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Emerging patterns of R&D in the Swiss economy

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Emerging Patterns of R&D
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Emerging Patterns of R&D in the Swiss Economy

Spyros Arvanitis and Heinz Hollenstein

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S&T Policy”**

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Emerging Patterns of R&D in the Swiss Economy

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1. 1. Introduction

Switzerland belongs to the most R&D-intensive economies, although it has lost some positions on the international ladder of R&D intensity at country level in recent years being superseded by some OECD countries which increased their R&D spending very much in this time (e.g. Finland and Korea).¹ The R&D/GNP ratio is of about 2¾ %, slightly less than in the eighties (3%). Three quarter of R&D is financed by the private sector, with some increase of public financing during the last two decades; nevertheless, the public share still belongs to the lowest among the OECD-countries. Although most R&D is done by large multinationals, Swiss SME's are more R&D-intensive than those of most other highly developed countries. R&D is thus a pervasive phenomenon in the Swiss economy.

Public R&D is very much oriented towards basic research (primarily at universities). As a percentage of GNP, basic research is by far the highest among all OECD countries. In the last decade, applied research became somewhat more important, since Switzerland a) increased its participation at the EU research programmes (EUREKA, Framework programmes, etc.), and b) established some research programmes oriented towards specific areas of national interest (promising technological fields like biotechnology, new materials, etc; areas of public concern like environment, health, etc.). Although public/private partnerships are encouraged in these programmes, the university sector remains dominant. There is only a small portion of R&D promotion which is clearly directed towards the private sector (programmes financed by the Commission of Technology and Innovation); in this case, however, the promotion of diffusion is at least as important as R&D in the narrow sense.

In view of the dominant role played by private R&D, our research concentrates on the analysis of the (emerging) patterns of R&D prevailing in Swiss firms; the public sector is only taken into account in its role as partner of private firms. More specifically, the research pertains to three areas, that is a) R&D networking (contract-R&D, R&D co-operation), b) internationalisation of R&D, and c) financing R&D-driven innovative activity. The first two refer to phenomena which play an ever increasing role in private R&D. The third one is relevant, since, in designing an optimal policy of promoting private R&D, it is necessary to know whether there are capital market imperfections leading to an underinvestment in R&D.

The analysis is descriptive (meso-level: sectors, industries, size classes) as well as explicative (firm-level). In the first place, we use data from the Swiss innovation survey of 1999 which is based on a stratified sample (28 industries; 3 industry-specific size classes). The survey yielded information for 2172 firms. By correcting for non-response and adequate weighting we obtained results which are representative for the underlying population (census firms with at least 5 employees). Additionally, we use data from earlier innovation survey (1990, 1993, 1996) to get information on the change of relevant variables. Moreover, we take into account data from a survey on "Internationalisation of the

¹ The data used in this introductory section are mainly from OECD (2001) and the R&D statistics published by the Swiss Federal Office of Statistics (Bundesamt für Statistik, 1999 and earlier editions)

Swiss economy” we conducted in winter 1998/99. The questionnaires used in these surveys can be downloaded from www.kof.ethz.ch.

In the next section, we present selected results from a descriptive analysis of R&D networking based on out-contracting of R&D as well as on R&D co-operation (see Arvanitis et. al., 2001a, Ch. 7). Section 3 is devoted to a descriptive and econometric analysis of the internationalisation of R&D (see Hollenstein, 2000; Arvanitis and Hollenstein, 2001; Arvanitis et al. 2001b). In Section 4, we present some empirical results regarding the financing of R&D based on Arvanitis and Marmet (2002). Finally, we draw some (policy) conclusions.

2. Knowledge networks

2.1 Internal vs. external R&D strategies

Competition based on innovative products and/or processes has intensified in recent years, since, among other things, a growing number of countries developed strong innovative capacities based on R&D, human skills, etc., and, at the same time, technological innovations tend to become more complex and (therefore) more expensive. In these circumstances, it is not surprising that a growing number of firms are coming under pressure to use their R&D funds more efficiently: Specialisation by concentrating R&D on very specific fields of activities; combining internal R&D, which is focused on core areas, with external R&D based on R&D contracts and/or R&D co-operations.

Table 1 shows that in 1999 more than 50% of Swiss firms followed R&D strategies which involve a combination of internal and some form of external R&D (“external R&D strategies”); 21% of firms relied on both forms of external R&D, i.e. contracts as well as co-operations (external strategy of type 3). The table gives the corresponding results by sector as well as for the most innovative industries. Among the industries for which external R&D is particularly important, we find almost exclusively highly innovative ones. In other words: less innovative industries are more inclined to concentrate on purely internal R&D strategies. The same holds true for small firms, whereas large firms rely more often on external strategies, and, among these, particularly on the most developed external strategy (type 3). Nevertheless, even among the three lowest size-classes (5-19, 20-49, 50-99 employees), a substantial amount of firms follows an external strategy of type 3. We conclude from these results that the knowledge network in the Swiss economy, in particular in the most innovative segments, is very tight.

