RESEARCH AND INNOVATION IN SWITZERLAND 2016

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this report. Sincere thanks are due to all of them.

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Preface

Whether you look at the EU Commission's Innovation Union Scoreboard, the World Economic Forum's Global Competitiveness Index or data published by the World Intellectual Property Organization, Switzerland is always to be found among the top-ranked countries. What is behind Switzerland's success as an innovative nation?

The fact that the public sector does not engage in innovation or industry politics in the narrower sense is doubtless the real secret of Switzerland's success. Innovation happens in the private sector. Creative minds understand how to transform ideas and discoveries into products and services. Innovative firms identify market potential, develop markets and create jobs and prospects for people.

The federal government is committed to providing a conducive environment for innovation actors. This includes Switzerland's flexible first-class education system with its strong dual-track vocational model and excellent, internationally renowned universities. But it also includes outstanding research institutions and successful instruments of promotion. Besides education and research, other framework conditions also play a key role, such as an open labour market, modern infrastructures, an attractive tax system as well as the level of safety and quality of life that Switzerland offers.

The present report endeavours to fathom the secret of innovative Switzerland's success. It marks the first-ever detailed investigation into research and innovation in Switzerland. It identifies the diverse parameters, describes the system, explains interactions, provides facts and figures, makes comparisons with other countries and examines selected topics. The report also discusses what is required to ensure that Switzerland continues to be seen as an innovative nation in future.

I would like to thank everyone who contributed to the success of this publication. My particular thanks are due to the group of experts, the advisory groups, the authors of the investigations and studies as well as the people involved from the State Secretariat for Education, Research and Innovation.

I wish you a stimulating read. I am convinced that the report will give rise to discussions and reflections. Research and innovation merit in-depth exploration. They are essential to competitiveness, work and the well-being of the individual and society as a whole. Let us strive jointly to ensure that tomorrow, too, a largely autonomous scientific and research community and an entrepreneurially independent business sector can develop their strengths to the best of their capabilities.

President of the Swiss Confederation
Head of the Federal Department of Economic Affairs, Education and Research

Foreword by the group of experts

Research and innovation are decisive for a country's social and economic development. Success is derived from the complex interplay of a wide variety of different factors. The specifics of higher education and research policy, the degree of entrepreneurial freedom and the level of international interconnectedness are essential components. The cultural and historic background, individual and social values and the nature of institutional dialogue and collaboration are likewise significant.

The current report is the first-ever endeavour to present a comprehensive picture of research and innovation in Switzerland, describe systemic interactions and identify unique characteristics in an international context and comparison. In our capacity as group of experts, we had an opportunity to oversee the report from the conception stage to editorial production.

The findings of the various analyses conducted for the purposes of the present report show that the Swiss research and innovation system is highly efficient both from a national perspective and when compared with other countries. Nevertheless, the research and innovation environment is in a state of constant change. In this context, we would like to briefly outline a number of the key elements behind Switzerland's research and innovation success. We also wish to identify six areas likely to pose challenges in future.

Factors behind Switzerland's success

A globally competitive business sector

The innovative performance of small and medium-sized enterprises (SMEs) in Switzerland is very high. This is especially evident when comparing Switzerland with the other countries examined in this report. The success of Switzerland's SMEs is attributable to the diversity and density of local knowledge and business networks in specific specialist areas and to the attractive framework conditions created by policymakers. However, the challenges encountered by SMEs include the difficulty in obtaining funding for research and innovation as well as in securing the transfer of knowledge from publicly financed research – problems familiar to all OECD countries.

Research and development (R&D) is financed and carried out primarily by large corporations. Those operating in the international arena efficiently combine their global strategies – which also include substantial R&D spending outside Switzerland – with considerable efforts to strengthen local science and business networks. This is seen clearly in the different positive impacts (e.g. knowledge and technology transfer, work and training places) being achieved by large internationally focused corporations at local level and which feed through into other firms, universities, vocational training providers and the job market.

Although not readily apparent from the statistics, an increase in the number of new innovative firms has been witnessed in the past few years. This dynamism is driven largely by the intensity of entrepreneurial activities of publicly funded research institutions and university hospitals.

High-quality publicly funded education and research institutions

Switzerland boasts an excellent education system. Its dual-track vocational model is a unique system that closely coordinates training curriculums with the needs of the labour market. Practical vocational programmes and university syllabuses are designed to provide a base of qualified workers and managers with the training and aggregate skill-mix to meet the business community's varied requirements.

The university sector successfully fulfils its triple mission to provide teaching, research and services. Each type of university (universities, universities of applied sciences, and universities of teacher education) weights the individual elements in accordance with its profile, thus producing an outstanding overall result. Universities in Switzerland are well positioned in an international comparison, with the majority of students enrolled at an institution among the top 200 of the Shanghai rankings.

Switzerland relies on a lean support infrastructure to promote research and innovation. While the Swiss National Science Foundation focuses chiefly on basic research, the Commission for Technology and Innovation funds applied research. All funding measures are driven by a bottom-up approach, freedom to choose the research topics and a quest for excellence.

Efficient knowledge and technology transfer (KTT)

KTT is efficient but there is still potential for improvement. As is the case in other countries, a strong correlation between firm size and the degree of KTT is also apparent in Switzerland.

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Generally speaking, the strengths of the Swiss research and innovation system can be summarised as follows:
- Excellence of human capital: This is encountered at all levels of qualification and along the entire value chain.
- Diversity of local networks: Although Switzerland has no actual "cluster policy" at national level, it boasts a wide variety of strong local and regional knowledge and business networks. They are sufficiently densely connected and provide enough institutional variety to ensure growth and renewal.
- Quality of framework conditions which is satisfactory overall.

Challenges facing Switzerland

These outstanding achievements are attributable to the quality of the institutions and to framework conditions as well as to historic circumstances in Switzerland during recent decades. Given the rapid pace of social and economic developments, the Swiss research and innovation system needs to be adaptable and flexible. From our viewpoint, six areas merit particular attention; areas likely to face the kind of urgent challenges whose solution will hinge on Switzerland's capability to adapt and be flexible:

- Talent recruitment: Switzerland increasingly relies on foreign talents to meet the growing demand for highly qualified employees in the research sector, at universities, in the engineering industry and for knowledge-intensive services. In itself, this heavy dependence on other countries does not pose a problem with regard to Switzerland's innovative capacity and could even be seen as an enrichment. Nevertheless, the situation could become critical if Switzerland's appeal were to diminish or young foreign graduates were to opt for a career abroad after completing their studies in Switzerland. Given the shortage of highly skilled employees, Switzerland must seek to retain and strengthen its appeal in order to keep foreign talents in Switzerland and attract new ones. On the other hand, free capacity among Switzerland's working population should also be tapped into. This applies in particular to women, who continue to make up a very low percentage of employees in research. The capacity of universities and the Federal Institutes of Technology to train these skilled workers and the capability of universities of applied sciences to provide the necessary courses without redundant academic content represent substantial challenges.

- International openness: A high level of mobility on the part of knowledge actors (students, researchers, lecturers and other specialist research and innovation personnel) in addition to strong national and international collaborations are key to achieving excellence in research and innovation. This is reinforced by international developments such as European integration and, in particular, European Union (EU) research and innovation activities, notably Horizon 2020 in the field of research and Erasmus+ in the field of education. The challenge here is for Switzerland to maintain its spirit of international openness, especially in terms of shaping its relationship with the EU – particularly as regards implementation of the mass immigration initiative. The objective is to preserve, as far as possible, the free movement of skilled workers, students, scientific personnel and professors. Every effort must be made to ensure that Switzerland's research and innovation sector can continue to recruit top international talents and that access to international programmes, organisations, testing facilities and laboratories remains open to Swiss research and innovation actors.

- Attractive domestic framework conditions for companies operating at the international level: The research and innovation activities of large internationally oriented corporations create huge advantages for their respective country locations. This has triggered fierce competition at international level among locations – including Switzerland – keen to attract research and innovation activities. Swiss firms invest more on R&D abroad than they do in Switzerland, which is uncommon compared to other countries. If Switzerland is to benefit from the internationalisation of operational research and innovation activities, it is important to keep existing research and innovation activities in Switzerland, as well as promote new ones and attract more from abroad. This calls for favourable framework conditions in tune with current developments.

- Coordination within Switzerland's university sector: Despite the progress achieved in recent years, there is still scope for improving higher education policy coordination and cooperation. A case in point is the need to effectively coordinate ongoing endeavours to upgrade the quality and performance of the public education and research infrastructure, including funding. Laboratory equipment, instruments, test facilities, measuring systems, etc. must be regularly brought into line with advances in science and technology. With resources becoming increasingly scarce and specifications extremely rigorous, efforts must be directed at achieving critical mass or defining focus areas as well as sharing tasks (e.g. in especially cost-intensive areas such as high-performance medicine) and building up international collaborations. All of these coordination issues are on the current agenda of the Swiss Conference of Higher Education Institutions, which commenced activities in 2015.

- Skill-mix: Shifts in the individual skills needed to play a productive role in society pose a challenge in terms of how to structure initial education and continuing education and training, as underlined by the shortage of MINT (mathematics, information sciences, natural sciences, and technology) professionals in the business sector. This leads to structural challenges (e.g. in respect of the balance between vocational training providers and universities of applied sciences on the one hand and secondary schools and universities on the other) concerning the role and significance of practical training or issues surrounding the flexibility between vocational and academic educational routes.

- Start-ups: Switzerland's outstanding achievements as described in this report are the result of the capabilities created by a three-pronged combination of SMEs, large international corporations and universities. Without doubt, this amalgam of strengths is no longer sufficient to meet today's needs, and a new "triumvirate" is called for, comprising universities, start-ups and venture capital. The question arises as to what achievements are to be expected from this new model and how they can be enhanced to ensure that Switzerland keeps its place at the forefront of R&D and innovation.

Switzerland has numerous strengths that it can rely on to address these challenges. Its strong trump cards are a largely decentralised system, the leeway enjoyed by business actors and their ability to find solutions in concert, the flexibility of the labour market and the autonomy of publicly funded research and innovation institutions. A key role in overcoming these challenges will also rest with society as a whole, whose support of excellent research and innovation and the concrete outcomes is vital for success.

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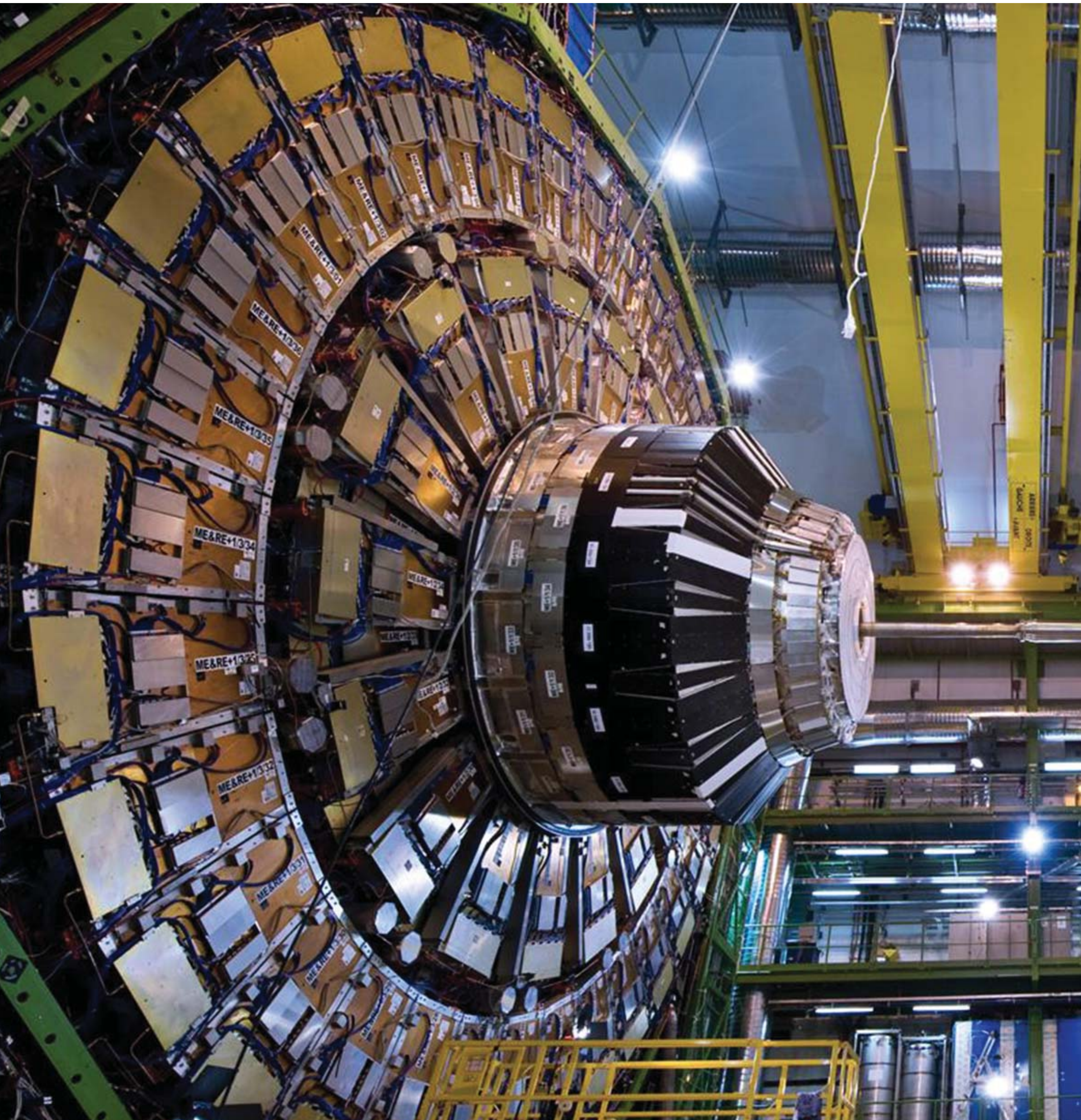
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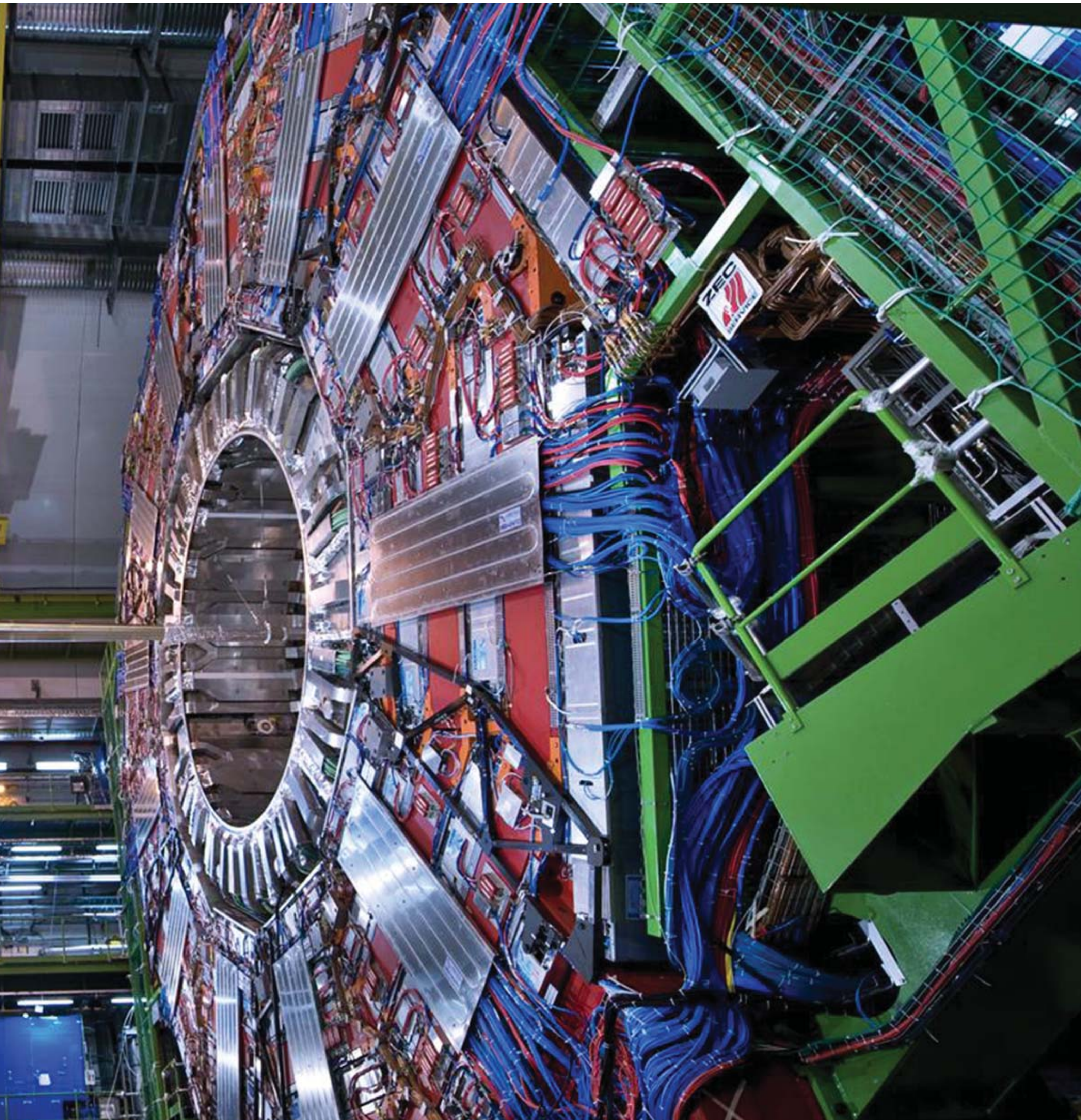
MANAGEMENT SUMMARY



CERN, situated on the outskirts of Geneva, is the largest laboratory in the world in the field of particle physics. Switzerland is a founder member and the host country of CERN. CERN is home to basic research in physics. Thanks to large particle accelerators – and in particular the largest of all, the Large Hadron Collider – the organisation of and interaction between elementary particles can be investigated. Scientists here are seeking answers to questions that have remained unresolved to this day, such as the origin of mass or the state of the universe immediately after the Big Bang. Photo: CERN

Part A: The Swiss research and innovation system

Part A provides an overview of the Swiss research and innovation system. It describes the general context, actors and funding of Swiss research and innovation, the key national and international instruments and measures for promoting research and innovation, as well as the federal government's general stance.

