-established rather old firms, which are export-oriented to an extremely high extent. The sectoral pattern is characterised by some over-representation of manufacturing (with the exception of pharmaceuticals/chemicals). Labour productivity and, even more so, physical capital intensity are above-average.

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 firms, 7.5% of employment). O-advantages of the firms of this cluster are slightly below-average. Innovation activities show a specific pattern. The firms are characterised by quite substantial innovation expenditures that reflect high outlays for engineering and innovation-related follow-up activities rather than R&D investments. As a result, these firms primarily generate incremental innovations. The supply-side as well as the demand-side environment for generating innovations is unfavourable (low technological opportunities and appropriability; slow growth of highly price-sensitive markets). In contrast to the only moderate internal innovation activities, these firms substantially draw on external knowledge available from other companies operating along the same value chain (suppliers, competitors, customers, firms of the same group). With regard to I-advantages the firms 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 about average, whereas labour productivity and physical capital intensity are much lower than in the other clusters.

We conclude form this sketch of the four portraits that the four clusters reflect distinct patterns of motives for investing in foreign R&D and are clearly different in terms of the theory-based categories of variables we used to characterise them (OLI-related variables, structural firm characteristics). Therefore, the four clusters safely may be interpreted as specific foreign R&D strategies. Some of the clusters represent mixed, broad-based strategies as they are driven by several motives (particularly strategy UNIV_HC), whereas others are more focused, in particular strategy MARKET.

In view of these results it is sensible to analyse foreign R&D strategies in terms of a combination of motives ("mixed strategies") rather than investigating the individual motives separately. The two-step procedure based on cluster analysis (step 1), complemented by a theory-based characterisation of the clusters (step 2), proves to be a suitable procedure to identify and assess such strategies.

5 Implications for economic policy in Switzerland

An assessment of the impact of foreign R&D of Swiss firms on the domestic economy is a precondition to draw policy conclusions and to recommend policy measures. The literature distinguishes two types of effects on the home country. Firstly, knowledge and technology transfer from foreign affiliates to the headquarter company may strengthen the knowledge base of the domestic economy (positive direct home-country effects). Secondly, the domestic economy may profit from knowledge spillovers from the headquarter company to other domestic firms such as suppliers or users and (public) institutions such as universities (positive indirect home-country effects). Empirical evidence related to the two types of home-country effects is scarce, particularly with respect to spillover effects (Veugelers et al., 2005).[3]

5.1 Direct home-country effects

Direct home-country effects, in the first instance, reflect the prevalence of the four foreign R&D strategies (number of firms, employment) as these have a different impact on the knowledge base of the headquarter:

- Strategy 3 (MARKET): Market-oriented strategies are the dominant feature of Swiss firms' foreign R&D. This strategy gives rise to firm-specific economies of scale at the headquarter. The concomitant higher return to domestic R&D is an incentive to spend more on R&D (positive direct effect). However, according to the scarce empirical evidence, the direct home-country effects of market-oriented R&D strategies seem to be rather weak.
- Strategy 2 (NETWORK) and 1 (UNIV_HC): Knowledge sourcing is an essential element of these two strategies. The direct effects are positive only if the knowledge acquired abroad is transferred to a significant extent to the domestic headquarters. In case of strategy 2, where affiliates source knowledge by operating in foreign networks of highly innovative firms, technology transfer works well according to the surveyed firms. The direct effects of strategy 1 that emphasises knowledge sourcing based on geographical proximity to universities and access to human capital, is not so obvious. In case of this strategy, knowledge transfer to the headquarter takes place but it is not the prime feature. This result, however, does not imply that knowledge transfer is not relevant. It

3 In the following, when commenting on the available evidence, we refer to the survey of these authors; we thus refrain, with some exceptions, from citing other references.

rather indicates that in the frame of this broad-based strategy other motives are more important. Moreover, as shown in Table 1, knowledge transfer of firms pursuing this strategy is more important by far than it is the case of strategy 3 and 4. Therefore, we presume that at least part of the knowledge gained abroad will flow back to the headquarter company. To sum up, we conclude that both strategies for which knowledge sourcing is a constituent element strengthen the domestic knowledge base (positive direct home-country effect). The results from other empirical studies tend to support this assessment.