At this stage of research, we are not yet able to present results with respect to the development over time of the relative importance of the four types of strategies distinguished in table 1. Nevertheless, we notice a distinct tendency towards external strategies, since R&D contracts as well as R&D co-operations have become more frequent during the nineties.

Table 1: Importance of Internal and External R&D Strategies 1997/99
(% of R&D performing firms)

	Internal	External R&D-strategies		
	R&D-strategy	Type 1	Type 2	Type 3
	Internal R&D only	Internal R&D and contract-R&D	Internal R&D and R&D co-operation	Internal R&D, contract-R&D and R&D co-operation
<i>Business sector total</i>	46.7	22.5	10.0	20.8
<i>Sector</i>				
Manufacturing	47.7	24.9	6.2	21.2
Services	45.9	17.1	18.1	18.9
<i>Industries with above-average external R&D</i>				
Textiles	34.9	29.9	4.1	31.1
Chemicals/Pharma	32.3	29.5	3.9	34.3
Machinery	38.8	21.8	8.6	30.8
Electrical machinery	44.8	33.2	0.5	21.5
Electronics/instruments	36.7	24.9	3.6	34.8
Transport/Telecom	29.7	22.8	28.6	18.9
Banking/Insurance	36.6	12.6	24.7	26.1
R&D-/ICT-services	14.9	24.1	25.3	35.7
Business services	46.6	23.6	14.4	15.4

Source: Arvanitis et al. (2001a)

2.2 R&D-contracts

The share of firms out-contracting R&D (solely or in combination with R&D co-operations) strongly increased in recent years, more precisely, from 25% in the years before 1997 to 43% in the period 1997/99.

Firms out-contract R&D most frequently to other firms (70% of all out-contracting firms). 50% of contracting is with the university sector, and 33% with other research institutions (specialised laboratories, etc.), which is a sector not so well-developed in Switzerland as in other countries like, for example, Germany. The frequency of contracts with other firms is about the same for small and for large firms, whereas contractual relationships with universities and other research institutions are more important in case of large firms. Nevertheless, it is quite remarkable that one third of out-contracting firms with less than 50 employees rely on university research.

Almost all firms out-contract R&D to Swiss partners. Nevertheless, contractual relationships are also international to a remarkable degree (what is obviously more probable in case of small countries), with EU countries as the most important partner (32%); 20% of out-contracting firms choose partners from other countries; the USA are the most important one (13%). It is not surprising that international out-contracting is size-dependent; this holds true more for partnerships with US firms/institutions than with European ones. However, almost 10% of out-contracting firms of each of the three lowest size-classes (5-19, 20-49, 50-99 employees) do so (also) with US partners. We conclude that Swiss firms, even the small ones, are capable of looking for the best supplier of the required knowledge on a world scale. In a policy perspective, it is worth noticing that distance matters. There is thus scope for national and European policy to reducing “distance” in the wide sense of the word (decentralised competence centres, efficient information flows over longer distance, etc.).

There is not much known about the motives for and determinants of out-contracting R&D, the relationship between internal R&D and out-contracting, the impact of out-contracting on R&D outcomes, etc. It is an objective of future work to investigate these relationships empirically based on econometric analyses of firm-level data. At this stage, we are able to present some descriptive results with respect to the motives of out-contracting and the problem of substitutionality vs. complementarity of out-contracted and in-house R&D.

The 1999 Innovation Survey yielded data on the firms’ assessments of four motives for out-contracting R&D (five-point scale ranging from “not important at all” to “highly important”):

- Efficiency-oriented substitutionality: Out-contracting combined with a reduction of internal R&D capacity; the same type of R&D can be performed at lower costs by other firms/institutions.
- Knowledge-oriented substitutionality: Out-contracting combined with a reduction of internal R&D; internal know-how is (and remains) insufficient to produce the required new knowledge.
- Efficiency-oriented complementarity: Out-contracting of R&D to complement own R&D (whose level is not reduced) with knowledge in very specific fields which can be produced at lower costs by other firms/institutions.
- Knowledge-oriented complementarity: Out-contracting of R&D to complement efficiently internal R&D (whose level is not reduced) with knowledge in fields of technology which are completely new for the firm.

Table 2 shows that, on balance, about 40% of firms substitute contract-R&D for own R&D, whereas for more than 60% of firms internal R&D and out-contracting are complementary (col. 3 vs. col. 6). Complementarity is more important than substitution in all industries and firm size classes, although to a different extent. The dominance of complementarity is particularly strong for large firms. The main driver behind complementary as well as substitutional out-contracting is not the anticipation of lower costs but rather the opportunity to source new (specialised) knowledge (col. 1 vs. 2 and col. 4 vs. 5 resp.). This again holds true for all industries and size classes, and is more accentuated for large firms, in particular in case of complementary out-contracting.

In sum, we observe a strongly increasing trend of out-contracting R&D independent of industry and firm size. “Distance”, widely interpreted, is an important parameter influencing the (regional) choice of partners. Both contracts between firms and those involving firms and research institutions are very important. Whereas the first type of partnership probably indicates a high potential for a two-way co-operation, the second one underlines the importance of an optimal (policy) design of science-industry relationships.