The sharing of tasks between the private and the public sector in the area of research and innovation is based on two fundamental pillars of Swiss politics: subsidiarity and a liberal economic system. The private sector therefore plays a significant role. Generally speaking, research and innovation operate in a complex system in which the respective responsibilities are partly interwoven.

General context

The bottom-up approach is one of the principles of public research and innovation promotion: firms or individual research teams take the initiative for research and innovation activities and themselves assume the responsibilities and risks. Key to the promotion system is project funding by the Swiss National Science Foundation (SNSF) and the Commission for Technology and Innovation (CTI). They allocate funding on a competitive basis and make their assessments on the basis of excellence. By international standards, Switzerland is reluctant to dictate, from the top down, the areas and programmes that are eligible for funding. Moreover, funding is not, as a rule, granted directly to companies.

Further hallmarks include the flexibility and adaptability of the actors in the business and higher education sectors, the rapid diffusion of innovations via science and business networks, as well as efforts to maintain Switzerland's considerable attractiveness as an education and research centre for talents and qualified professionals from all over the world.

The state promotes an education system that is founded on a complementary mix of vocational and academic training options. At the same time, the Swiss education system is also highly flexible both within and between the vocational and academic teaching sectors. These elements facilitate the training of well-qualified specialists and equip them to work along the entire value chain, a factor that is instrumental to Switzerland's research and innovation achievements.

Switzerland has a competitive market economy driven by private initiative with – by international standards – relatively little government regulation and intervention. The various markets for labour, capital, goods and services are largely competition-driven; thanks to multilateral and bilateral agreements, access to international markets is free and open. This affords the business sector a high degree of flexibility and mobility and enables it to rapidly absorb change. Switzerland also has clear regulations in place to protect intellectual property. The fiscal environment is relatively attractive, with no particular preferential treatment for research and innovation. Framework conditions to launch a business in Switzerland are at the top end of the middle range compared with other countries.

Responsibilities

Public research and innovation promotion essentially falls within the domain of the federal government. The scope and organization of the federal government's research and innovation promotion tasks are framed by the Federal Act on the Promotion of Research and Innovation (RIPA). It covers national as well as international promotion tasks undertaken by the federal government. Furthermore, it defines the tasks, procedures and responsibilities of the promotion bodies.

In accordance with the Federal Act on Funding and Coordination of the Swiss Higher Education Sector (HEdA), the federal government – working in concert with the cantons – ensures the quality and competitiveness of Switzerland's entire higher education sector, which, on the strength of its commitment to research, makes major contributions to downstream innovation activities.

The key actors and institutions responsible for research and innovation promotion at federal level are the Federal Department of Economic Affairs, Education and Research (EAER), the State Secretariat for Education, Research and Innovation (SERI), the State Secretariat for Economic Affairs (SECO), as well as the Board of the Federal Institutes of Technology (ETH Board), representing the institutions of the ETH Domain. Other departments such as the Federal Department of the Environment, Transport, Energy and Communications (DETEC) are also directly or indirectly engaged in research and innovation promotion. The Swiss Science and Innovation Council (SSIC) is the advisory body to the Federal Council for all research and innovation policy issues.

As responsible bodies for the universities, universities of applied sciences (UAS) and universities of teacher education (UTE), the cantons are also involved in research and innovation promotion. The universities, UAS and UTE themselves also number among the research and innovation actors. They enjoy a considerable amount of autonomy and are self-organising. Cities and municipalities play a role in innovation promotion, for instance by building technology and innovation parks.

Funding and performing research and innovation

The business community and the state, as well as national and international programmes and organisations, not only fund but also conduct research and development (R&D).[1] The private sector accounts for the lion's share, funding and performing some two thirds of R&D activities. The state (federal government and cantons) focuses mainly on funding. Responsibility for conducting R&D projects lies primarily with the higher education institutions.

The main private sector actors comprise a few large research-heavy corporations and particularly innovative small and medium-sized enterprises (SMEs) engaged chiefly in development.

Basic research is essentially performed within the ETH Domain, at the ten cantonal universities and in the private sector by a small number of large corporations. UAS and vocational trainers put together the initial education and continuing education and training programmes to supply the labour market and, above all, the SME-dominated technology-oriented business sector with a suitably qualified workforce. Drawing on applied research and development (aR&D), as well as on diverse collaborations with firms, UAS help to increase the business sector's competitive leverage. What is more, various non-university research establishments also play a part in creating added scientific value in their specialist areas.

The Federal Administration relies on R&D results to fulfil its tasks and itself conducts or, more commonly, commissions scientific research (Federal Government Research).

In the course of time, a wide variety of forms of collaboration between the different actors and institutions have proven beneficial in terms of R&D and the innovation process. Technology transfer offices with differing institutional structures have been set up to promote and support knowledge and technology transfer (KTT).

Promotion of research and innovation

The federal government promotes research and innovation primarily through the two national promotion bodies SNSF and CTI. The SNSF, Switzerland's foremost institution for the promotion of scientific research, also devotes particular attention to the advancement of young scientists. The CTI is the federal government's promotion agency for knowledge-based innovation. It works toward KTT between public research and the business sector.

The cantons – acting either alone or in multi-cantonal groups, with or without federal funding –encourage the creation of new businesses and support regional networks.
Non-profit foundations also play a significant role in the promotion of research and innovation in Switzerland.

[1] Numerous official statistics refer only to R&E and not to research and innovation which is why certain indicators presented here refer to R&D.

International collaboration

Cross-border collaborations give Swiss actors access to key international networks and produce scientific, technological and economic benefits for Switzerland.

Switzerland participates chiefly in the Research Framework Programmes (FPs) and in the education and mobility programmes of the EU. Currently underway in the 2014 to 2020 period are Horizon 2020 – The EU Framework Programme for Research and Innovation (8th programme generation) and Erasmus+, the EU programme for education, training and youth. By participating in FPs, Switzerland also gains access to numerous other initiatives, projects and programmes co-financed by these FPs. The adoption, in 2014, of the "Stop mass immigration" popular initiative resulted in Switzerland being relegated from full "associated country" status with membership rights to "partial association" (Horizon 2020) and "third country" (Erasmus+) status. It remains the declared aim of the federal government to re-attain full associated country status for Horizon 2020 and Erasmus+ at the earliest possible date.

By virtue of its participation (founded on international agreements) in multilateral research organisations and infrastructures, the federal government also supports efforts to integrate Swiss research into the international collaborative community. International collaboration is sought where national critical mass is insufficient to provide the necessary infrastructure, e.g. in the areas of astronomy, high-energy and particle physics, the material sciences or nuclear fusion.

The federal government also has bilateral programmes in place for the funding of research collaboration with priority countries outside Europe and can avail itself of the global ERI Network of Science Consulates and Science and Technology Councils.

Part B: Swiss research and innovation in international comparison

The objective of Part B is to assess Switzerland's international standing in the area of research and innovation. To this end, Switzerland is compared with other industrialised nations and with emerging countries[2] and the changes in its standing over time are also examined. In order to describe research and innovation activities, various indicators are shown which relate to investments, interactions and performance.

The Swiss research and innovation system is very productive. A comparison of Switzerland with its main competitors and business partners places it among the highest-ranking countries in the field of research and innovation. On the whole, though, the differences between the various countries are narrowing. For this reason, particular attention needs to be paid to those areas where Switzerland's performance leaves some scope for improvement and where it could fall behind.

Framework conditions

An investigation of the framework conditions for research and innovation reveals a very positive picture for Switzerland. Switzerland features among the frontrunners for the majority of indicators. It has a high-calibre infrastructure in place. Corporate taxes are very low. Among the reference countries, Switzerland has the most flexible labour market. The quality of life is excellent, and new businesses face only minor obstacles. However, in terms of how long it takes to establish a company, Switzerland finds itself in the middle rankings among the reference countries.

Education and qualifications

The Swiss research and innovation sector can rely on the quality of the education system. While the percentage of the population with a higher education qualification in Switzerland is not especially high, it has to do with the significance of vocational training. This is a decisive factor in the education and training of the qualified personnel that business and society need. The outstanding results that Switzerland achieves in the area of research and innovation can be explained in part by the marked internationalisation of the education system. The excellent reputation of Switzerland's higher education institutions makes it an attractive choice for students and doctoral candidates from other countries. On the other hand, Switzerland has not reached its full potential in respect of the number of natural sciences and engineering students.

Personnel in research and innovation

Switzerland boasts an outstanding pool of human capital, a considerable proportion of which work in science and technology. However, measured by the share of researchers in the total workforce, it sits in the lower rankings among the reference countries. The share of women in the total research labour force also presents a challenge for Switzerland. Its competitiveness could also be diminished by the increasing difficulty that companies and research establishments face in recruiting the talents they require to maintain their innovative capabilities.

Expenditure on research and innovation

Switzerland ranks among the countries with the highest ratio of R&D investment to gross domestic product (GDP). Private firms account for just under two thirds of R&D expenditure. This high private-sector share testifies to the attractive framework conditions enjoyed in Switzerland by companies working in knowledge-intensive sectors. Responsible for over 25% of total R&D expenditure, Switzerland's higher education institutions also play a key role. The pharmaceutical industry is the main beneficiary of R&D output in Switzerland.

Funding of research and innovation

In common with all other reference countries, the bulk of R&D funding in Switzerland comes from the private sector. However, the Swiss federal government and the cantons have a long tradition of funding R&D, regardless of economic trends. Research grants are continually being increased. Switzerland lies in the middle when it comes to venture capital, its efforts in this area proving relatively modest compared to the USA.

Participation in EU Research Framework Programmes

Switzerland has a long history of participating in international research programmes. The number of Swiss project participations under the FPs is comparable with other small countries, but has been rising continually between 1992 and 2013. The same applies – with a higher growth rate – to grants awarded to researchers in Switzerland. The high success rate for Swiss project proposals is worthy of mention.

[2] Switzerland was compared against the following reference countries for the purpose of the analysis: Austria, China, Denmark, Finland, France, Germany, Italy, Japan, Korea, the Netherlands, Sweden, the UK and the USA.

Scientific publications

Switzerland has achieved some remarkable results as regards scientific publications. Despite growing competition from certain emerging countries, it maintains an output of scientific articles that is considerable for its size. The impact of scientific publications produced in Switzerland is also impressive. The Swiss research sector's strong international reach is attributable to the fact that Switzerland's researchers very frequently work with foreign research institutions. Switzerland occupies a prominent position in the fields of physics, chemistry and the geosciences in terms of all indicators of production, impact and collaboration.

Patents

Switzerland is a leader in the patent rankings. Measured against the country's population, the number of patent applications is particularly high here. Also warranting a mention is its strong global patent presence, which is borne out by the patents resulting from international collaborations and the patent applications filed by foreign companies. This serves to demonstrate the strong appeal of the Swiss research and innovation system. A breakdown by individual sectors shows that Switzerland's strengths lie in the areas of health technologies and biotechnology.

Knowledge and technology transfer

Switzerland stands out for efficient KTT. The close ties between higher education institutions and the corporate sector help to explain the success of the Swiss research and innovation sector. That said, there is still some leeway for improvements given that, in Switzerland as elsewhere, there is a very strong correlation between intensity of KTT and firm size.

Innovation activities of firms

Swiss companies have a very good track record overall when it comes to innovation activities. What particularly sets Switzerland apart from the reference countries are the outstanding achievements of the SMEs. In all probability, these successes are due to the diversity and density of local business systems in specific special fields.

Economic performance

With regard to economic output, Switzerland is well positioned, as measured both by the percentage of companies active in knowledge-intensive areas (high-tech industry and knowledge-intensive services) and by exports of high and medium-tech products.

Comparison with innovation regions

A comparison with regions with a strong focus on research and innovation[3] confirms Switzerland's excellent positioning. However, the result is less impressive than in the comparison against the reference countries. For instance, the ratio of R&D spending to GDP is considerably higher in Baden-Württemberg and New England. Switzerland's volume of publications per researcher is only marginally ahead of the figures for New England and Lombardy/Piedmont. Measured by the number of patents per 1000 inhabitants, Switzerland is clearly surpassed by Baden-Württemberg and Bavaria. These two innovation-centric regions in Germany also rank ahead of Switzerland on several other innovation indicators. Expressed as a percentage of the total work force, the number of people employed in Switzerland's research and knowledge-intensive sectors place it in the middle range, although high-tech industries have a stronger presence in Switzerland than in most of the analysed innovation-centric regions. It must also be borne in mind, though, that these regions profit from the size of the countries that they are located in. They can draw on a pool of talents and ideas from an entire large nation, while small Switzerland has to make up for the size disadvantage by adopting an open stance.

[3] The following regions were selected for comparison: Baden-Württemberg and Bavaria in Germany, Northwest Italy (Lombardy and Piedmont), the Greater Paris area (Ile-de-France), the Greater London area (South East England) and the US New England states in the narrower sense.

Part C: Specific topics

The objective of Part C is to investigate overriding or transversal issues that have a significant impact on the Swiss research and innovation system. For this purpose, four studies were carried out by experts from the academic community.

1 Research and innovation activities of small and medium-sized enterprises in Switzerland

Innovations are regarded as key success drivers for SMEs. The study investigates what characterises and influences the innovation activities of SMEs in Switzerland.

The scope of research and innovation activities conducted by SMEs in Switzerland

SMEs in Switzerland are more innovative, on average, than their counterparts in other European countries. Marketing and organisational innovations are the most widespread, followed by product and process innovations, but there are considerable differences from sector to sector.

While the share of innovative SMEs has decreased in recent years, the proportion of revenue from innovative products has risen slightly, suggesting an increased concentration of innovation activities at fewer SMEs.

SMEs tend to bring fewer innovations onto the market than large corporations. Seen from a relative perspective, the picture is a different one though: Whereas in proportion to revenue Swiss SMEs invest less money in innovation activities, relative to revenue they generate more earnings with innovative products than large corporations. These findings indicate that SMEs deploy their resources for innovation activities very efficiently.

SMEs channel their innovation expenditure largely into near-market activities such as product development as well as construction and design.

Knowledge sources and collaborations

The two main sources of knowledge for innovations at SMEs are customers and suppliers. What is more, SMEs in Switzerland do not engage in research and innovation collaborations any less frequently than SMEs in other European countries. Small firms collaborate less frequently with higher education institutions and research establishments than larger companies do.

Obstacles to innovation

High costs and long amortisation periods, compounded by insufficient own resources, present obstacles to innovation activities for SMEs. Small firms in particular find it harder than larger ones to fund innovation activities. However, there are also signs that a desire to remain independent is prompting SMEs to consciously refrain from acquiring funding from external financial backers.

2 Research and innovation activities of multinationals in Switzerland

Competition has arisen at international level between different locations (including Switzerland) keen to attract research and innovation activities, much of which are conducted by multinational enterprises. The reason for this competition is the benefit that multinationals bring to their locations, including the substantial contribution that they make to GDP (around 36% in Switzerland's case) and the creation of attractive jobs.