- Strategy 4 (COST_HC): Firms pursuing this strategy primarily seek to lower their R&D costs. As the cluster analysis yields no evidence for a significant reverse knowledge transfer, the direct home-country effects probably are negative (relocation of R&D activities).

Based on the prevalence of the four strategies and the assessment of their direct home-country effects we conclude that foreign and domestic R&D, on balance, are complements. The unambiguously complementary strategies 2 and 3 are pursued by 60% of firms employing 81% of workers, whereas only 15% of firms (8% of employment) adhere to strategy 4 that may have a negative effect on domestic R&D. This interpretation is a cautious one as it does not consider strategy 1, where the impact on the headquarters' knowledge base is not so straightforward but is probably positive as well. Our overall assessment is in line with the findings of our earlier work (Arvanitis and Hollenstein, 2001, 2007; Hollenstein, 2005), which was based on an econometric analysis of a firm's decision to invest in foreign R&D.

5.2 Indirect home-country effects

If indirect home-country effects (knowledge spillovers) are positive as well, the balance would tilt even further towards complementarity of foreign and domestic R&D. The extent of knowledge spillovers is determined by several factors such as the firms ability to prevent know-how from leaking to competitors, or their willingness to share knowledge with local suppliers and users in order to improve the own market position. Most importantly, however, spillovers are the larger, the higher the capacity of domestic firms to absorb external knowledge.

As already mentioned, there is not much evidence with respect to the size of knowledge spillovers. Nevertheless, we argue that in the Swiss economy, as compared to other countries, domestic firms are likely to benefit a lot from such spillovers. Firstly, absorptive capacity of Swiss firms is particularly high, since SMEs are more innovative than firms of the same size class in all EU Member States.[4] In these circumstances, the knowledge base of the economy is highly distributed what fosters knowledge diffusion. The large share of highly qualified personnel in science and technology employed by Swiss firms (see OECD, 2007) also facilitates the absorption of external knowledge. Secondly, firms performing R&D at foreign locations are well embedded in the domestic innovation system, as (domestic) R&D cooperation is more widespread than in most EU countries (with Scandinavian

4 The comparisons with the EU countries are based on the results of the most recent "Community Innovation Survey" (CIS IV) and the Swiss Innovation Survey 2005 (see Arvanitis et al., 2007).

countries as the main exception), and technology transfer between science (which is of very high standard in Switzerland) and industry works well (Arvanitis and Woerter, 2006). Moreover there are some important clusters of knowledge-intensive industries such as pharmaceuticals/biotechnology/ chemicals, banking/insurance or scientific instruments. We conclude that, in the Swiss case, indirect home-country effects of foreign R&D (knowledge spillovers) are likely to add substantially to the positive direct home-country effects.

5.3 Policy recommendations

Notwithstanding this positive assessment, policy may support the Swiss economy to capitalise even more on foreign R&D activities than it does to date. The aim of such a policy basically should be to secure the attractiveness of Switzerland as a location for R&D-intensive headquarters of firms pursuing an active foreign R&D strategy, and to facilitate knowledge spillovers from headquarter companies to other domestic firms.