Table 2: Motives for R&D out-contracting by industry and firm size, 1997/99

(Share of firms for which a certain contracting strategy is highly important (multiple answers possible))

	Substitution			Complementarity		
	Efficiency-oriented	Knowledge-oriented	All	Efficiency-oriented	Knowledge-oriented	All
<i>Industry</i>						
Chemicals/Pharma	10,3	34,5	34,5	20,7	51,7	58,6
Plastics	7,7	46,2	46,2	30,8	61,5	61,5
Machinery	9,8	35,4	39,0	26,8	54,9	61,0
Electrical machinery	25,0	55,0	65,0	40,0	60,0	75,0
Electronics/Instruments	9,6	36,5	38,5	32,7	59,6	71,2
Banking/Insurance	10,5	31,6	36,8	31,6	73,7	73,4
R&D-/ICT services	16,7	50,0	50,0	33,3	83,3	83,3
Business services	19,0	33,3	38,1	38,1	23,8	42,9
<i>Firm size</i>						
6-19	14,9	40,4	40,3	34,0	38,3	44,3
20-49	18,5	46,2	42,3	27,7	47,7	50,7
50-99	11,3	40,8	41,3	28,2	47,9	48,8
100-199	19,1	44,9	46,8	34,8	53,9	61,7
200-499	8,1	37,4	40,2	22,2	57,6	61,8
500-999	7,3	24,4	26,8	31,7	75,6	82,3
> 999	7,1	28,6	27,3	35,7	64,3	60,1
Total	12,9	39,5	40,9	29,7	54,0	59,1

Source: Arvanitis et al. (2001a)

2.3 R&D co-operation

In 1997/99 about every third R&D performing firm co-operated with other firms or with research institutions (data from the 1999 Innovation survey, grossed up to census data). R&D co-operations have become a core element of National Innovations Systems. In what follows, the main features of

the pattern of R&D co-operation are given; a more detailed analysis can be found in Arvanitis et al. (2001a).² At this stage of research, we are not yet able to present results from econometric work dealing, for example, with the explanation of the frequency and type of co-operations, the role of strategic variables such as the motives for co-operations. It might also be sensible to look for specific profiles of co-operating firms by means of cluster analysis of the various dimensions of this phenomenon (form, partner, regional orientation, motives), in order to see, for example, whether there are specific profiles, that are particularly successful in terms of innovativeness or whether they differ by firm size. This type of questions will be at the core of future work.³

R&D co-operations can take different forms. We distinguish five forms ranging from informal technology-related information exchange as the loosest form of engagement up to equity-based joint ventures with a majority stake as the tightest one. The most frequent forms of co-operations (multiple answers) are contract-based agreements to execute common research projects, and, not surprisingly, informal information exchange (about 60% of firms). Nevertheless, more than 20% of co-operating firms are (also) engaged in equity-based co-operations (majority or minority stakes).

We distinguished eight types of partners which are grouped in three categories, that is a) vertical co-operations (co-operation partners in this case are: users, suppliers of materials/intermediate goods and services, suppliers of investment goods, other partners like consultants or firms of the same enterprise group), b) horizontal co-operation (competitors), and c) co-operation with research institutions (universities/polytechnics, other public or private research institutes). Vertical co-operation is the most frequent type of co-operation (90% of firms), followed by science-related partners (62%) and horizontal partnerships (42%). Differences between sectors/industries and size classes with respect to this pattern are quite small; services firms are more often engaged in horizontal co-operations, and the manufacturing sector as well as large firms are, compared to the business sector as a whole, somewhat overrepresented in science-oriented relationships.

Firms co-operate most frequently with Swiss partners (44% of all partnerships; multiple answers rebased to 100%). However, partners from other regions are also very important, in the first place institutions located in the EU (31%), but, to a lesser extent, also partners from overseas (USA 14%, Japan 5%). Looking at the structure of regional partnerships by type of partner, we find no differences between the various regions with respect to vertical co-operation. Horizontal co-operations are particularly frequent in co-operations with Swiss and EU partners, whereas US partners take a prominent position in science-oriented relationships. The size-dependence of the three types of partnerships is weak; only in case of science-related co-operations we find that large firms are overrepresented. There is also a positive relationship between firm size and the distance of the partner (region); in particular, partners from overseas are not easily accessible for smaller firms. From the results for R&D co-operation by type of partner and its regional orientation we conclude a) that

² A comparison of the pattern of R&D co-operation in 1997/99 with those of 1991/93 and 1994/96 is not presented because there are some methodological problems to be solved to ensure comparability.

³ For an econometric analysis of R&D co-operation based on data collected in the course of the Swiss Innovation Survey 1993, see Lenz (1998).

distance matters and b) that world-wide orientation of partnership is characteristic for the Swiss economy, even for SME's. These results reflect the small size of the country, but also its tradition of outward-looking economic activity. Nevertheless, there are some specific features in case of SME's, that is its underrepresentation in science-related co-operations and its smaller geographic radius. These characteristics may be a rationale for supporting SME's through public policy or measures taken by industry associations (e.g. information, support for co-operative research).