In order to understand which factors are central to this competition between different locations, the study investigates the benefit that the research and innovation activities of multinationals create for Switzerland. It also looks at why multinationals choose to conduct these activities in Switzerland and where the appeal of various other research and innovation locations lies. For the purposes of the study, both a qualitative and a quantitative investigation were carried out.

The benefits of research and innovation activities conducted by multinationals in Switzerland

Multinational enterprises play a pivotal role in Switzerland's national innovation system since they typically maintain multilateral ties with various innovation actors such as higher education institutions, SMEs and service providers. Multinationals thus make a major contribution to disseminating knowledge, subsequently generating new knowledge and commercialising it.

By choosing to locate their research and innovation activities in Switzerland, multinationals greatly benefit the country's economy by creating skilled jobs, collaborating with higher education institutions and regional companies, contributing to international technology transfer and increasing Switzerland's capacity to absorb foreign knowledge.

Choice of location and reasons for establishing research and innovation activities there

The survey shows that Switzerland is by far the most important research and innovation location for multinational enterprises headquartered there. On the other hand, multinationals with headquarters abroad name the USA as their first choice, followed by Germany and then Switzerland.

The main reasons for multinationals to establish research and innovation activities in Switzerland are, first, the excellent access to highly qualified specialists and, second, the proximity to cutting-edge research centres, above all the Federal Institutes of Technology in Zurich (ETH Zurich) and Lausanne (EPFL). Tax advantages are an additional factor conducive to setting up research and innovation activities in Switzerland.

Among the principal reasons for establishing research and innovation activities abroad are the proximity to science talent pools and leading academic institutions as well as access to key markets.

Switzerland's appeal as a research and innovation location for multinationals

Since capital is mobile, multinational enterprises are a good barometer of the appeal of a research and innovation location. Switzerland is still an attractive country, but other nations are gaining ground.

Multinationals believe their key requirement of access to foreign specialists and top talents is jeopardised by the adoption of the mass immigration initiative. It is of uppermost priority for multinational that measures to implement the initiative include a solution conducive to the research and innovation landscape.

In conclusion, the overall environment for research and innovation activities of multinational enterprises is still favourable in Switzerland, but international openness and strong encouragement of research and innovation are particularly important given the fiercer international competition.

3 Supply and demand in public innovation promotion

Public innovation promotion in Switzerland currently takes place at national, cantonal and regional level. This raises issues about coordination and coherence as well as the duplication of activities by state agencies.

One of the objectives of the study is to produce a compilation of providers of innovation promotion services. Furthermore, it addresses the question of demand for public innovation promotion, also factoring in an assessment of the supply side from the perspective of benefits, visibility, coordination, coherence and duplication. The focus is on the needs of particularly innovative firms. To this end, a survey was carried out among companies that had been nominated for one of Switzerland's top innovation awards. The findings of the survey were discussed at an expert workshop with providers and other specialists at cantonal, regional and national level.

Assessment of the supply situation by the firms surveyed

Public innovation promotion is rated as important by the majority of innovation award nominee companies surveyed.

Over two thirds of respondent firms had contact with public innovation promoters. The benefit of such contacts is generally rated as high. Overall, respondent companies gave a rating of higher than average to the benefit derived from contact with cantonal and regional promoters as well as from "soft" services such as information and advice.

Many of the respondent companies cited a lack of visibility in respect of public innovation promoters and their services. This opinion was expressed largely by those firms which had never requested support. They find it difficult to locate the right promoters and feel that the services provided by the federal government and the cantons/regions do not dovetail to optimum effect.

Assessment of duplication from the point of view of promoters and the firms surveyed

Public innovation promoters and innovation award nominee companies share the view that duplication is encountered in Switzerland's innovation policy. However, the study shows that the majority of promoters do not see this as a problem, but more as an element of diversity that stimulates competition. Conversely, the respondent companies are more critical in their assessment of duplication.

4 Universities of applied sciences in the Swiss research and innovation system

The study investigates the role of UAS in Switzerland's research and innovation landscape. It looks at the development of UAS and their contribution to the Swiss research and innovation system and also examines their profile and collaborations with firms and universities. The study also addresses the complementarity of UAS and universities and identifies potential challenges in connection with the new HEdA.

Development of universities of applied sciences and their contribution to the Swiss research and innovation system

The UAS were founded in the late 1990s with two principal aims in mind, the first of which was to improve the education of qualified specialists at higher education level, while the second objective was for UAS to support the research and innovation activities of SMEs, since even today the latter often have insufficient research and innovation capacities in-house and are dependent on collaboration partners that can offer aR&D and knowledge transfer.

The UAS have witnessed a rapid expansion in terms of resources, student count and R&D volume to become central actors in the Swiss research and innovation system. Currently, UAS account for more than half of all enrolments on bachelor's degree programmes and approximately 10% of all R&D in the higher education sector.

Employment and income data also confirm that the profile of UAS graduates generally covers the needs of the labour market (with some differences depending on the industry). Playing a pivotal role in meeting demand for highly qualified specialists, UAS are also key actors in the continuing education sector.

Profile and collaborations

The UAS have established an aR&D-led profile, making them a major collaboration partner for the private corporate sector, as evidenced by the large number of collaboration projects and R&D contracts with companies.

Examples of successful collaborations between UAS and universities are to be found in particular in the engineering sector, where the profiles of the two higher education institution types clearly differ. Tasks are often shared in such a way that the universities carry out the basic research, while the UAS perform the aR&D. The situation is different in the areas of economics, the social sciences, healthcare and the arts, where the UAS have little research experience, the definition of aR&D is less clear, and the collaboration partners tend to have fewer resources for cooperation ventures.

Complementarity of universities of applied sciences and conventional universities

These positive findings are attributable mainly to the fact that the UAS have developed a profile which clearly sets them apart from universities. Switzerland has been relatively successful in integrating UAS and universities into a single system, while preserving the unique characteristics of the respective profiles. Other countries, by contrast, have seen more assimilation. The new legal framework enshrined in the HEdA is expected to promote collaboration and complementarity between the two types of higher education institutions. At the same time, the Act presents new challenges with regard to of the division of tasks between UAS and universities.

INTRODUCTION

One of the glass facades of the Swiss Convention Center at the Federal Institute of Technology in Lausanne (EPFL) which is covered with Graetzel cells. These translucent, coloured solar panels, inspired by plant-based photosynthesis and developed by Professor Michael Graetzel at EPFL, serve as a sun screen that produces electricity: a very promising source of renewable energy. Photo: EPFL

Research and innovation play an essential role in a country's social and economic development. Social well-being and the ability to compete depend on the capacity to produce, disseminate and use knowledge and to create and commercially exploit new products, processes and services –this is what innovation means! This applies all the more for a country like Switzerland, which has few natural resources.

Switzerland tops a number of global rankings[1] for research and innovation. But, going forward, will it be able to maintain the current quality and competitiveness of its science and technology? And if so, how?

To answer these questions calls for regular monitoring of Swiss research and innovation. Whereas numerous countries periodically publish reports on the effectiveness of their research and innovation systems, there has to date been no such mechanism in Switzerland. The present report, produced under the auspices of the State Secretariat for Education, Research and Innovation (SERI), fills this gap.

To ensure strict accuracy of the information, appropriate treatment of the subject matter and a balance between the points of view expressed, experts outside the federal government and stakeholders have been involved in the elaboration of this report (see Annex 3). A regular update of the report every four years is planned.

Three examples

A large number of globally recognised and utilised innovations originated in Switzerland. Some took shape after many years of research, while others were by-products of a field of research or sheer chance.

Graetzel cells are an example of an innovation resulting from research. Developed by Professor Michael Graetzel at the EPFL, these cells absorb light and store it on a very porous organic layer in order to convert it into energy. They are much cheaper than the standard industrial cells on silicon layers.

The **Web,** invented by Tim Berners-Lee at CERN, was itself not a subject of scientific research, but materialised as a by-product of particle research. The World Wide Web project was originally developed with the aim of enabling scientists at universities and institutes throughout the world to share information in real time.

The **Velcro fastener,** which is frequently used for jackets, shoes and bags, is an innovation which does not owe its origins to R&D at all. The story goes that the Swiss engineer Georges de Mestral invented Velcro after a country walk, looking through a magnifying glass at the burrs clinging to his trousers.

[1] For example, the Innovation Union Scoreboard (IUS), the Global Innovation Index, the World Competitiveness Report, the World Competitiveness Yearbook.

Objectives and structure of the report

The aim of the report "Research and Innovation in Switzerland" is to contribute to a better understanding of the Swiss research and innovation scene and stimulate discussion. Devised as a work of reference, the Report primarily addresses politicians (partly as discussion material on the Swiss Federal Council Dispatches on the promotion of education, research and innovation). It also addresses institutions with a role in encouraging research and innovation and educational institutions (e.g. for the preparation of their multi-year programmes). Finally, it is for firms, organisations and anyone interested in research and innovation in Switzerland.

The report pursues three objectives:

1) To describe the structure and functioning of the Swiss system of research and innovation.
   Part A describes the general context, actors and funding of Swiss research and innovation, as well as the key national and international instruments and measures for the promotion of research and innovation.
2) To look at Switzerland's international positioning in research and innovation, and compare it with other advanced and emerging economies and see how it has developed in the course of time.
   Part B examines the performance of Swiss research and innovation on the basis of an international comparison of the most common key indicators in the field. It is planned to update this part and make it available in electronic form every two years.
3) And to investigate systemic or cross-cutting issues of central significance for the Swiss system of research and innovation.
   Part C comprises four studies on selected topics carried out by experts from the science community.

We would add that the goal of the Report is not to propose measures which might steer the Swiss system of research and innovation, nor to conduct a strategic audit of Swiss policy in this area. It does not seek to identify which activities are conducive to Switzerland's economic prosperity. While it is generally acknowledged that research and innovation have a positive impact on the economy and society as a whole, it is extremely difficult, if not impossible, to isolate the effects of an individual activity and demonstrate precise causal links.

Definition of research and innovation

There are various definitions of research and innovation. Some derive from legal texts; others from the concepts used by the agencies which promote research and innovation (see box). These definitions may also vary from country to country. In order to include all scientific and technological activities and to guarantee the international comparability of the relevant data, the present report (unless otherwise expressly stated) references the internationally recognised definitions contained in the Frascati Manual (OECD, 2015) and the Oslo Manual (OECD & Eurostat, 2005).

Definitions of research and innovation in Switzerland

The **Federal Act on the Promotion of Research and Innovation (RIPA)** defines scientific research as the method-based search for new knowledge. Its main purpose may be gaining knowledge (basic research) or contributing solutions to practical problems (applied research). Science-based innovation embraces the development of new products, methods, processes and services and the exploitation of its results.

The **Swiss National Science Foundation (SNSF)** distinguishes between research aimed at a general gain in knowledge (basic research), research focused on a specific application (applied research) and research that combines both components (application-oriented basic research). In medicine, the third category is referred to as translational research.

The **Commission for Technology and Innovation (CTI)** employs the terms science-based innovation and applied research.

Research and development (R&D) according to the Frascati Manual

The Frascati Manual distinguishes between three types of R&D activities:

- "**Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
- **Applied research** is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective.
- **Experimental development** is systematic work, drawing on existing knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes." (p. 45)

Innovation according to the Oslo Manual

The Oslo Manual distinguishes between four types of innovation:[2]

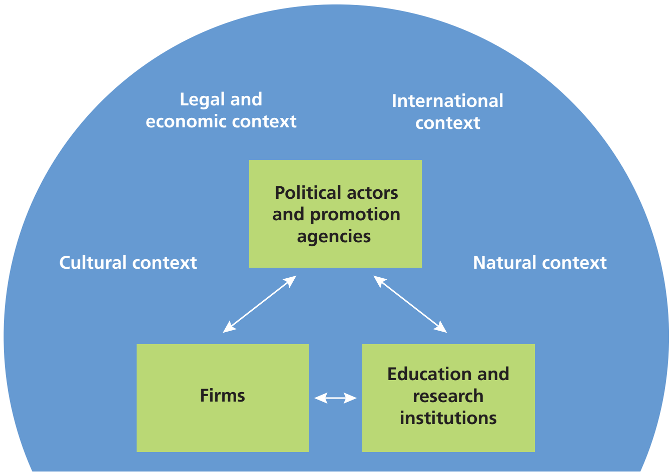
- "A **product innovation** is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics." (p. 48)
- "A **process innovation** is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software." (p. 49)
- "A **marketing innovation** is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing." (p. 49)
- "An **organisational innovation** is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations." (p. 51)

[2] Social innovations and innovations in the arts are gaining in significance. Since defining these types of innovation poses numerous methodological challenges, the definitions cited do not (yet) include them.

A broad view of research and innovation

In addition to the definitions cited above, the present report makes reference to the concept of "national innovation system" (Lundvall, 1992; Nelson, 1993), which allows a broader perspective in order to factor in the context in which the research and innovation is taking place.

The national innovation system



Based on Lundvall (1992)

This approach takes into account the interactions between the institutions and actors which develop and spread knowledge and innovations, and the retroactive effects and the synergies which derive from them. It also challenges the view that basic research, applied research and innovation occur in linear sequence. Applied research may prompt questions for basic research – and applications and innovations can result directly from basic research. What is more, innovation frequently happens without R&D.

PART A: THE SWISS RESEARCH AND INNOVATION SYSTEM

Numerous Swiss hospitals cooperate closely with universities in cutting-edge medical research and also participate in the training and continuing education and training of medical staff. The method known as deep brain stimulation consists of a mini-invasive surgical intervention in which the patient is fitted with very fine electrodes which generate a chronic stimulation of the brain. In allowing pathological faults to be corrected and brain functions to be improved, these electrodes result in a net reduction of the symptoms of locomotor disorders such as Parkinson's disease, trembling, dystonia or psychiatric illnesses such as obsessive-compulsive disorder and depression. In Switzerland, most operations of this type are carried out at the University Hospital in Bern, and this is also where patients receive follow-up neurological care. Photo: Inselspital, Bern

Contents

Part A provides an overview of the Swiss research and innovation system. It describes the general context for research and innovation, the actors and funding of Swiss research and innovation, the key national and international instruments and measures for promoting research and innovation, as well as the federal government's general stance.[1]

1 General context

1.1 Framework conditions

Favourable conditions are a core requirement if Switzerland is to achieve strong research and innovation results and successfully position itself in the international competitive arena. These conditions include the guarantee of fundamental rights, a well-developed infrastructure and the protection of intellectual property.

Fundamental rights
"Freedom of research and teaching is guaranteed" (Art. 20 Federal Constitution, Cst). According to Schweizer (2011), this can summarily be interpreted as: The state must respect and promote the scientific freedom of individuals and institutions to pursue research.

In common with other fundamental rights, scientific freedom also operates within the general framework of society. It may collide with other parties' defence and protection entitlements founded in other fundamental rights, including, for instance, the personal freedom of patients or the economic freedom of companies wishing to safeguard their business and manufacturing secrets. Furthermore, constitutional and other public law provisions in various areas need to be complied with (e.g. the protection of life and health). An appropriate balance needs to be found between scientific freedom and protective measures.

The Federal Constitution also requires legislators to impose certain limitations on research. Accordingly, scientific freedom is limited, for example, by the Constitution and gene technology legislation. In Switzerland, particular restrictions are placed on non-human gene technology.[2]

Infrastructure
Compared with other countries, Switzerland has a well-developed infrastructure with a high level of modernisation. Traffic, transport and energy services are of a high standard, and the uninterrupted security of supply and operations is guaranteed. The information and communication technology (ICT) infrastructure, including transmission and processing power, is among the best in the world. What is more, the publicly funded higher education and research infrastructure provides an excellent environment for first-rate scientific achievements as well as an innovation-friendly competitive culture that is strong by international standards.

Largely deregulated markets
Switzerland's hallmarks are competition and private initiative with relatively little, albeit effective, government regulation and intervention. The markets for labour, capital, goods and services are largely competition-driven. Thanks to multilateral and bilateral agreements, access to international markets is free and open.

Compared with other countries, Swiss labour market rules permit a high degree of flexibility and mobility on the part of employees. This allows companies to rapidly adopt innovations.

The gradual introduction of the free movement of persons with the European Union (EU) enhances[3] the already attractive conditions in core areas of the domestic labour market. Switzerland can attract talents from the EU and the entire world. Measured against other countries, the degree of internationalisation at universities (students, support staff, faculty) and among research and development (R&D) personnel[4] in the business sector is very high. This spells a huge competitive advantage for Switzerland as a location for research and industry.