There is a wide range of policies which may contribute to reaching these objectives. Without making a claim to be complete, we propose five lines of action:

- Measures to increase the insufficient domestic supply of highly qualified labour, which is not higher than the OECD average. The intensive use of human capital in the Swiss economy is highly dependent on immigration and the inflow of cross-border workers (see OECD, 2007), what, in a long-run perspective, is not feasible. Therefore, tertiary education must get top priority in public spending. Moreover, it is necessary to promote labour market participation of women (investment in the social infrastructure, tax incentives) and to mobilise the untapped intellectual potential of the large number of foreign children living in Switzerland (integration policy).
- It is necessary to keep the high standard of university research, in particular in science and engineering, and to foster frontier research (science policy).
- Technology policy should promote the application of the results of science in the business sector: favourable regulations of IPR; avoiding a too restrictive regulatory framework for the usage of fundamentally new technologies such as biotechnology and nanotechnology; promoting science-industry co-operation and technology transfer; providing an environment conducive to start-ups in high-tech and knowledge-intensive industries, etc.).
- Strengthening the linkages between the domestic MNEs and other local companies (suppliers, users) as well as science and education institutions by means of cluster-oriented policies (“embeddedness”).
- Finally, general policy measures to make Switzerland an even more attractive location for doing business (e.g. low, incentive-oriented taxation, deregulation of markets, etc.).

The proposed measures are part of a framework-oriented policy design rather than reflecting a more interventionist policy concept.

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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 strategies (cluster means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	All Firms N =156
Supporting local production/sales	26	30	61	29	40
Geographic proximity to leading universities	67	5	21	0	26
Geographic proximity to highly innovative firms (networks)	44	59	16	29	35
Transfer of knowledge and 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	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 are more or less self-evident as they reflect the relative importance of the seven motives.

Source: Swiss Innovation Survey 2002.

Table 2a: Innovative activities 2000/02

Innovation indicators	R&D strategies (cluster means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	All firms 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
New or fundamentally improved products	20	17	18	21	19
New and all kind of improved products	43	35	36	41	38

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

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	All firms 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 and 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 (science-related knowledge)	.34	-.13	-.03	-.18	0
SUPPLIER (supplier-related knowledge)	.01	.05	-.10	.13	0
GENERAL (general accessible knowledge)	.17	.18	-.28	.10	0
MARKET (market-related knowledge)	.02	-.14	-.13	.49	0
GROUP (group-internal knowledge flows)	.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 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 of the five categories of knowledge sources as a measure of the total input of external knowledge. For detailed results see Table A.2 in Hollenstein (2006).

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	All firms 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					
Market growth 2000-2005 [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 2001					
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 market growth, respectively, as high (score 4 or 5 on a 5-point Likert scale).

[2] Factor scores based on a principal component analysis (one-factor solution) of the importance of eight dimensions of non price competition as assessed by the firms themselves (5-point Likert-scale). The table shows the mean scores by cluster and for the full sample (which is zero as a result of standardisation). For detailed results see Table A.3 in Hollenstein (2006).

[3] Mio. SFR.

Source: Swiss Innovation Survey 2002.

Table 2d: Obstacles to innovation

Obstacles	R&D strategies (cluster means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	All firms 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 highly 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
Severe protection of environment	33	13	17	27	22
Restrictive regulation of land use and construction	31	13	25	22	21
b) Aggregate measure of the importance of ten obstacles to innovation (mean of factor scores) [2]					
REGULATION (restrictive regulatory environment)	0.26	*-0.29*	0.08	0.12	0
SUPPORT (tax- and subsidy related obstacles)	0.32	-0.11	-0.08	-0.12	0
LABOUR (lack of highly qualified personnel)	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 highly 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 of the three categories of obstacles to innovation as a measure of the total level of hindrances. For detailed results see Table A.4 in Hollenstein (2006).

Source: Swiss Innovation Survey 2002.

Table 2e: Selected structural characteristics of firms 2001

Characteristics	R&D strategies (cluster means) UNIV_HC N = 39	NETWORK N = 37	MARKET N =56	COST_HC N =24	All Firms 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)					
0 - 29	18	38	27	29	28
30 - 74	31	30	18	25	25
75 - 100	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)					
Less than 20 years	23	24	7	13	16
20 or more	77	76	93	87	84

Source: Swiss Innovation Survey 2002.