Information about the motives for engaging in R&D co-operations allow some insight into the importance of specific R&D strategies. To this end, table 3 shows the importance of seven categories of motives differentiated by type of co-operation. The motive "pooling together complementary knowledge" and "access to specific knowledge" which, together with "building know-how in new fields of technologies", aim at an enhancement of firms' knowledge base. This category of motives is clearly the most important one, whereas the "classical" instruments of internalising the benefits of new knowledge (risk and cost sharing) are not very relevant. This is also true for the motive of profiting from public support, which is not surprising, since technology policy in Switzerland is rather "low key" (see Section 1). The differences between firm size classes are small for each of the seven motives we distinguish. In sum, we find that R&D co-operation is overwhelmingly related to a strategy of enhancing a firm's knowledge base, to some extent, we presume, in the course of specialisation of R&D resources on core competencies. The three categories of partners differ somewhat with respect to the role played by the various motives. Vertical co-operations show a patterns which is very similar to the average reflecting the high frequency of this type of co-operation. In case of horizontal co-operations, "speeding-up R&D projects" and "access to specific technologies" are less important than on average, probably because these two motives affect sensitive parameters of (horizontal) innovation competition. For science/industry partnerships, except for the first two motives which are primarily related to market transactions, all motives are more important than in case of the two other categories of co-operation. Obviously, this type of partnership is compatible with a broad array of objectives; in other words, universities and other research institutions are seen as particularly well suited partners to contribute to the enhancement of the firm's knowledge base. This result underlines the importance of an optimal design of the relationship between science and private business. It is thus not surprising that "profiting from public support" is a quite important motive for R&D co-operation with science institutions.

As already mentioned, R&D co-operation is of growing importance; however, is it also successful? To answer this question, in many cases, measures of economic performance are used to investigate whether performance is higher in case of firms co-operating in R&D compared to those exclusively relying on internal R&D. However, since R&D co-operation is only one, and certainly not the most important factor determining economic performance, it is may be more sensible to look at some "intermediate goal variable" that is directly linked to R&D co-operation. In this vein, we collected

Table 3: Motives for R&D co-operation by partner type, 1997/99
 (Share of firms for which a specific motive is highly important; multiple answers possible)

Partner	Motive						
	Risk sharing	Cost sharing	Speeding-up R&D projects	Access to specific technology	Pooling together complementary knowledge	Building of know-how in new technology fields	Profit from public support
Vertical co-operation	19,7	26,9	51,7	61,2	60,9	41,2	11,6
Horizontal co-operation	17,6	28,2	39,7	55,7	60,3	36,6	10,7
Co-operation with research institutions	21,4	27,9	54,7	68,7	66,2	52,2	18,9
Total	18,4	26,8	48,3	59,7	60,3	41,3	12,9

Source: Arvanitis et al. (2001a)

information on various components of “co-operation output” ranging from science-related outcomes (publications) onto market oriented results in terms of new products ready to be introduced on the market or production techniques ready to be adopted by the firm (see table 4). In general, R&D co-operations, as assessed by the firms themselves, seem to have been very successful, with a (very) high percentage of firms having realised new products or processes ready to be introduced. It looks quite plausible that the share of co-operating firms bringing out patents and publications is lower than that generating new products/processes, since the appropriation strategy of some of the firms are based on other strategies than patenting (i.e. time lead) and some co-operations are, from the very beginning, not science-related (i.e. publications are no objective of co-operation). Against this background, the fact that co-operation led to publications in case of every third firm points to a high science-orientation of R&D co-operation.

This assessment also holds true for smaller firms, since there is no significant relationship between firm size and publication output (at least if only the criterion “publication yes/no” is used). The co-operation output in terms of new products and processes is also not size-dependent. We can find such a relationship only for patents (probably reflecting, in case of small firms, the higher costs of patenting and difficulties to enforce patents if they are challenged by large firms), and, to a lesser extent, for prototypes.

As shown in table 4, vertical co-operations and those with research institutions are more successful than horizontal ones. Science-oriented co-operations are clearly the most “productive” ones in terms of the output criteria used in this comparison. Since this type of partnership, at the same time, is motivated more often than others by “profiting from public support”, we conclude that technology policy fostering public/private R&D partnerships is an effective way of strengthening innovative activity.

Table 4: Output of R&D co-operation by type of partner

(Share of firms with co-operations leading to a specific type of output; multiple answers)

Partner	Publications	Patents	Prototypes/ test versions	New products	New Processes
Vertical co-operation	31,4	47,6	67,9	89,3	54,8
Horizontal co-operation	33,9	36,9	57,7	83,9	59,2
Co-operation with research institutions	44,8	56,7	77,6	90,1	57,7
Total	31,8	46,0	65,7	88,0	54,0

Source: Arvanitis et al. (2001a)

2.4 Conclusion

External R&D strategies based on out-contracting R&D and/or R&D co-operations have become much more important during the last decade. By now, R&D networking is a core element of the Swiss Innovation System. This networking is primarily home-oriented but it also has an international dimension. This holds true, although to a lesser extent, also for SME’s. Nevertheless, distance matters

in choosing co-operation partners. Reducing “distance”, for example, in the framework of European technology policy could help to improving the technological position of SME’s.