Market order in sectors such as telecommunications and energy (in particular electricity) is especially relevant not only for innovation in those sectors, but also for the national economy overall, because these sectors are essential for the generation, processing and dissemination of knowledge. Switzerland's telecommunications and energy industries are not quite as widely deregulated as in the EU in general.

Strong protection for intellectual property
Companies or universities aiming to make their inventions a success on the market need to protect them against third-party imitation. This is the only way to secure a competitive advantage and find opportunities to fund their research expenditure.

Switzerland is a member of the European Patent Organisation, which runs the European Patent Office (EPO) in Munich. Over 90% of Swiss patent applications are examined there for novelty and inventive step. The patents subsequently granted are valid in Switzerland. Patent applications can also be filed directly in Switzerland. The fact that Swiss national patents are presently not examined for novelty or inventive step diminishes their worth. A study commissioned by the Swiss Federal Institute of Intellectual Property (IPI) investigated the potential for optimising Switzerland's

[1] Part A is based on a text by Beat Hotz-Hart, Professor Emeritus of the University of Zurich.

[2] This falls under the Federal Act on Non-Human Gene Technology and a moratorium (expiring in 2017) on the commercial exploitation of genetically modified plants in agriculture. Whereas their commercial exploitation in agriculture is prohibited, field research is allowed, subject to highly restrictive authorisation procedures.

[3] Impact of the adoption of the "Stop mass immigration" initiative, see Section 3.2.

[4] Since numerous official statistics relate solely to R&D, (where no research and innovation data is available) R&D figures are used. This applies in particular to data on R&D expenditure and R&D personnel.

patent system. One possible proposal is to upgrade the Swiss national patent to a full patent based on the European Patent Office model (IPI, 2015).

Any company under the impression that someone is infringing its patents must have recourse to an efficient justice system. Patent cases in Switzerland were heard by the cantonal commercial courts up until the end of 2011. Competence for settling patent disputes was subsequently transferred to the Federal Patent Court, resulting in a significant reduction in both the length of proceedings and in legal uncertainty.

Under the provisions of the law, employees' contractual obligations mean that any inventions made by them are the property of the employer, i.e. the company or university. The intellectual property rights to R&D results achieved by researchers in their capacity as employees are governed by employment contract legislation (Code of Obligations). The domain of the federal institutes of technology (ETH Domain) is subject to additional provisions contained in the ETH Act. The cantonal universities and universities of applied sciences (UAS) are also bound by the provisions in the relevant cantonal higher education legislation. Intellectual property rights to the results of R&D activities supported with public funds, e.g. from the Swiss National Science Foundation (SNSF) or the Commission for Technology and Innovation (CTI), are defined in the Federal Act on the Promotion of Research and Innovation (RIPA). In these cases, the federal government or its funding agencies can tie promotion measures in with stipulations on intellectual property and exploitation of the results.

Fiscal environment and climate for starting new businesses

Switzerland's tax system is highly federalistic. Taxes and tax rates are set by the federal government, the cantons and the municipalities. This produces regional and local differences in corporate tax burdens.

A generally attractive fiscal regime for companies acts as a stimulus for innovation, as it also impacts positively on costs and options to (self-)fund R&D activities.

The fact that taxes in Switzerland are generally low by international standards helps to create an environment that is conducive for business and innovation. As is the case in most other countries, current R&D expenditure is today recognised as an expense in Switzerland, which reduces the tax burden. However, unlike other countries such as the Netherlands and Canada, Switzerland does not provide special tax incentives for R&D activities, nor does it give tax breaks to venture capital companies or venture financiers. Start-up projects and small fast-growing companies benefit from the fact that Switzerland does not levy a tax on capital gains. The only other tax breaks available to the innovation sector are in the form of environmental and energy policy instruments.

Moreover, the Federal Council adopted a corporate tax reform (CTR III) in June 2015. If this reform is approved by Parliament, revenues in connection with patents and comparable rights will in future be taxed at a reduced rate. The cantons will additionally have the option of increasing tax deductions for R&D expenditure (current as at January 2016).

Patenting as a strategy for protecting intellectual property

Various strategies may be adopted to protect intellectual property (Hotz-Hart & Rohner, 2014). One of them is patenting. The right to a patent is accorded to the inventor, his or her legal successor or a third party who owns the invention on other legal grounds. Where several parties made the invention independently of one another, this right is accorded to the party which can invoke the first-to-file principle. A patent gives the patent owner the opportunity to prevent others from exploiting his or her invention for a maximum of 20 years. In return, the inventor is required to lay a patent specification open to public inspection. The patent system is designed to establish a market for inventions. Companies may trade their inventions on this market, e.g. by offering them for sale or licensing them to third parties. The proceeds from such transactions offer an incentive to make further investments in R&D.

1.2 Legal basis

1.2.1 Federal level

In accordance with the Federal Constitution (Art. 64 Cst), the promotion of scientific research is a core task of the federal government. The federal government and the cantons are jointly responsible for the coordination and guarantee of quality in Swiss higher education (Art. 63a Cst). The Constitution also requires the federal government to issue regulations on vocational training and to encourage the provision of a diverse and accessible range of courses (Art. 63 Cst).

Research and innovation

The scope and organisation of the federal government's research and innovation promotion tasks are framed by the Federal Act on the Promotion of Research and Innovation (RIPA). In tandem with the Federal Act on Funding and Coordination of the Swiss Higher Education Sector (HEdA), the RIPA provides a key legal framework for ensuring optimum efficiency of the Swiss research and innovation system. The RIPA defines the tasks, procedures and responsibilities of the funding agencies included in the RIPA, the SNSF, the CTI and the Swiss Academies of Arts and Sciences, as well as under international scientific collaborations. It also lays down rules for planning, coordination and quality assurance measures for Federal Government Research. Furthermore, it creates the legal basis for supporting a Swiss Innovation Park and harmonising research promotion in cost-intensive areas with the HEdA.

The RIPA draws a conceptual distinction between scientific research and science-based innovation. Scientific research is defined as a method-led search for new knowledge. It embraces basic research, the main goal of which is to gain knowledge, and applied research, the main goal of which is to contribute solutions to practical problems. The RIPA also covers science-based innovation, which is defined as the development of new products, procedures, processes and services in business and society through research, particularly applied research and the exploitation of its results. This explains the pragmatic sharing of tasks between the SNSF and the CTI.

Energy legislation offers a specific and relatively far-reaching legal basis for research and innovation. The Energy Act gives the federal government, in collaboration with the cantons, the authority to promote research, development and demonstration in addition to information and consulting as well as training and continuing education and training. As a consequence, the federal government promotes basic research, applied research and the research-based development of new energy technologies aimed in particular at the economical and rational use of energy and the harnessing of renewable energy sources. In doing so, the federal government builds on the efforts of the cantons and the business sector. After a consultative hearing with the host cantons, it may opt to support pilot and demonstration facilities and projects as well as field trials and analyses serving to test and assess energy technologies, evaluate energy measures or capture the necessary data.

Universities

In accordance with the Federal Act on Funding and Coordination of the Swiss Higher Education Sector (HEdA), the federal government, together with the cantons, is responsible for the coordination, quality and competitiveness of Switzerland's higher education domain. For this purpose, the HEdA establishes the basic principles for the Swiss-wide coordination of higher education policy, namely through the stipulation of joint bodies, quality assurance and accreditation, the funding of universities and other institutions in the higher education domain, the allocation of tasks in particularly cost-intensive areas and the granting of federal contributions. However, the latter applies solely to the cantonal universities and UAS, but not to the federal institutes of technology (ETH) and universities of teacher education (UTE).

The Federal Act on the Federal Institutes of Technology (ETH Act) regulates the tasks and organisation of the ETH domain, which comprises the Federal Institute of Technology Zurich (ETH Zurich), the Federal Institute of Technology Lausanne (EPFL) and the four research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa) as well as the Swiss Federal Institute of Aquatic Science and Technology (Eawag). The two Federal Institutes of Technology and the four research institutes are mandated to train students and specialists in scientific and technical fields and ensure their continuing development, to expand scientific knowledge through research, to foster young scientists, to ensure a dialogue with the public and to exploit research findings, in line with Switzerland's needs.

Vocational and professional education and training

The Federal Act on Vocational and Professional Education and Training (Vocational and Professional Education and Training Act, VPETA) is designed to underpin the effectiveness of Switzerland's innovation system. As a driver for the modernisation of vocational and professional education and training, the Act takes account of the major changes happening in the working world and enables new developments. It allows for different types of vocational route and provides flexibility in the vocational education system. It also promotes and develops a capability and willingness on the part of qualified professionals to be flexible in terms of job choice and so survive in a changing work environment. The Act also fosters a vocational and professional education and training system which enables companies to become more competitive (Art. 3 VPETA). Professional education programmes provide a crucial practice-based conduit to advanced qualifications at tertiary level.

Funding

Every four years the Federal Council presents a Dispatch on the promotion of education, research and innovation (ERI Dispatch) to Parliament. It contains policy guidelines and measures covering those areas of the Swiss education and research and innovation system for which the federal government is primarily responsible: ETH Domain, vocational and professional education and training, research and innovation promotion, and international education and research collaboration. The Dispatch also outlines the federal government's commitment to those parts of the system primarily funded by and falling under the purview of the cantons: i.e. cantonal universities, UAS, the enactment of vocational and professional education and training legislation, and the provision of grants. On the basis of the ERI Dispatch, Parliament defines the parameters for ERI funding over a four-year performance mandate period. Funding of Switzerland's participation in the European Union (EU) Framework Programmes in the areas of research and innovation and education is outlined in separate Dispatches of the same frequency as the Programmes.

1.2.2 Cantons

The cantons define their policies on cantonal universities, UAS and vocational and professional education and training legislation individually.

Cantonal university affairs are regulated by cantonal university laws. Generally speaking, the purpose and mandate of a university is to engage in scientific research and teaching for the common good. In this connection, the university is also expected to render services (including knowledge and technology transfer). It provides scientific education and training and creates a basis for the pursuit of academic activities and professions. The university also cultivates continuing academic development and fosters young scientists.

Cantonal UAS laws provide the basis for the administration of a university of applied sciences. As a rule, they address collaboration in the higher education domain with other cantons and the federal government. They define the role of the cantonal parliament and government with regard to UAS and provide guidelines on the organisation, responsibilities, rights and obligations of UAS members and UAS governing bodies, as well as on financial matters. The statutory performance mandate of the UAS covers degree courses, continuing education and training, applied research and development (aR&D), and services. The UTE are universities governed by cantonal legislation. While they are also bound by the principle of coordination embodied in the HEdA, they are financed exclusively with cantonal funding.

The Federal Act on Vocational and Professional Education and Training mandates the cantons to secure the necessary vocational education and training, professional education and continuing education and training resources as well as to ensure vocational, educational and career guidance. This mandate has the force of an executive order for cantonal vocational and professional education and training laws. As a rule, the objectives of these laws include collaboration and coordination with the federal government, other cantons and organisations in the working world. They also define how the various requirements of the Federal Act are to be implemented and regulate matters pertaining to the partnerships and funding.

Innovation promotion under the mantle of cantonal business promotion is based on special cantonal laws such as the Business Promotion Act in Canton Berne, the Location Promotion Act in Canton Aargau, the Location Promotion Act in Canton St. Gallen or the Act on Business Promotion in Canton Freiburg.

1.3 Public sector responsibilities for research and innovation

1.3.1 Federal government

Acting at the request of the Federal Department of Economic Affairs, Education and Research (EAER), the Federal Council (executive) submits federal ERI policies and related promotion measures and instruments to Parliament for approval and adoption.

Federal Department of Economic Affairs, Education and Research
At federal level, the Federal Department of Economic Affairs, Education and Research (EAER) has prime responsibility for ERI matters. Part of the EAER, the State Secretariat for Education, Research and Innovation (SERI) is the federal agency responsible for national and international matters concerning general education, vocational and professional education and training, UAS and university education, research and innovation promotion and aerospace.

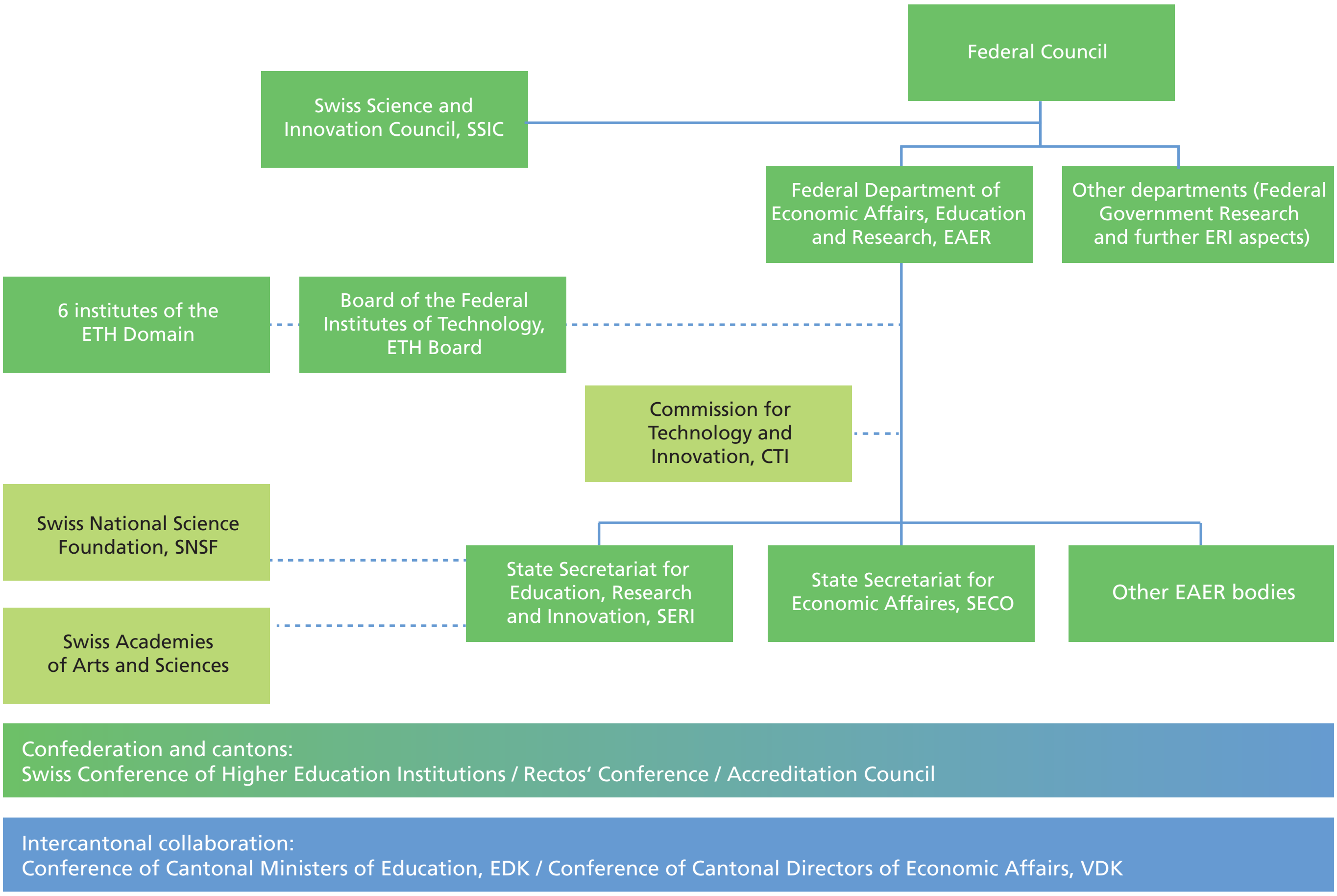
SERI's areas of activity include – in collaboration with the cantons – the funding, strengthening and ongoing development of vocational and professional education and training and the recognition of cantonal and non-Swiss school-leaving certificates. SERI is also responsible for the promotion of cantonal universities and UAS in accordance with the HEdA, as well as for coordinating research and innovation promotion policy with the joint higher education policy of the federal government and the cantons. Further areas under SERI's responsibility include enforcing the RIPA, providing grants, and preparing and monitoring implementation of the performance mandate given to the ETH Domain. At international level, SERI is responsible for the federal government's foreign education and scientific policy. This includes participation on Switzerland's behalf in European and global education programmes, representing Switzerland in international organisations and programmes (in particular in the EU Research Framework Programmes, the European Space Agency ESA and the European Organization for Nuclear Research CERN) and promoting international scientific contacts via the ERI Network. SERI's activities are instrumental in ensuring that qualified personnel are trained and that Switzerland asserts itself as a strong and attractive education and research hub.

Besides SERI, other EAER units also play a part in directly or indirectly promoting research and innovation. These include the Commission for Technology and Innovation (CTI) and the State Secretariat for Economic Affairs (SECO). The Swiss National Science Foundation (SNSF) and the Swiss Academies of Arts and Sciences are associated with SERI through service level agreements.

Domain of the Federal Institutes of Technology
The ETH Domain comprises ETH Zurich, EPFL and the four research institutes Paul Scherrer Institute (PSI), Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Swiss Federal Laboratories for Materials Science and Technology (Empa) and Swiss Federal Institute of Aquatic Science and Technology (Eawag). Its core tasks include teaching, research and knowledge and technology transfer (KTT).

The Board of the Federal Institutes of Technology (ETH Board) is responsible for strategic management of the ETH domain and oversight of its institutes. It defines the strategy of the ETH Domain within the parameters of the performance mandate from the Federal Council. The ETH Board represents the domain vis-à-vis federal policymakers and authorities. It agrees objectives with the two Federal Institutes of Technology and the four research institutes, approves their development plans and – on the basis of the institutes' budget proposals – allocates resources within the expenditure ceiling set by Parliament. It issues controlling regulations, carries out strategic controlling and monitors implementation of the development plans.

Figure A 1.1: Public bodies



Source: Hotz-Hart & Kissling (2013), edited by SERI

Other areas at federal level

The competences and decisions of federal and cantonal actors in different policy areas outside the ERI ambit in the narrow sense also have an indirect but no less significant impact on research and innovation. In the area of energy research, for instance, the Federal Department of the Environment, Transport, Energy and Communications (DETEC) has a relevant role to play. Its Federal Office of Energy (SFOE) carries out measures under the headings of information and consulting, initial education and continuing education and training, as well as research, development and demonstration.

Federal Government Research (see Section 2.5) and other interdepartmental instruments (e.g. the Federal Council's Sustainable Development Strategy 2012–2015, the Green Economy Action Plan or the Swiss Cleantech Masterplan 2011) also have (indirect) implications for research and innovation policy.

Swiss Science and Innovation Council

Either acting on its own initiative or on the instructions of the Federal Council or the EAER, the Swiss Science and Innovation Council (SSIC) is the advisory body to the Federal Council for all research and innovation-related issues. It has the status of an extra-parliamentary committee.

The SSIC evaluates how far promotion measures taken by the federal government and its research bodies are meeting the mandate. In addition to conducting periodic reviews of the instruments used by research promotion institutions as well as of the Federal Government Research measures, the SSIC takes positions on individual research and innovation programmes and issues and assists the EAER with its periodic reviews of Swiss research and innovation policy.

1.3.2 Cantons

Responsible bodies for the cantonal universities, the universities of applied sciences and the universities of teacher education

Unless the Federal Constitution expressly stipulates the federal government, the cantons are responsible for education. They also bear the main financial burden (see Section 1.3.5).

Switzerland's ten cantonal universities fall under cantonal jurisdiction. Seven of the nine UAS are are within the responsibility of one or more cantons, and two are private. The cantons are responsible for regulating and funding the 14 UTE. The higher education policies of the cantons are a key factor behind innovation output.

Under the Federal Constitution, the federal government and the cantons are jointly responsible for ensuring a competitive, coordinated and high quality higher education domain for the whole of Switzerland. The cantons are bound to the HEdA via an intercantonal concordat and a collaboration agreement between the federal government and the cantons. The collaboration agreement lays down the shared objectives of the federal government and the cantons, creates joint bodies and vests in them the powers defined in the HEdA.

The cantonal universities are largely autonomous. They plan, regulate and manage their affairs independently within the provisions of the Constitution and the law. Ultimate supervision rests with the cantonal parliaments. Among other matters, they decide on the overall budget and the approval of further government services. They also approve the report on activities and agreements on university funding and concordats. The cantonal government has general oversight of the cantonal university and can itself also definitively decide on various issues, including the imposition of admission restrictions.

UAS make a crucial contribution to applied research and innovation output in Switzerland. They fall under the responsibility of the funding cantons, whose powers are defined in cantonal UAS laws. UAS are also autonomous and self-organising within the parameters of the Constitution and the law.

UTE are the responsibility of the cantons. They commission UTE to conduct development projects, which in turn play a direct role in school evolution and fundamental pedagogic innovations. Since UTE fall under their responsibility, the cantons are the main funders of innovation in schooling, especially in the compulsory sector.

Innovation and business promotion

By virtue of their responsibilities and initiatives, the cantons are actors of cantonal and regional innovation and business promotion. The majority of them have business promotion legislation which includes innovation promotion instruments. Among other things, this allows them to encourage the creation of new businesses, to support regional networks or clusters and to offer tax breaks to stimulate business. Other instruments can also be put in place, depending on regional business conditions and special interests. This gives rise to competition between cantons and, to some degree, even municipalities.

Under its New Regional Policy, the federal government can support the cantons (including financially) in their efforts to promote innovation in the regions (Federal Council, 2015; Egli, 2015).

Intercantonal government and directors' conferences

Intercantonal government and directors' conferences are a vehicle for the cantons to liaise, step up collaboration and present common concerns and positions to the federal government and other actors. The two conferences particularly prominent in the area of research and innovation are the Swiss Conference of Cantonal Ministers of Education (EDK) and the Conference of Cantonal Directors of Economic Affairs (VDK).

Acting as a policy body, the EDK coordinates the work of cantonal ministers of education at national level. The EDK has a subsidiary function and fulfils tasks that cannot be performed by the language regions or individual cantons.

The VDK performs comparable tasks to the EDK, but in matters of economic relevance. Innovation policy is also on the VDK agenda, e.g. in connection with the Swiss Innovation Park and regional policy.

1.3.3 Joint federal and cantonal bodies

The federal government and the cantons have three joint bodies mandated to ensure the coordination, quality and competitiveness of Switzerland's higher education sector: the Swiss Conference of Higher Education Institutions, the Swiss Conference of Rectors of Higher Education Institutions and the Swiss Accreditation Council.

The Swiss Conference of Higher Education Institutions is Switzerland's top-level higher education policy body. It is responsible for the Swiss-wide coordination of federal and cantonal higher education activities. It meets in plenary assembly or convenes as the Swiss Higher Education Council. In his or her capacity as the Federal Council member with the higher education portfolio, the Head of the EAER chairs both assemblies. All cantons which have ratified the Intercantonal Agreement on the Swiss Higher Education Sector (Higher Education Concordat) are members are of the plenary assembly. The ten university cantons (BE, BS, FR, GE, LU, NE, SG, TI, VD, ZH) and four additional university funder cantons designated by the Higher Education Concordat are represented on the Higher Education Council.

The Swiss Conference of Rectors of Higher Education Institutions (swissuniversities) is made up of the rectors and presidents of the universities, universities of applied sciences and universities of teacher education. As the body responsible for collaboration and coordination among the universities, it takes positions on the business of the Swiss Conference of Higher Education Institutions and submits proposals to the latter on behalf of the universities. Besides its other duties, it also represents the interests of Switzerland's universities at national and international level.

The Swiss Accreditation Council comprises 15 to 20 independent members representing mainly universities, the work community, students, and university support staff and teachers. It decides on accreditations on the basis of the HEdA (institutional accreditations and programme accreditations).

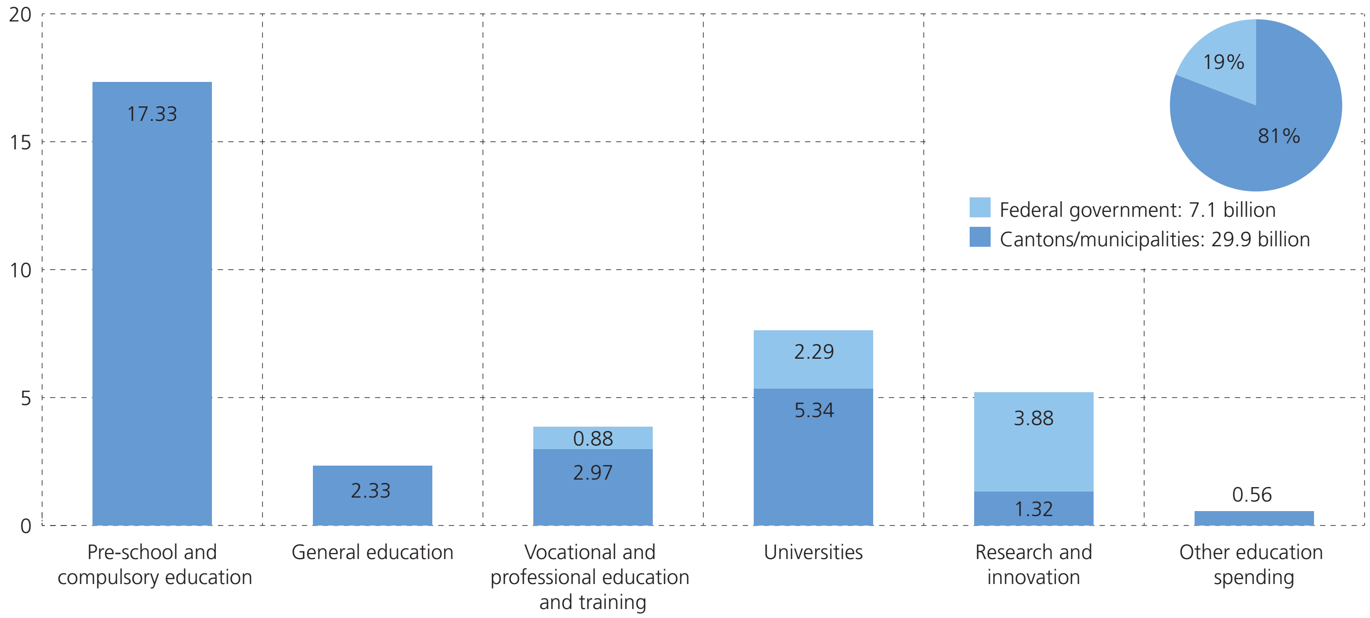
1.3.4 Municipalities

The municipalities have research and innovation responsibilities not only in the area of education and training but, above all, also in the infrastructure sector, e.g. in the context of attracting innovating companies and building technology and innovation parks.

1.3.5 Overview of public ERI funding

In 2013, public sector (federal government, cantons and municipalities) ERI expenditure totalled almost CHF 37 billion. More than 80% of this amount came from the cantons and municipalities, and approximately 20% from the federal government (Figure A 1.2).

Figure A 1.2: Federal government, cantonal and municipal ERI spending, in CHF billion, 2013



Source: FSO, FFA, chart SERI

2 Research and innovation funding, performing and actors

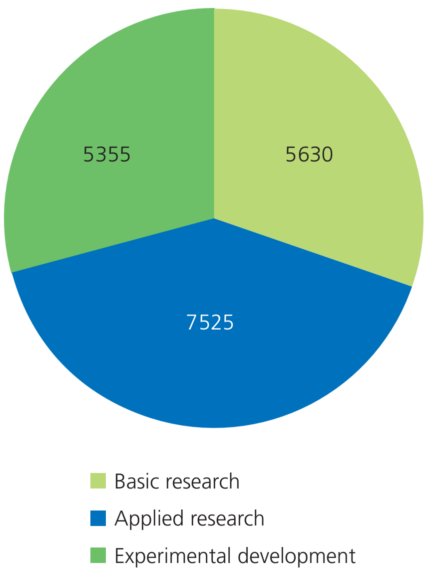
Research and development (R&D) activities totalling CHF 18.5 billion were carried out in Switzerland in 2012. This corresponds to around 3% of the country's gross domestic product (GDP), placing Switzerland among the OECD's top R&D spenders.

Figure A 2.1 shows that the biggest share (41%, or CHF 7.5 billion) went to applied research. Basic research (CHF 5.6 billion) and experimental development (CHF 5.4 billion) each accounted for almost 30%.

Roughly two thirds of R&D expenditure in Switzerland are funded and performed by the private sector, in large part by a small number of big corporations. Numerous small and medium-sized enterprises (SMEs) are also key players in the development sector.

Both R&D expenditure and R&D personnel reveal a high degree of internationalisation in the private sector and at universities. Switzerland is very open in this regard compared with other countries. This kindles intense international competition in Switzerland as a research hub and makes the domestic research and innovation system stronger.

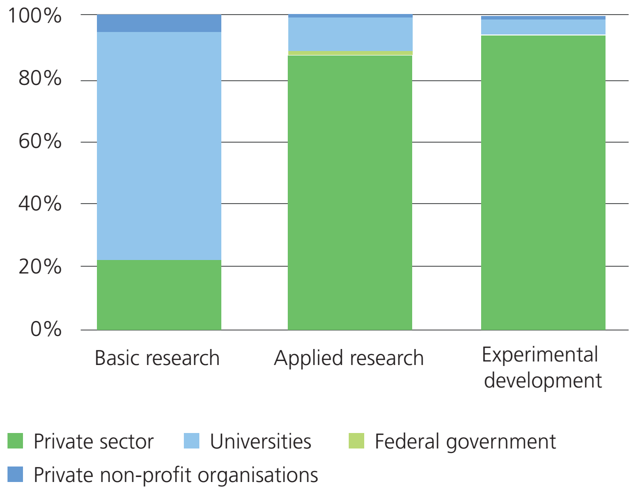
Figure A 2.1: Intramural R&D expenditure in Switzerland by research category, in CHF million, 2012[5]



Source: FSO

[5] The term "intramural R&D expenditure" refers to all expenditure on R&D activities which an actor performs on their own premises, i.e. "within their own walls". In Switzerland, total intramural R&D expenditure refers to overall expenditure invested in R&D by the private sector, the federal government, universities and private non-profit organisations

Figure A 2.2: Intramural R&D expenditure in Switzerland by sector and research category, 2012



Source: FSO

Figure A 2.2 shows that the bulk of basic research is performed by the universities, which are largely publicly funded. By contrast, the private sector chiefly funds applied research and experimental development.

2.1 Flows of funds in the R&D sector

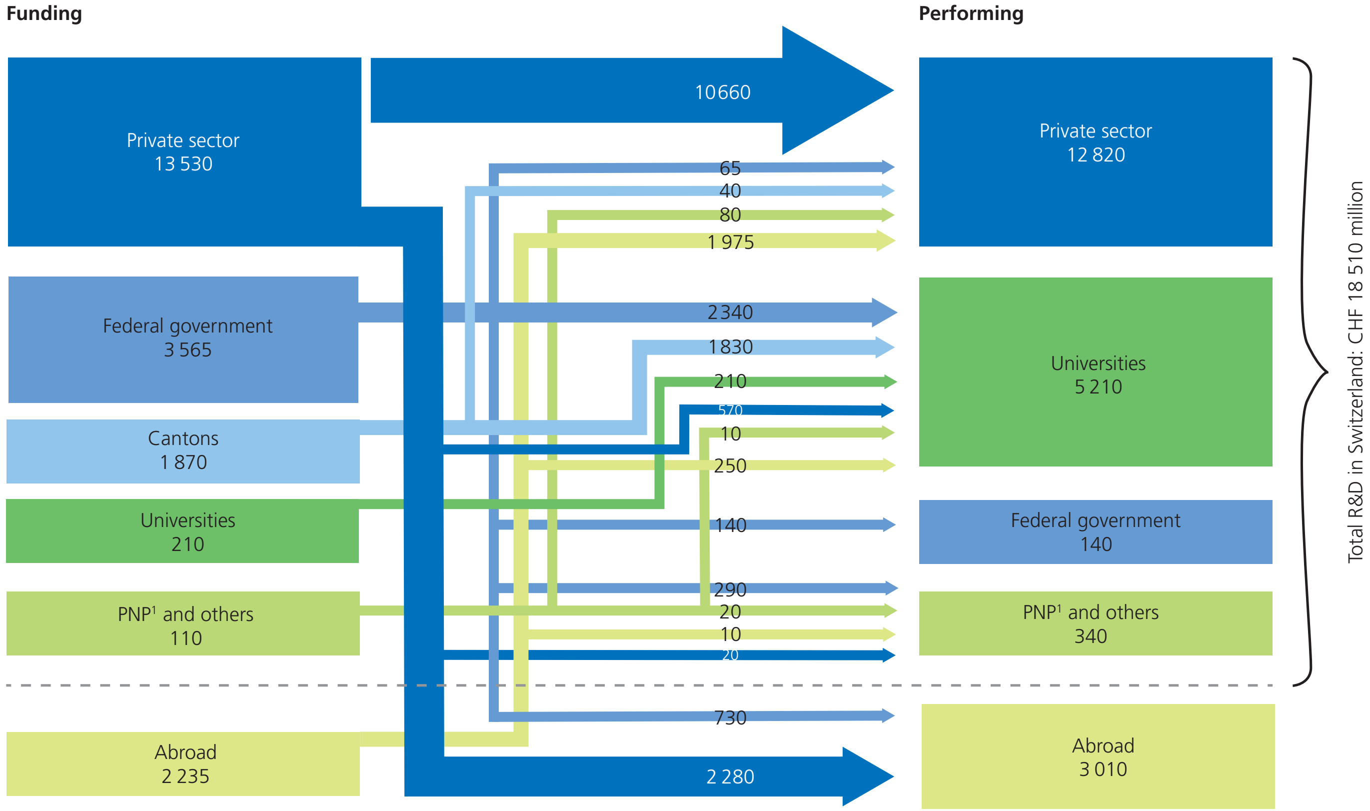
The business sector, the public sector, universities and other countries are all involved in both funding and performing R&D activities. It is possible for R&D activities to be funded from Switzerland and performed abroad, and vice versa. Universities and companies may also perform their R&D themselves or mandate outside actors to carry it out. Some research and innovation work is performed on a collaborative basis under national and international partnerships between companies, or between companies and public universities (public-private partnerships, PPP).