Research institutions are important recipients of R&D contracts and a frequent partner in R&D co-operations. Science/industry relationships, for which public support is an important incentive, turned out to be very effective in terms of various output indicators. Therefore, supporting joint R&D projects (in particular in case of SME’s) is a sensible policy measure. Moreover, since SME’s are somewhat underrepresented in this type of partnerships, it is necessary to facilitate their access to research institutions, not only through subsidies but also by measures to improve information flows between these two agents (awareness, information about knowledge potentially useful for SME’s). In this field, private institutions could also play a beneficiary role.

3. Internationalisation of R&D

The internationalisation of economic activity very much increased in the course of the last two decades, as shown by various statistics published by international organisations (OECD, 2001; UNCTAD, 2000 et al.). Until the mid-eighties the driving force has been international trade with foreign direct investment (FDI) increasing about at the same rate as GDP. Afterwards, FDI grew much faster than trade and production; between the mid-eighties and the end of the nineties, FDI increased by about factor 10, compared to factor 4 in case of the trade volume. Although FDI originating from Switzerland did not increase at this pace (what is not surprising given the already large stock of capital held in foreign countries in the base year), the degree of internationalisation, measured by the stock of FDI as a percentage of GDP, is (still) the highest (together with that of the Netherlands) among the developed countries.

This trends refers to investment capital flows. In case of Switzerland, we also dispose of information referring to the number of firms having engaged in international activities. These data collected in the course of the Swiss Internationalisation Survey 1998 (see Arvanitis et al., 2001b) are based on a broader definition of “internationalisation” covering also international activities which do not (necessarily) involve FDI. A firm is defined as being internationalised if it is engaged in foreign countries by one (ore various) of the following activities: distribution, manufacturing, sourcing, R&D and some specific contractual agreements (e.g. franchising or licensing). In these terms, 21% of Swiss firms (employment-weighted) with at least five employees have been internationalised in 1998. In the nineties, this share doubled with even higher growth rates in case of services firms and SME’s (defined as firms with less than 100 employees in Switzerland).

The process of internationalisation is often accompanied by foreign activity in R&D (OECD, 1998, 2001). Switzerland takes a top position also in this respect. Swiss affiliates in the USA perform as much R&D as UK, Canada and Germany which are the most significant investors in that country; taking into account the small size of the Swiss economy, it is by far the top R&D investor in the USA. Besides, more than 40% of patent applications to the European Patent Office owned by Swiss residents are based on foreign research; this share is almost the highest among the OECD countries.

According to data from our Internationalisation Survey, there is no Swiss-based firm performing foreign R&D which, at the same time, did not internationalise other business functions as well (see table 5). This result is consistent with the stages approach to internationalisation hypothesising that this process starts with exporting and reaches its highest stage with foreign R&D activities (see, for example, Johanson and Vahlne, 1977). The table shows that 25% of the firms engaged in (any type of) foreign activities do so also in R&D. This high percentage reflects the high R&D intensity of the Swiss economy as well as the very strong presence at foreign locations in general; this holds also for SME's.

Table 5: Percentage of Swiss firms with international activities by combination of business functions, 1998

Combination of business functions	SME's	Large firms	All firms
Distribution/other activities *	33.2	29.5	31.3
Fabrication/sourcing only	13.0	9.2	11.1
R&D only	0.0	0.0	0.0
Distribution/other and fabrication/sourcing	28.2	31.3	29.8
R&D and distribution/other or R&D and fabrication/sourcing	5.2	3.8	4.5
Distribution/other and fabrication/sourcing and R&D	20.4	26.2	23.3
Total	100	100	100

* Other activities: franchising; licensing, service centres, consulting or management contracts
Source: Arvanitis et. al. (2001b) and Hollenstein (2001)

It is interesting to notice that foreign R&D engagements rely most frequently on full control, probably as a means of appropriating new knowledge as completely as possible (18% of firms performing R&D at foreign locations do so through fully-owned affiliates or R&D laboratories). If full control is not guaranteed, firms prefer the relatively loose form of (purely) contractual engagements (12%), whereas capital-based joint ventures (including minority stakes) are relatively rare (5% of firms).

The build-up of R&D activities abroad has been a cause for concern in Switzerland as well as in other countries (OECD, 1998), because it is feared that the technology base of a country may erode. In the Swiss case, it is pointed to differences between the patent portfolio “produced” in Switzerland and that of Swiss-owned firms (irrespective of the origin of patenting). Based on data for about 40 Swiss multinationals, it is shown that the firm-specific portfolio is oriented stronger towards “new”, fast-growing patent fields than the location-specific portfolio (Hotz and Küchler, 1999). These authors conclude that the internationalisation of R&D substitutes for domestic R&D.

The opposite hypothesis posits that foreign and domestic R&D are complements. It is argued that the internationalisation of R&D is a strategy to get access to technology and knowledge which complements the technology base at home; in other words, it is a means to exploit specialisation advantages in R&D in a similar way as it is the case with other business functions since many years.