Figure A 2.3 provides an overview of the flows of funds between the individual sectors (data from 2012). It shows total flows of R&D funds in Switzerland and the volume of funding coming from or going abroad. The sources of funding for Swiss R&D are named on the left. The right-hand column shows the four sectors in Switzerland in which R&D is performed, plus one box for Swiss R&D activities outside Switzerland.

Private sector

The private sector contributed the lion's share within Switzerland's R&D realm in 2012, both in terms of funding (totalling CHF 13.5 billion, consisting of CHF 11.25 billion for R&D in Switzerland and CHF 2.28 billion for R&D abroad) and performing (CHF 12.8 bil-

Figure A 2.3: Funding and performing of R&D in Switzerland by sector, in CHF million, 2012 (excluding affiliate of Swiss companies abroad)



[1] Private non-profit organisations

Source: FSO (2014)

lion). Companies largely funded their own R&D activities themselves, although the self-financed proportion was down from 87% (2008) to 79% (2012).

In 2012, the private sector provided CHF 2.3 billion in funding for R&D performed beyond the Swiss border. Companies have been increasingly buying in R&D abroad since 2000. What is more, affiliate of Swiss companies abroad carried out CHF 15 billion in R&D in 2012 (see Section 2.2).

Public sector (federal government and cantons)

The public sector is engaged mainly in R&D funding. In 2012, the federal government and the cantons together funded 25% of national R&D activities. However, the federal government itself only carried out research amounting to 1% of total R&D expenditure in Switzerland. Of the CHF 5.4 billion in public funds, CHF 4.2 billion went to universities (CHF 2.34 billion from the federal government and CHF 1.83 billion from the cantons), with the remainder channelled into other areas. The federal government also financed international instruments of research promotion and collaboration in an amount of CHF 730 million, essentially comprising membership fees payable to international programmes and organisations. The main recipients were the European Union Framework Programmes for Research (FPs), the European Space Agency (ESA) and the European Organization for Nuclear Research (CERN). In return, these membership fees benefit researchers in Switzerland in the form of project grants and access to international networks and infrastructures.

Financed primarily with public funds, the universities are engaged mainly in the conduct of R&D. In 2012, universities invested CHF 5.2 billion in R&D, representing a share of 28% in gross domestic R&D expenditure. Over 80% of funds came from the public sector, as opposed to 10% covered by companies domiciled in Switzerland. FP subsidies paid to Swiss research groups represent a key source of third-party funding as well as a strategic element of research promotion at universities. The FPs complement national research promotion: Thanks to their systematic focus on international research collaboration, the FPs are designed to and indeed do provide a strong complement to the national instruments of research funding in place. These in turn play a crucial part in building up the capabilities needed to qualify for international funding.

Outside Switzerland

Actors from outside Switzerland provided CHF 2.2 billion in funding for research projects carried out in Switzerland in 2012. This corresponds to 12.1% of total expenditure on R&D in Switzerland and represents a significant increase in the previous ten years.

Almost CHF 2 billion of this amount was used for R&D in the private sector, chiefly in the form of mandates from companies within the same group. Universities received CHF 250 million from abroad in the same year. As mentioned above, these funds came primarily from European Union Framework Programmes. Conversely, Switzerland's private sector provided CHF 2.3 billion in funding for R&D activities abroad, mainly in the form of mandates to companies beyond the Swiss border.

In Switzerland, other actors (private non-profit organisations, e.g. foundations, etc.) play a comparatively minor role in terms of both the funding and the conduct of research.

2.2 Research and innovation activities in the private sector

As mentioned above, the bulk of research and innovation in Switzerland is carried out by companies in the private sector. In 2012, companies in Switzerland performed R&D amounting to CHF 12.8 billion (FSO, 2014). This represents 2.2% of GDP. 34% of all private sector spending was channelled into pharmaceutical and chemical R&D.

The main hallmarks of how research and innovation is performed in the Swiss private sector are:

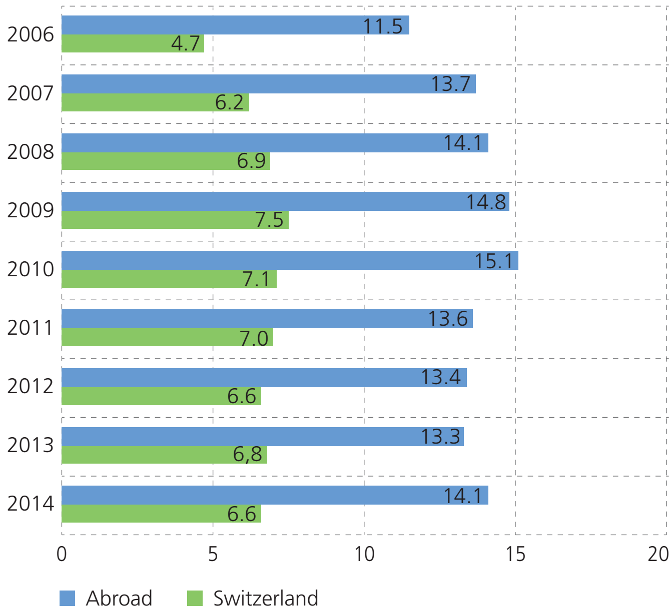
- A few large corporations in the pharmaceutical, chemical, machinery and food industries account for the majority of research and innovation efforts. Measured in terms of R&D expenditure, Hoffmann-La Roche (EUR 7 billion) and Novartis (EUR 6.9 billion) rank among the world's top ten corporate R&D players (European Commission, 2013).
- That being said, R&D collaboration between SMEs and large corporations is also significant. SMEs supply the large corporations with highly specialised components, which in turn allows the SMEs to integrate their R&D activities into these corporations' value chains and reach niche markets (see Part C, Study 2).
- Companies in technology-intensive sectors such as ICT are primarily interested in applied R&D and less in basic research.
- SMEs play a significant part. To a greater extent than in other European countries, their development input makes them a key factor behind Switzerland's innovation output (Arvanitis et al., 2013).
- Its broad mix of differently sized companies sets Switzerland apart from many other countries and is a particular boon in terms of innovation achievements.

International aspects of R&D activities in the private sector

The private companies invested heavily in R&D tend to be international players. This is clearly reflected in research expenditure of the top ten member companies of scienceindustries (Figure A 2.4).

Swiss controlled affiliates abroad performed R&D costing CHF 15 billion in 2012. This is higher than the amount spent by the private sector on R&D in Switzerland. While absolute R&D expenditure of Swiss controlled affiliates abroad increased by a significant 64.2% from 2004 to 2008 (partly due to the acquisition of research-intensive firms), it fell by 4.6% in the period from 2008 to 2012, but is still higher than R&D expenditure in Switzerland.[6]

Figure A 2.4: Research expenditure of the top ten member companies of scienceindustries in Switzerland and abroad, in CHF billion



Source: scienceindustries (2015; Business Association Chemistry Pharma Biotech)

Compared with earlier years (2004: CHF 9.6 billion) and given the increase in cross-border R&D mandates, Switzerland has witnessed far more R&D sharing with other countries and, as a consequence, much greater internationalisation on the part of Swiss R&D groups. 78% of mandates were awarded abroad and 22% in Switzerland, predominantly to other companies and only in small part to universities. Examples of research-intensive Swiss groups with a strong international focus include Hoffmann-La Roche, Novartis and Syngenta as well as ABB and Nestlé.

R&D personnel also attest to a high degree of internationalisation (FSO, 2014): 20,100 foreign nationals made up close on 40% of the total R&D personnel in the Swiss private sector in 2012. The percentage was 47% in the highly research-intensive chemical and pharmaceutical industries, contrasting with only 21% in the food sector.

[6] When interpreting expenditure on R&D performed abroad, the strong appreciation of the Swiss franc between 2008 and 2012 (in particular against the euro and the US dollar) must be factored in. Since R&D performed abroad was stated in Swiss francs by respondents, the figures are impacted by exchange rate fluctuations that are not quantifiable but may still influence the result (FSO, 2014).

2.3 New businesses

One way to bring knowledge and new technologies to the market is to establish companies that are seeking to garner success with innovative business models that are frequently based on new technologies. Their economic significance lies less in the number of newly created jobs than in the business momentum that they generate. New businesses can be freely created on the market, formed via spin-offs from research institutes (mainly universities) or through management buyouts, where management purchases all or some of the company's assets and operations from the previous owners.

Switzerland numbers some 578,000 companies (2013). Each year around 12,000 new companies are founded, more than 80% of which are in the tertiary sector. However, half of these companies do not survive longer than five years (FSO - Company demographics).

Between 35 and 45 spin-offs and start-ups emerge from the ETH Domain annually, chiefly in the high-tech sector. Their survival rate is well above average. Under its CTI Start-up Programme, the CTI accepts between 65 and 75 start-ups for coaching each year and issues just under 30 labels.

Despite Switzerland's dynamic venture capital market, numerous founders encounter funding problems in the early stage. This is because venture capital companies and other investors tend to shy away from the high risks and uncertainties associated with this particular phase. To what extent Switzerland faces a lack of venture capital is a matter of contention.

Venture capitalists: examples
While venture capital commitments are low overall in the banking sector (SECO, 2012), there are individual banks that support newly created businesses. Aside from the cantonal banks traditionally operating in this area, Credit Suisse, for instance, provided venture capital to the tune of CHF 100 million in 2010, funding the Swiss Venture Club (SVC) via a long-term strategic partnership. The Venture Incubator (VI) also supports promising start-ups with capital, consulting and networks. Established in 2001 by McKinsey & Company and ETH Zurich, VI manages a CHF 101 million investment fund. Attractive start-ups also arouse the interest of international venture capital investors operating in Switzerland. Furthermore, in 2014, Swiss parliament approved the Graber motion (13.4184), which requires the Federal Council to examine the establishment of a private sector future fund using pension fund assets, the objective being to improve venture capital funding for young entrepreneurs. The question of whether and how a private future fund can be set up under existing structures is being discussed in a working group made up of federal representatives. The working group is engaged in extensive idea sharing with pension funds and representatives of the venture capital industry.

In the medium term, politicians can best serve entrepreneurs by promoting favourable business conditions, i.e. lean procedures for the creation of new businesses, innovation-friendly company and bankruptcy laws, an attractive tax system as well as clear and simple legislation for the protection of intellectual property and licences. With these conditions in place, Switzerland was placed 20th in the World Bank's ease of doing business rankings for 2014 (behind e.g. Germany at rank 14). Providing fertile ground for future innovations and nurturing a greater awareness of entrepreneurial activities, Switzerland's well-organised and well-funded education and research system provides advantageous conditions for the creation of new businesses.

2.4 Activities at universities and the role of vocational and professional education and training

Domain of the Federal Institutes of Technology and cantonal universities
The domain of the Federal Institutes of Technology (ETH Domain) is one of the key engines of the technological and scientific implementation of knowledge in Switzerland. Its activities mainly embrace areas of strategic importance to Switzerland's competitiveness, e.g. the life sciences, nanotechnology, and ICT. ETH Zurich and EPFL jointly numbered almost 28,000 students in 2014, including some 6,000 doctoral students. These are the only two higher education institutions outside the UAS sector to offer engineering syllabuses.

A total of 116,000 students were enrolled at the ten cantonal universities in 2014, almost 18,000 of whom were doctoral students. Albeit in different constellations, the cantonal universities have faculties and institutes in the areas of law and social sciences, mathematics and natural sciences, the humanities, economics, and medicine. In common with the ETH Domain, basic research is among the core activities of the cantonal universities, forming the foundation for first-rate university teaching in addition to successes in terms of knowledge and technology transfer.

By international comparison, Switzerland's academic system produces outstanding results. The majority of students in Switzerland are enrolled at an ETH institute or cantonal university among the world's top 200 in various international rankings. Measured according to the impact of a country's scientific publications in various fields of research, in the period 2007–2011, Switzerland ranked 1st in the three areas "technology, engineering and information sciences", "physics, chemistry and geosciences" and "agriculture, biology and environmental sciences", 3rd in the life sciences, 4th in the social and behavioural sciences, and 7th in clinical medicine (SERI, 2014a).

Universities of applied sciences
The seven public UAS had a total student count of 70,000 in 2014 (excluding students at the universities of teacher education). The UAS put together the initial education and continuing education

and training programmes to supply the labour market with a suitably qualified workforce. Approximately two thirds of engineers in the Swiss business sector are UAS-educated (see Part C, Study 4).

The UAS are also heavily engaged in applied R&D, which they closely align with the needs of the business sector, society and the arts, and in so doing play a vital role in translating knowledge into marketable innovations. In particular, the UAS work hand in hand with SMEs, as well as public and semi-public institutions in the areas of healthcare, welfare and the arts. With their strong regional presence and reach, the UAS are a productive and indispensable partner to Switzerland's innovation-driven business sector with its strong SME base.

The UTE trained a total of 19,500 teachers in 2014. UTE address questions of organisational and teaching methodology, subject didactics, the psychology of learning, the education system and its actors. Their research and evaluation findings create the basis for the ongoing evolution of lessons and schools, teaching professions, and evidence-based educational policy decisions. The pedagogical and subject teaching research they conduct fosters new methods and theoretical standards in teaching.

Vocational and professional education and training

University graduates are not the sole key drivers of corporate Switzerland's innovative and competitive leverage. Skilled workers who have completed a vocational apprenticeship, some of whom have gone on to earn tertiary professional qualifications, are also vital. They are instrumental in making innovations marketable and implementing them.

In Switzerland, vocational and professional education and training takes place at the upper secondary (vocational education and training) and tertiary (professional education) levels. It provides an equally valuable adjunct to general education and the more academic university curriculums.

The fact that vocational and professional education and training is fully integrated into the entire education system offers a high level of flexibility. The principle of no dead-end qualifications applies both within and between the vocational and professional education and training sectors and the general or university education sectors.

Vocational and professional education and training in Switzerland is very much geared to the labour market. Organisations in the working world define and update the content of professional initial education and continuing education and training programmes to ensure that they meet the actual needs of the labour market.

Approximately two thirds of young people begin their working careers with vocational education and training (upper secondary level). Dual training at the workplace (practice) and vocational school (theory) is the most common type of vocational education and training in Switzerland. Companies play a central role in aligning training to the labour market by integrating trainees into real work processes. Trainees are already productive during their apprenticeships. Training also pays dividends for companies, particularly in terms of securing the next generation of skilled workers and, in many cases, it also pays off financially. A 2009 survey showed that gross training costs amounted to CHF 5.3 billion as against productive output of CHF 5.8 billion, equating to a net benefit of CHF 0.5 billion for companies (Strupler & Wolter, 2012).

Following on from vocational education and training, professional education at tertiary level allows professionals holding a Federal Vocational Education and Training Diploma or equivalent to specialise and acquire advanced qualifications, including management diplomas.

With around 64,900 trainees successfully completing basic training each year and some 25,500 skilled professionals earning higher vocational qualifications, the business and administration sectors can draw on a pool of proven skilled workers with recognised federal qualifications. Vocational and professional education and training is an essential part of the process of producing well-qualified specialists equipped to work along the entire value chain, a factor that is critical to Switzerland's research and innovation capabilities.

2.5 Federal Government Research

Professional administrative work and the systematic handling of complex policy situations demand well-founded scientific knowledge. This knowledge is acquired in part through Federal Government Research, which the administrative offices either conduct themselves or commission universities or private companies to carry out.

The federal government operates its own research institutes and so has the R&D resources and the capabilities to conduct R&D. Among the federal offices that carry out R&D are Agroscope, a research station attached to the Federal Office for Agriculture, and MeteoSwiss, the national weather and climate services provider. On the other hand, under the mantle of Federal Government Research, the federal government also awards outside R&D contracts and grants as a means of promoting research (see Section 3.1.2).

2.6 Interaction between research and innovation actors

Collaboration between companies and between companies and universities is becoming increasingly important for innovation success. The capabilities and services of partners can be strategically deployed to actively enhance an innovator's own innovation potential.

Interaction of this kind is witnessed to varying degrees in Switzerland. Switzerland is one of the five most innovative economies in Europe (in order of ranking: Switzerland, Sweden, Denmark, Finland, Germany; European Commission, 2015). While in terms of public-private co-publications Switzerland performs well compared with the countries named, measured by collaboration among innovative SMEs it is well below the mean for these same countries (European Commission, 2015). The significance of this last indicator is put into perspective by the fact that Swiss SMEs score well on an international comparison when it comes to the launch of innovative products or processes (Foray & Hollanders, 2015).

Knowledge and technology transfer (KTT) is the exchange, provision and transmission of information, competencies and R&D results between universities and research institutes on the one hand and societal institutions (such as companies and pubic administration) on the other. The objective is to initiate and reinforce innovation processes, with partners focusing on the commercial exploitation of available and/or jointly created knowledge.

The legal framework expressly provides that services and KTT are among the tasks of ETH Zurich, EPFL, cantonal universities and UAS. Since KTT traditionally centres on research and teaching, the main proponents are well educated graduates working in the corporate sector ("brain transfer"). Over the past ten years, KTT has been continually enhanced and increasingly institutionalised and formalised.

With Switzerland a member of the European Space Agency (ESA), the federal government is pursuing a space technology policy that likewise explicitly requires KTT and promotes it via the ESA's technology development programmes. The federal government also uses ESA channels to engage in KTT from the ESA's institutional programmes to the commercial market. Supplementary national measures are also being implemented to promote KTT in the space technology sector.

Also of significance is knowledge transfer from the domains of healthcare, welfare, the arts, the humanities and the social sciences in the form of consulting, situation appraisals, analyses and potential solutions offering innovative prospects for areas of society.

Technology transfer offices

The technology transfer or KTT offices of research institutes and education establishments source experts in the field within and outside their institutions for R&D projects, they identify and evaluate research results with commercial potential, define an exploitation strategy in consultation with the researchers and implement it jointly with the latter and companies in the business sector.

There are three different types of institutional KTT office in Switzerland:

- The KTT office serves as a central administrative or specialist unit that is fully integrated into the university. This is the form chosen by the majority of such universities, e.g. "ETH transfer" at ETH Zurich.
- The KTT office is integrated into the university, but its activities are carried out mainly on a decentralised basis in the various departments and in connection with outside KTT mandates. This type of organisational model is seen at several UAS.
- KTT is funded under a collaborative venture between several universities. A company, co-owned by them, is mandated to serve as external KTT office to oversee and drive transfer processes. Unitectra AG, set up jointly by the Universities of Zurich, Berne and Basel, is an example of this type of solution.

The Swiss Technology Transfer Association (swiTT) is the association of technology transfer professionals who are primarily engaged in collaborations between public and private research institutes, hospitals and other non-profit research organisations. The association facilitates KTT networking between research institutes and the business sector. Members and other KTT actors in the academic and business sectors benefit from professional support and development accompanied by a broad range of services. swiTT keeps a dialogue going with research institutes, businesses and administrative agencies to help secure optimum conditions for KTT. The association maintains the only comprehensive list in Switzerland of technologies offered by universities to the private sector.

Centres of technological excellence and public-private partnerships

Centres of technological excellence according to Art. 15c RIPA also have a technology transfer mandate and an associated strategy. As a rule, they are legally independent non-university research institutes of national significance that work together with universities and the private sector. Examples include the Centre suisse d'électronique et de microtechnique (CSEM), Campus Biotech Geneva and inspire AG, which is active in the area of mechatronic production systems and manufacturing technology. Positioned at the interface between (university) research and practical business application, these centres make a major contribution to KTT.

Centres of technological excellence are financed according to the matching funds principle: The federal government can furnish them with basic funding if cantons, other public bodies, universities or private entities also make a substantial contribution. The law provides for collaboration on a non-commercial basis. Accordingly, revenues from patents or the assignment of rights of use to third parties must be re-invested.

In general, the KTT potential offered by public-private partnerships between universities and the private sector is being increasingly tapped into in Switzerland. The European Space Agency ESA is implementing more and more programmes in the form of public-private partnerships in which Swiss companies are actively participating as consortium members. One such initiative is ESA BIC Switzerland, put in place to develop a business incubation and acceleration centre for start-ups which are active in space technologies or transfer and apply them to non-space technology areas. This model, which is co-financed subsidiarily through the ESA membership fees paid by the federal government, envisages the gradual phasing out of funding, namely by using profits earned on successful start-ups to re-finance new start-up ventures. This spreads both the risk and the success between public and private partners.

Swiss Innovation Park

Swiss Parliament defined the idea of a Swiss Innovation Park as a federally harmonised national network with various locations and enshrined it in the RIPA: "The innovation park serves a greater national interest, competitiveness, resource efficiency and sustainable development" (RIPA, Art. 32, para. 1, let. a).

The Swiss Innovation Park is a revenue-generating project to secure private R&D investments and the long-term sustainable strengthening and dynamisation of Switzerland in the face of international locational competition. The underlying aims are to make networking between the science and business communities even better, to create optimum innovation-friendly conditions for local companies and researchers, and to encourage new actors to locate here. Internationally recognised, highly productive companies with a strong and busy research and innovation track record need to be won over for the project.

The initial configuration of the park as at 1 January 2016 consists of two hub locations in the vicinity of the two Federal Institutes of Technology and three network locations in the canton of Aargau, in Biel/Bienne and in north-western Switzerland. The concept and implementation of the Swiss Innovation Park are intended to complement and strengthen the existing tried and proven innovation system and the various regional subsystems. The design and organisation are flexible enough to allow a dynamic development of the Innovation Park. In accordance with the provisions of the RIPA, the Swiss Innovation Park Foundation was set up in spring 2015 by private individuals as the park's umbrella organisation.

The local site sponsors (cantons), the private sector and the universities involved will be responsible for the operation of the Swiss Innovation Park.

3 Research and innovation promotion: Instruments and measures

3.1 Public sector and foundations in Switzerland

3.1.1 Federal promotion institutions

The Swiss National Science Foundation (SNSF) is the federal institution for the promotion of research. The Commission for Technology and Innovation (CTI) is the federal agency responsible for the promotion of science-based innovation. Serving in an advisory role, the Swiss Academies of Arts and Sciences seek to foster a dialogue between the science community and society.

The small number of promotion institutions in Switzerland contrasts with other European countries such as France, Germany and the UK, which have a great many more promotion agencies. The fact that Switzerland's institutions are financed entirely with federal funds is something else that sets the Swiss model apart from many of its foreign counterparts. For instance, the Deutsche Forschungsgemeinschaft (DFG), Germany's equivalent to the SNSF, is co-funded by the German states.

Swiss National Science Foundation

The SNSF is Switzerland's foremost institution for the promotion of scientific research and young scientists. All scientific disciplines from history to medicine to engineering have access to SNSF grants.

The SNSF's strategic goals are derived from its Statutes and mission statement:

- Support high-quality research as well as researchers in their quest for excellence.
- Bring research funding closer into line with the researchers' needs.
- Support the spread of knowledge in society, the economy and politics and demonstrate the value of research.

To ensure its independence, the SNSF was established as a private foundation in 1952. Based on a multi-year programme with research priorities, a service level agreement between the SNSF and the SERI stipulates the binding goals and performance indicators for the relevant four-year period. Both parties regularly monitor goal attainment.

The SNSF meets the multi-faceted needs of researchers. Its promotion activities are directed at two research categories, as reflected in its multi-year programmes. The SNSF primarily promotes pure basic research (research contributing to a general gain in knowledge without any specific application or exploitation) and not applied research aimed at the direct exploitation of results for commercial purposes. The broader impact of the category "use-inspired basic research" is also factored in as an evaluation criterion and outside experts working in the field are called in as reviewers.

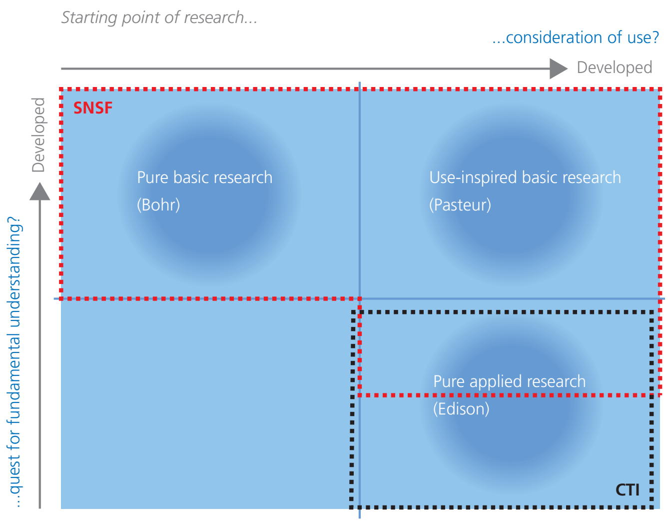
The SNSF follows Pasteur's quadrant model (Stokes, 1997), which draws a distinction between research aimed at bringing about a general gain in knowledge and research which serves a specific application (Figure A 3.1):

- Research designed to produce a general gain in knowledge without any specific application or exploitation is referred to as "pure basic research".
- If the focus is on a specific application, we refer to "pure applied research". It contributes to finding practical solutions to problems and engenders innovations.
- Research combining both components is labelled "use-inspired basic research" (SNSF, 2010).

The SNSF has a broad range of research promotion instruments at its disposal. Funding is on a competitive basis.

The main instrument is project funding, for which the SNSF uses approximately half of approved grants under its service level agreement with the federal government. The SNSF creates the necessary leeway for innovative ideas by allowing researchers receiving project funding to freely choose the topic and scope of their research.

Figure A 3.1: Areas promoted by the SNSF and the CTI, broken down according to the model "Pasteur's Quadrant – Basic Science and Technological Innovation"



Source: SNSF (2010), edited by SERI

In the case of other funding vehicles, the general thematic, conceptional and organisational parameters are prescribed. This applies in particular to the National Research Programmes (NRP) and the National Centres of Competence in Research (NCCR):

- NRP generate scientific knowledge aimed at solving Switzerland's most pressing problems. Limited on average to a period of five years, they are solution-driven and therefore qualify as applied research. KTT is a prime objective. The topics are specified by the Federal Council on the basis of calls for proposals open to all scientific disciplines and the subsequent evaluation of the proposals received.
- NCCR, on the other hand, support the long-term establishment of centres of excellence and networks in research areas of key strategic importance for the future of Switzerland's scientific community, business sector and society, e.g. the nano sciences, life sciences, robotics, climate and democracy. With a longer timeframe of approximately ten years, NCCR are designed to help create a powerful research structure. The funding framework for NCCR is decided by Parliament. In addition to the federal contribution allocated, it is imperative that NCCR receive co-funding from universities and third parties. NCCR topics are likewise stipulated by the Federal Council following an evaluation process and referred to the SNSF for execution.

Other SNSF programmes currently ongoing are focused on collaborative projects, clinical research and international cooperation.

The training of young scientists is a core responsibility of the SNSF. Each year it supports some 4,500 doctoral students and 2,500 postdocs through projects and programmes. The SNSF's career promotion efforts are aimed at supporting young talents specifically from the dissertation stage up to an assistant professorship – e.g. through fellowships abroad or SNSF professorships. Other new career assistance measures designed to improve conditions for the rising generation of scientists in Switzerland include support grants for young SNSF-funded researchers with families, or individual and flexible supplementary career development subsidies in the form of gender equality grants for young women researchers being funded by the SNSF.

At international level, the SNSF also provides funding to facilitate cross-border collaborations entered into by research groups and institutions. The SNSF pursues two main objectives here: In the context of collaborations with industrial and emerging countries, and as far as the instruments at its disposal allow, the SNSF aims to support existing partnerships, smooth the way for new initiatives and help Swiss researchers gain access to international research programmes. In respect of developing and transitioning nations such as the former Eastern bloc states, the goal is to secure access for Swiss researchers to local research groups and help raise scientific capabilities in these countries to international standard.

Commission for Technology and Innovation

The CTI is the federal agency for the promotion of innovation. It encourages science-based innovation and the development of new products, procedures, processes and services for the business sector and society through research (predominantly applied research) and the exploitation of its results.

The CTI has the status of a federal commission with decision-making powers. It is affiliated to the EAER. It forms part of the decentralised Federal Administration and has the autonomy to act at its own discretion. Acting on behalf of the EAER, SERI agrees multi-year funding programmes with the CTI. SERI also assumes any sovereign tasks in this dossier, including the negotiation of international agreements in the area of innovation promotion, drafting principles of federal innovation policy and evaluating the CTI and its funding activities. Work is currently underway on an organisational reform of the CTI that is scheduled to enter into force in 2018. In November 2015, Federal Council referred its Dispatch on the Federal Act on the Swiss Innovation Promotion Agency (Innosuisse Act) to Parliament. The bill is intended to put in place the legal basis to transform the CTI into a public-law entity.

The core task of the CTI is to provide project funding which, as a general rule, is available to all disciplines. Approval of an application for project funding hinges mainly on the innovative content and the prospects for effective implementation of the research findings to the benefit of the business sector and society. A further condition is that the project is unlikely to be realised without federal project funding. CTI project funding is also contingent on the formation of an alliance between a higher education institution or non-commercial research establishment and one or more private or public sector partners willing to assume responsibility for exploitation (implementation partners). This latter stipulation ensures that CTI projects directly drive KTT. Funds are allocated exclusively to public sector partners and are used mainly to cover personnel expenditure. Implementation partners are required to co-fund at least half of the project with their own resources plus, as a rule, a cash contribution of minimum 10%. Exceptions are possible. Research funding in Switzerland in general and from the CTI in particular is, in principle, not paid directly to companies.

In addition to its core role as project funder, the CTI also performs the following innovation promotion tasks:

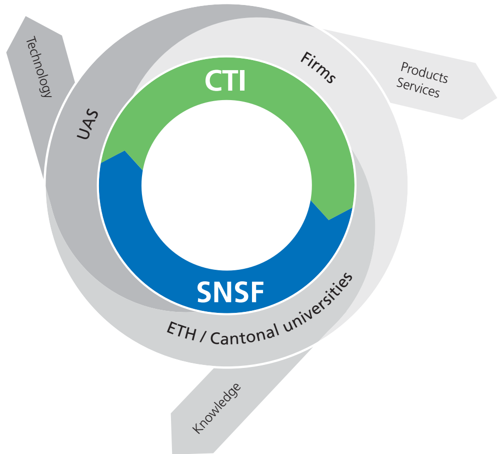
- The CTI provides coaching and continuing education and training opportunities in order to promote science-based entrepreneurship in Switzerland and support the founding and establishment of science-based companies.[7]
- SMEs can apply for a CTI innovation cheque worth CHF 7,500 to help fund minor preliminary project studies.
- Through its participation in international bodies and programmes, the CTI also engages in the conception, planning and implementation of R&D promotion activities and the evaluation of international projects, unless another agency is responsible under international treaties.

[7] The CTI Start-up initiative supports start-ups with coaching and network-based platforms. CTI Entrepreneurship is a parallel initiative designed to foster entrepreneurship in knowledge-intensive and technology-based areas.

During the 2013–2016 funding period, the CTI is deploying three instruments designed to promote KTT between companies and universities and sustainably support Swiss innovative activities in the Swiss corporate sector:

- National thematic networks (NTN): NTN are nationwide networks specialising in a specific innovative topic. They put companies in touch with researchers at universities, provide access to infrastructures and promote collaborations with suitable research institutes.
- (Regional) innovation mentors: CTI innovation mentors with a professional background in research and business inform SMEs of the innovation funding opportunities open to them in Switzerland and provide help in drawing up applications for project funding.
- Information and networking via thematic platforms: KTT platforms bring representatives of the business and science communities together and connect innovation mentors and national thematic networks both physically and interactively.

Figure A 3.2: Partnership in the innovation process



Source: SNSF

Collaboration between SNSF and CTI

Under their legal mandates, the SNSF promotes scientific research and the CTI science-based innovation.

The lines between the two are fluid. At the SNSF, promotion centres on gaining scientific knowledge. The focus of promotion at the CTI is on the development of new products, procedures, processes and services. Whereas the participation of a paying implementation partner as a condition of funding clearly sets the CTI apart from the SNSF, there is nonetheless some overlap in terms of promotion. In such cases the CTI and SNSF coordinate their strategies, resulting in numerous fields and forms of collaboration, e.g. under Switzerland's Coordinated Energy Research action plan from 2013 to 2016. A further goal of collaboration is to close research funding gaps between pure basic research to gain knowledge (financed by the SNSF) and directly applied research for the purpose of implementation and marketing (frequently financed by the CTI).