To assess the two conflicting hypotheses, we performed a) a descriptive analysis based on information about the motives for foreign R&D stemming from the Internationalisation Survey 1998 (Arvanitis et al., 2001b), and b) two econometric investigations based on firm-level data, the first one (Arvanitis and Hollenstein, 2001) using information of Swiss Innovation Survey 1996, the second one (Hollenstein, 2000) based on the Internationalisation Survey.

Table 6 shows the importance of various motives for undertaking R&D abroad as assessed by the surveyed firms. The motives 3 and 4 are consistent with the complementarity hypothesis, whereas the motives 5 to 7 are in accordance with substitution of foreign for domestic R&D. We argue that the motives 1 and 2 are also related to complementarity, since they stand for the exploitation of foreign R&D potentials which are not available at home (e.g. make use of the proximity to top universities or to highly innovative firms concentrated in a certain region like the Boston area).

Table 6: Motives for performing R&D activities at foreign locations 1998
 (% of internationalised firms assessing a specific motive as important: value 4 or 5 on a 5-point scale; multiple answers)

Motives	%
Proximity to leading universities/research institutions	49.8
Proximity to innovative firms (networks)	56.4
Knowledge transfer to Swiss locations	47.3
Support for fabrication/marketing abroad	40.7
Profit from higher availability of R&D personnel	56.5
Profit from lower R&D costs	39.5
Profit from more intensive promotion of R&D (subsidies, taxes, etc.)	54.6

Source: Arvanitis et. al. (2001a)

If one accepts this interpretation, what can we conclude from table 6? It shows that both categories of motives (1 to 4 vs. 5 to 7) are important, but it is not clear which type of motives are more relevant. Although, there is some hint that the complementary relationship is more important than substitutionality at a more disaggregated level, the descriptive analysis is not able to discriminate between the two hypotheses.

In contrast to the descriptive analysis, the results of the econometric work are unambiguous. Both studies mentioned above clearly support the complementarity hypothesis. Using the OLI paradigm developed by John Dunning (for a recent account of this approach, see Dunning, 2000) we estimated the probability of an R&D-performing firm to do so also at foreign locations. It turned out that firm-specific capabilities (O-advantages) and advantages based on the internalising of market transactions (I-advantages) are the driving forces for going abroad, whereas locational disadvantages (L) of Switzerland, for example, with respect to the availability of R&D personnel, the costs of R&D, the

deficiency of R&D-related subsidies and tax relief or resistance to new technologies do not have any impact.

R&D performed in Switzerland by affiliates of foreign companies is another important aspect of the internationalisation in this field. There is some information on such inward investments which can easily be extracted from the Innovation Surveys of 1996 and 1999. Both data sets show that the share of R&D performing manufacturing firms is higher in case of foreign affiliates than for Swiss-owned firms (1999: 72% vs. 60%). Similarly, the intensity of R&D activities of foreign affiliates is higher than that of domestic firms. The same holds true only for 3 out of 11 OECD countries for which data are available, that is Ireland, Australia and the United Kingdom; in the USA and in Finland, the R&D intensity of these two types of firms is about the same (OECD, 1998). Since the R&D intensity of the Swiss economy is high, this result reflects the attractiveness of Switzerland as a location for R&D activities. The presence of R&D performing foreign-owned affiliates is advantageous for the Swiss economy for their direct contribution to R&D capacity (financing additional R&D) and to human resources as well as for the positive spillover effects resulting from their activity.

In sum, we conclude that R&D activities of Swiss firms in foreign countries are beneficial to the Swiss economy. They are an instrument to benefit from specific technological knowledge and human capital abroad complementing domestic capabilities. For a small country like Switzerland aiming at defending a top position on the world-wide “welfare ladder”, this type of technological specialisation is indispensable. In addition, the Swiss economy gains from intensive R&D performed in Switzerland by affiliates of foreign companies. Stating that Swiss R&D in foreign countries is complementary to domestic R&D and, at the same time, that Switzerland benefits from inward R&D investment is no contradiction; it only reflects the advantages of international specialisation for both parties.

The implications of these results for policy are straightforward. Measures to make Switzerland an even more attractive location for R&D are welcome. Improving and enhancing the stock of human capital, securing the quality of university research (and its long-term orientation) and optimising science/industry relationships are probably the most effective ways to achieve this objective. Such measures help to attract R&D-intensive activities of foreign firms and improve the preconditions for exploiting the potential of R&D abroad.

4. Financing R&D-driven innovations

How do firms finance innovation activities, particularly R&D projects? R&D projects are above-average risky as compared to more conventional investment projects (e.g. new equipment, new buildings, etc.). Given the information asymmetry between (external) investors and managers with respect to risks and benefits of R&D projects (an important form of capital market imperfection), one should expect investors to be reluctant towards financing risky projects, thus demanding higher-than-average interest for funds lent for this purpose. This means that firms would find it in general cheaper to finance risky projects through internal funds than through loans, whereas external finance would be used to finance recurrent investments (‘pecking order’ theory; see e.g. Myers and Majluf, 1984).

Other things kept constant, given the expected higher risk of bankruptcy for small firms (as compared to large ones) it seems reasonable for investors to discriminate against small (and young) firms with respect to lending conditions, thus rendering the access to external funds more difficult for this category of enterprises. On the other hand, small and young firms may not be able to acquire adequate internal funds to finance an innovation project of a certain magnitude just because of their small size. In sum, there may exist a clear disadvantage of small and young firms with respect to R&D financing, which leads to a suboptimal level of innovation investment for this group of firms and, consequently, often to policy correctives.⁴

In a recent study we identified such financing impediments of innovation activity of small and young firms and investigated their determinants (Arvanitis and Marmet 2002). In the following we present selected results of this research based on data collected in an addendum to the standard questionnaire of the Swiss Innovation Survey 1999 especially for the above-mentioned study. In a second step we discuss, whether the firms' assessments of financing impediments did really exercise an influence on their choice of the financing mix. Third, we present the results with respect to the factors explaining the probability of a firm to be confronted with a certain category of financial impediments.

Table 7 shows the importance of seventeen instruments used to finance innovative activity and R&D which are classified in three categories, i.e. internal funding and external funding either through equity or through loans. In addition, public assistance is used as a special category of financing innovative activity. It turns out that internal funding is by far the most frequently used instrument (particularly profits). Among several types of external funding, loans (from banks in the first place) are more important than equity. Venture capital seems to be relevant only in few cases: surprisingly, firms in the age range of 10 to 14 and 15 to 19 years use venture capital more often than the very young firms. The mode of financing innovations does not much vary across firm size and age classes; only for some elements of internal funding (profits, depreciations) we find that large firms use them more often than small ones; these, however, are the most important instruments to finance innovative activities.

As already mentioned, we expect that R&D projects and far-reaching (product) innovations are financed to a larger extent by internal funds than low-profile innovations. In addition, with respect to external funding, equity financing should be more frequent in case of more risky innovations than loans. As can be seen from table 7, these expectations are mostly confirmed ;see, for example, the role of financing by profits in case of R&D performing firms vs. those without R&D activities (col. 2 vs. 1), or high-intensity vs. low-intensity product innovations (col. 4 vs. 3). Quite surprisingly, we do not find that venture capital is primarily used to finance high-risk projects. This holds, however, in case of projects (co-)financed by public funds which corresponds to the intentions of policy makers.

⁴ For a survey of theoretical as well as empirical literature on this subject see Harris and Raviv (1991), Goodacre and Tonks (1995) and Myers (2001).

Table 7: Financing R&D and innovative activity by financial instrument

(share of firms assessing the importance of a specific financial instrument as (highly) important; value 4 or 5 on a five-point scale; multiple answers possible)

	R&D activities		Innovation intensity				All innovating firms
	No	Yes	Product		Process		
			Low	High	Low	High	
<i>Internal funding</i>							
Profits	47.7	60.3	50.7	61.2	54.0	57.9	55.9
Depreciation	24.2	25.9	23.6	26.9	23.9	26.6	25.3
Reserves	13.8	16.8	14.1	17.3	13.7	17.7	15.7
Selling-off of assets	2.4	2.8	2.3	3.1	2.3	3.2	2.7
<i>External funding</i>							
<i>Equity</i>							
Increase of equity	5.1	8.5	7.1	7.6	7.9	6.8	7.4
Emission of new equity	1.5	3.5	2.4	3.2	3.4	2.2	2.8
Venture Capital	1.6	1.5	1.7	1.5	1.8	1.4	1.6
<i>Loans, etc.</i>							
Loans from affiliated firms	3.9	10.9	6.8	10.4	6.6	10.6	8.6
Loans from banks	14.4	14.0	12.3	16.0	13.1	15.2	14.1
Loans from suppliers	2.6	1.8	2.2	1.9	2.0	2.2	2.1
Loans from users	0.8	1.2	0.9	1.2	0.6	1.5	1.0
Leasing	7.1	6.6	6.3	7.3	6.6	7.0	6.8
Public support	1.7	3.8	2.4	3.8	3.2	3.1	3.1

Source: Arvantis und Marmet (2002)

The questionnaire also yielded information with respect to 17 obstacles to financing innovative activity which are classified in the same way into three categories as the financial instruments (impediments with respect to internal funding and external funding through equity or loans). Table 8 shows that 24% of firms, according to their assessment, are impeded by at least one of the seventeen potential obstacles with much variation across sectors. However, financial obstacles are distinctly less important for large than for small firms; in this respect, one can clearly distinguish three size categories (below 100, between 100 and 500, more than 500 employees). No size-dependence is detected across different categories of firm age.

We also find differences with respect to the importance of obstacles if these are differentiated by the three categories mentioned above. Problems with external funding (loans: 63% of firms; equity: 61%)

are more serious than those related to internal funding (51%), which is the most prominent form of financing innovative activity. This more disaggregated analysis shows also that the size-dependence of financial obstacles is primarily due to larger problems of small firms with respect to bank loans.

Table 8: Share of firms with significant problems to finance innovations 1997/99 by sector, firm size and firm age (%)

<i>Total</i>	24.0
<i>Sector</i>	
Manufacturing	26.0
Construction	26.7
Services	22.0
<i>Firm size (employment)</i>	
6-19	24.8
20-49	23.7
50-99	30.7
100-199	13.9
200-499	15.3
500-999	3.8
1000 and more	2.3
<i>Firm age (years)</i>	
Up to 5	22.4
5-9	21.4
10-14	42.9
15-19	18.8
20 and more	23.3

Source: Arvanitis and Marmet (2002)

Did impediments (measured by firms' assessments) really hinder firms from choosing the one or other form of financing? To answer this question we estimated probit models regressing measures of the extent of using a particular financing modus against, among other things, variables measuring the importance of the impediments of this type of financing. We found that the impediments of internal financing (particularly profits) have been really a restricting factor, reducing considerably the extent of use of this type of financing (negative sign of the corresponding variable). In case of external financing positive signs of the corresponding variable showed that the assessed impediments did not virtually restrict this kind of financing, but rather reflect a high sensibility of firms with respect to financing problems.

Even if financing restrictions are binding, can we validly conclude that e.g. small and young firms have been discriminated by investors? Experiencing financial restrictions, either with respect to internal or external financing, may reflect for a considerable number of firms only a low performance (profitability) level of these firms. In this case, financial difficulties are not structural problems requiring policy intervention. To investigate this question, we estimated a probit model regressing measures of different financial obstacles (internal, external financing, etc.) on firm size, firm age, a set of performance indicators, a measure of technological and/or commercial risk as well as some control variables (industry affiliation, legal status). If structural problems are the reason for a firm to experience financial problems, then the dummies for firm size and/or firm age should explain most of the variance (the smaller and/or younger a firm, the higher the probability for this firm to be confronted with financial restrictions). On the contrary, if these dummies are not statistically significant and/or the measures of performance, risk, etc. explain most of the variance of the regression, we can conclude that the financial restrictions experienced by the firms are real structural problems to be traced back to capital market imperfections.

Our empirical results are mixed. We find that firm size, indeed, seems to be a structural problem particularly in case of external financing by loans (for firms with less than 500 employees), to a lesser extent also in case of internal (for firms with less than 100 employees) and equity funding (for firms with less than 50 employees). Firms with less than 50 (or 100) employees are also structurally impeded in getting access to venture capital. In contrast to firm size, we do not find any impact of firm age, even if firm size is excluded from the regressions. This results presumably reflects the skewed distribution of the sample by age (82% of firms are at least 20 years old). Hence, we are not able to assess whether young firms are structurally discriminated by capital markets. Further, we find that, in general, low-performing firms have more problems in financing innovations. We conclude therefore, that, although there are structural obstacles to financing innovations, these also reflect to some extent general weaknesses of the firms which are no reason for considering corrective policy measures.

In sum, innovative activities are financed primarily through internal funds; there are impediments for this type of financing which seem to restrict the use of internal financing. Obstacles to either internal or of external financing of innovations tend to be to some extent structural especially with respect to small firms, thus reflecting capital market imperfections.

5. Conclusions

The policy conclusions we can draw from the analysis of the pattern of R&D activity in Switzerland in this paper are straightforward. Moreover, it is interesting to notice that the policy implications of our analysis of R&D networking, the internationalisation of R&D and the financing R&D-driven innovations are similar in several respects.

There are mainly six points we want to stress: a) supporting high-quality research and strengthening the human capital base is probably the most important way of enhancing the innovation capacity of the Swiss economy; b) optimisation of science/industry relationships would strongly contribute to the

effectiveness of knowledge production and knowledge diffusion; c) there is some evidence for capital market imperfections which should be corrected by R&D subsidies or tax reliefs; d) geographical distance works as a barrier to exploiting knowledge potentials (e.g. lack of information on foreign knowledge sources); e) there is a need to design specific policy measures oriented towards SME's (which play an even more prominent role in case of Switzerland than in many other countries), since these firms are most hit by the problems addressed under the headings b), c) and d); finally, although, and in the first place, public policy is required (from the regional to the European level), there is also scope for non-governmental action (e.g. industry associations contributing to the overcoming of information problems).

In future work, we shall deepen our analysis of R&D networking and of the internationalisation of R&D. In the first field of research, we aim at the formulation and simultaneous estimation of a R&D out-contracting equation and a R&D co-operation equation.. In a further step, we shall try to extract from the data specific modes of co-operations, for example, by performing a cluster analysis of firms with respect to a set of co-operation parameters (type of partner, motives, etc), and describe them in terms of some structural characteristics of firms (size, industry affiliation, export propensity, etc.) and performance measures (co-operation output, innovation performance, productivity); based on such an analysis, one could propose policy measures which take into account the heterogeneity of co-operation patterns. Secondly, we plan a more comprehensive analysis of the factors determining the internationalisation of R&D and its impact on the domestic economy. To this end, we shall exploit more intensively the firm data we dispose of, for example, with respect to the motives for internationalisation of R&D. In addition, it is planned to collect more data in this field by means of the Swiss Innovation Survey 2002. In methodological terms, most research will be based on the econometric analysis of firm data.

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