While the SNSF and the CTI essentially have different and complementary task profiles, both organisations welcome funding applications from all specialist areas and disciplines. Neither the SNSF nor the CTI applies quotas in favour of universities, individual research institutes or regions. The decisive criterion is not the provenance (e.g. cantonal university, ETH or UAS), but the content, primary objective and quality of the projects. However, practice shows that the majority of funding applications for projects from universities are submitted to the SNSF, whereas most UAS submissions go to the CTI.

Swiss Academies of Arts and Sciences

The Swiss Academies of Arts and Sciences receive approximately CHF 30 million in funding annually from the federal government and also have a service level agreement with the latter. The academies are committed to fostering a dialogue between the science community and society at large and they advise policymakers and civil society actors on socially relevant science-based issues. They represent the sciences across institutions and disciplines. Established in the scientific community, the academies have access to excellence and expertise, which they draw on to address overarching questions of concern for that community (scientific culture, infrastructure planning, etc.), to inject specialist know-how into key political discussions, to engender a fundamental understanding of science on the part of society and to promote debate with its members.

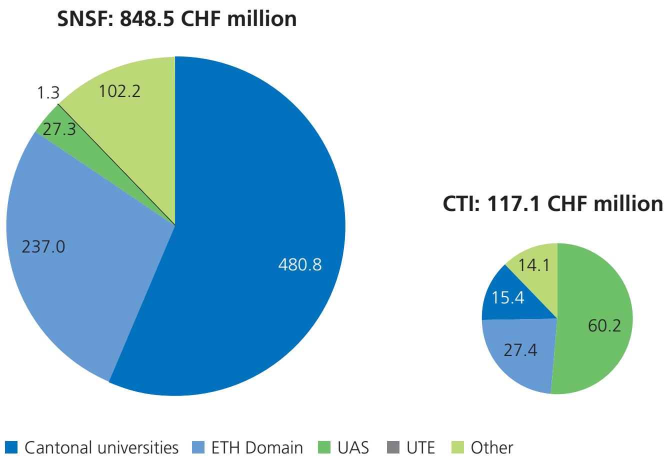
The Swiss Academies of Arts and Sciences comprise the Swiss Academy of Sciences (SCNAT), the Swiss Academy of Humanities and Social Sciences (SAHS), the Swiss Academy of Medical Sciences (SAMS) and the Swiss Academy of Engineering Sciences (SATW). Affiliate organisations include the Centre for Technology Assessment (TA-SWISS), the foundation Science et Cité (a low-threshold interface between scientists and the public), as well as other scientific networks.

3.1.2 Federal Government Research

Federal Government Research is initiated by the federal government when it needs the relevant findings to be able to fulfil its tasks (see Section 2.5). The federal government has its own research facilities for this purpose, but it also gives funding to outside parties and conducts its own research programmes in collaboration with university research institutes and research and innovation promotion agencies.

The federal government also awards research contracts (contract research). These contracts are usually for expert assessments and opinions or for follow-up studies to review the efficacy of ratified political measures. Federal Government Research also provides the federal government with a conduit to engage in research promotion. It can award contracts for practically all types of scientific research, from basic or applied research to near-market development, such as the engineering of pilot and demonstration facilities.

Figure A 3.3: SNSF and CTI funding commitments, by institution, 2014[8]



Source: SNSF and CTI

Over 30 federal offices are involved in Federal Government Research, which, in the interests of optimum coordination, has been divided by the Federal Council into eleven policy areas. Normally covering a four-year period, a research concept is drawn up by the lead government office, aided by outside scientific consultants, for each of these policy areas. SERI is responsible for coordination. In 2014, the federal government invested around CHF 286 million in Federal Government Research.

3.1.3 Regional innovation systems under the federal government's New Regional Policy

Regions are playing an increasingly significant role in innovation promotion (OECD, 2011b) on account of inter-regional disparities in competitiveness and innovative capabilities within a country. An international cross-comparison shows that Switzerland has for several years been ranking high in various innovation ratings, while the share of innovating companies differs according to type of region (regiosuisse, 2014).

Since coming into force in 2008, the federal government's New Regional Policy – under SECO's stewardship – has been directed at making the regions more competitive by promoting regional innovation and entrepreneurial momentum.

In order to take into consideration the different needs of the broad SME base in the regions and be able to lock into the available innovation potential, the New Regional Policy (in keeping with the OECD recommendation in its Territorial Review of Switzerland 2011, OECD, 2011a) takes a holistic view of innovation, which embraces scientific as well as knowledge-based innovations.

Coordinated with the CTI, the promotion of innovation in the regions is a priority of the federal government's next regional policy programme (2016–2023). The objective is to increase innovation dynamism in the regions by making regional innovation systems (RIS) stronger. RIS need to have critical mass if they are to deliver an effective and efficient services portfolio and at the same time be sufficiently close to the SMEs. From the federal government's perspective, Switzerland has the potential to accommodate six to seven intercantonal and partly cross-border RIS that are also coordinated with one another via their interfaces (Federal Council, 2015; SECO, 2012b). In the area of innovation promotion, the New Regional Policy provides incentives to ensure that the cantons funding an RIS improve coordination of the underlying promotion instruments, align them with a common innovation strategy and manage the RIS jointly. Particular focus is to be placed on improving the support options available to SMEs. Once all of this is achieved, the cantons can use regional policy to support the region's SMEs through customised programmes designed to help them realise their innovation projects.

A "no wrong door" approach should be taken towards companies. Regardless of which actor (e.g. cluster, business and economic development or technology transfer office) that they contact within an RIS, they should be referred to the appropriate network partner or partners to look after their specific needs.

Since regional policy is shared between the federal government and the cantons, the latter – in accordance with the principle of subsidiarity – are given considerable rein in the concrete formulation of their RIS programmes and the choice of services they offer. Services portfolios will therefore differ from RIS to RIS (e.g. clusters, innovation coaching, events, sector-wide coordination projects, skilled worker initiatives).

The vision is that the overall impact of the federal government's national innovation promotion efforts will be strengthened by tying in the regions and their complementary measures to foster regional innovation.

3.1.4 Cantonal R&D and innovation promotion

The large majority of cantons engage in innovation and business promotion, partly supported by regional policy measures. The services portfolio may include start-up support or the promotion of regional networks and clusters in close contact with companies (Hess & Klöpper, 2011) and in some cases specific coaching. The cantons operate through business and economic development offices of their own or in association with other cantons. These offices inform companies about the locational advantages of their canton, they maintain contact with investors, make location proposals, organise support for investors, and provide local customer

[8] SNSF figures relate to grants awarded in the funding categories projects, careers, programmes, infrastructures and science communication. In addition to the figures shown, in 2014 the SNSF set up Temporary Backup Schemes totalling CHF 92 million to make up for lost EU funding during Switzerland's temporary exclusion from the EU Framework Programmes for Research (following the adoption of the "Stop mass immigration" initiative on 9 February 2014). The CTI figures relate to commitments for approved projects as part of regular R&D project funding.

care. Various cantons offer tax breaks to promote business. The cantons also use their education and training establishments as vehicles to promote regional development.

Cantonal and regional innovation and business promotion: examples

Canton Aargau: The aim of the Hightech Aargau Initiative is to ensure that, going forward, Aargau remains fit-for-purpose as a production and research location. The goal is that new and existing companies profit from the optimum conditions and services that the canton provides in the area of innovation and technology transfer. Hightech Aargau promotes exchange and collaboration between SMEs, universities and research facilities, and large internationally oriented corporations.

Canton Berne: The canton promotes innovation activities in individual clusters within its business sector, including ICT, precision engineering, medical technology, energy and environmental technology, as well as design and luxury goods. It passes on certain tasks to technology brokers and business incubators, in some instances under service level agreements. In the case of CTI-funded R&D projects (prototype development) conducted by Bernese SMEs and start-ups, the canton also assumes part of the business financing that the latter are required to provide.

Canton St. Gallen: The canton supports innovation drives by companies carrying out projects aimed at specifically furthering KTT and generating momentum for future collaborations. It also runs an innovation office, which provides data on R&D partners and technology capabilities in the canton and region, as well as supplying information on networks and promotion programmes.

Canton Ticino: Cantonal legislation has been in place since 1997 to promote, where possible, all industrial and service companies engaged in commercial innovations. Support may be in the form of funding or of an indirect nature (support for industrial zones, consulting and intermediation, continuing education and training, creation of new businesses). Above and beyond this, under the auspices of its regional economic policy programme, the canton of Ticino established the Agire Foundation (Agenzia per l'innovazione regionale del Cantone Ticino) together with the local UAS (Scuola universitaria professionale della Svizzera italiana, SUPSI), the university (Università della Svizzera italiana, USI), the Camera di commercio, dell'industria, dell'artigianato e dei servizi (CC-TI) and the Associazione Industrie Ticino (AITI). Agire is a platform for KTT and entrepreneurial promotion, mainly in the area of innovative technologies.

Within the framework of regional policy, the cantons in French-speaking Switzerland have been promoting a joint entrepreneurship and innovation programme since 2008. One element of this joint innovation promotion venture is platinn, an association established under private law. Its Executive Committee is composed of business promoters appointed by the six participating cantons. platinn supports start-ups and SMEs in their innovation projects to help them develop their capacity to innovate and compete. Support is provided by a network of accredited coaches. If necessary, they will bring in specialists in areas such as intellectual property, strategy or finance. platinn coordinates a network of experts and partners themselves firmly rooted in the participating cantons. Cantonal antennas have the shortest and most direct access to local companies. They make platinn's support services known to start-ups and SMEs and coordinate these with cantonal instruments and promotion strategies. Selected and mandated by the respective cantons, the cantonal antennas are Fri Up (Fribourg), Innovaud (Vaud), CimArk (Valais), Service de l'économie (Neuchâtel), OPI (Geneva) and Creapole (Jura).

Cantonal banks

As active promoters of innovation, cantonal banks as well as some regional banks are also part of the innovation system. They offer special start-up funding and equity financing. A number of cantonal banks offer support in direct partnership with, say, a technopark or business angels. For instance, at the instigation of Technopark Lucerne, Luzerner Kantonalbank launched the venture capital firm Wachstumskapital AG, an innovative financing instrument for start-ups in the region. Members of the Technopark have already successfully presented several projects to the firm's investment committee. St. Galler Kantonalbank is engaged (including financially) in the STARTFELD Foundation, which provides early-stage start-up financing. Since January 2015, Berner Kantonalbank (BEKB) has offered an early-stage service on its electronic trading platform for unlisted Swiss shares. This new tool is intended primarily for trading in shares of fast-growing start-ups.

Cantonal banks are widely involved in competitions and sponsorships for particularly innovative firms. St. Galler Kantonalbank is a case in point, each year presenting an award for top entrepreneurial achievements that stand out in terms of innovative strength, sustainability and the substantial contribution they make to the location's appeal. The award goes to companies whose business activities also have implications for society at large in that they serve to enhance the region's well-being economically, ecologically and socially.

Various cantonal banks provide assistance in the form of start-up handbooks and models, e.g. "A business start-up guide" and "The ideal toolkit for entrepreneurs" from Banque Cantonale de Genève or the Berner Kantonalbank toolbox for SMEs and start-ups containing practical templates for day-to-day business.

3.1.5 Communal innovation promotion

The cities and municipalities also engage in innovation promotion. Business incubators and technoparks are fairly widespread. As a general rule - TECHNOPARK® Zurich being one example – they are privately financed, sometimes in cooperation with the public sector. Normally, a real estate firm provides a building, and an operating company selects innovative firms to use the premises and supports them with diverse services.

3.1.6 Foundations

Foundations also promote research and innovation. In 2013, almost 13,000 non-profit foundations enriched Switzerland's cultural, social and scientific life. Just under one fifth of them provided funding to universities (Eckhardt et al., 2015).

For example, the foundation Gebert Rüf Stiftung (established in 1997) defines its purpose as promoting Switzerland as a place to live and do business. With an annual budget of around CHF 10 million, it finances projects at Swiss universities. It supports innovation by promoting new methods and selected young scientists at start-ups and elsewhere during the "valley of death" phase, a lean period between public R&D funding and initial commercial loans. The Foundation's interest is directed at ambitious initiatives from qualified project managers wishing to break new ground.

The Swiss Cancer Research Foundation funds projects from the entire spectrum of oncological research, awards grants, supports Swiss research organisations and international organisations and stages scientific congresses and workshops.

Since foundations finance a large and varied array of research and innovation projects and apply widely diverging funding criteria, they are instrumental to the diversity of research and innovation promotion.

By way of illustration, the open support provided by the Hasler Foundation complements public funding instruments in cases where they cannot be accessed, be it for formal or material reasons.

3.2 International research and innovation collaboration

In 2010, the Federal Council defined its international strategy for R&D and innovation promotion and drew up long-term guidelines (SER & OPET, 2010). The underlying intention is to consolidate Switzerland as one of the world's most competitive ERI locations and to enter into cross-border collaborations to systematically create the conditions needed to achieve this. International instruments of research and innovation promotion complement the national instruments and give Swiss actors access to key international networks.

3.2.1 Cooperation with the European Union

Relations between Switzerland and the European Union (EU) in the areas of education, research and innovation are, where possible, defined on the basis of bilateral agreements.

European Union Framework Programmes for Research and Innovation

The multi-year EU Framework Programmes for Research, Technical Development and Demonstration Activities (Framework Programmes for Research, FPs) have been the EU's chief instrument for the promotion of R&D and innovation since 1984. FP funding is awarded competitively on the basis of Europe-wide calls for proposals.

The Research Accord of 2004 concluded subsequent to the Bilateral Agreements I afforded Switzerland "associated country" status, enabling it to participate widely in the 6th European Framework Programmes (Research and Euratom). The Accord was renewed for the 7th programme generation (2007–2013).

The follow-up programme "Horizon 2020 – The EU Framework Programme for Research and Innovation" from 2014 to 2020 has a budget of EUR 80 billion for research and innovation. The world's largest instrument for the promotion of research and innovation, it covers a broad spectrum of thematic areas (e.g. medicine, information technologies, the humanities and social sciences, the environment, nutrition, transport, aerospace). "Horizon 2020" is targeted at individual researchers, academic consortiums, companies and collaborations between the science and business communities. The main focus is on enhancing scientific excellence, on strengthening the European business sector's innovative capacity (including an increase in venture funding and innovation output within the SME segment) and on the contribution that research and innovation outcomes can make towards solving the central challenges facing society. As a cross-sectoral undertaking, Horizon 2020 also provides support for the European Institute of Innovation and Technology (EIT) with the aim of reinforcing collaboration between Europe's most productive institutes, universities and industrial research centres. Falling within the ambit of Horizon 2020, the Marie Skłodowska-Curie actions continue to provide travel grants for researchers.

Aimed at peaceful uses of nuclear power, the European Atomic Energy Community's Framework Programme for Research and Training Activities in the Nuclear Field (Euratom Programme) will run parallel and complementarily to Horizon 2020. Under a collaboration agreement, Switzerland (predominantly EPFL, the Paul Scherrer Institute and the University of Basel) has been participating in the Euratom Programme in the area of controlled nuclear fusion and plasma physics since 1978. Switzerland has also been working concurrently on the major International Thermonuclear Experimental Reactor (ITER) project in Southern France. Horizon 2020, the Euratom Programme and the ITER project together make up the so-called "Horizon 2020 package".

Participating in the Horizon 2020 package brings the Swiss research community many benefits. Researchers from Switzerland can work on international projects with the world's research elite since FPs are also open to researchers from e.g. the USA and China. The proportion of successful project applications from Switzerland has been exceptionally high, including for generous ERC grants awarded by the European Research Council which was introduced at the same time as FP7. As a partially associated country paying a GDP-based flat-rate amount into the overall budget for all FPs, Switzerland derives a net financial benefit since the competitively won EU grants have to date been higher than the flat-rate membership fee remitted by the federal government. It is, however, more difficult to assess the numerous positive research-based and network-specific scientific and technological consequences of Switzerland's participation in the FPs or the impact of the ensuing innovations on the Swiss economy. Switzerland's particular strengths within the FPs lie in the future-proof areas of ICT, healthcare and nanotechnology (SERI, 2014b).

The Euresearch information network is mandated by SERI to provide researchers from public institutions and the private sector with information and advice on participating in the European Union Research Framework Programmes. Euresearch is an association with a Head Office in Berne comprising the National Contact Points for the EU Research Framework Programmes, as well as Regional Offices providing consulting services at more than ten cantonal university locations.

In addition to Euresearch, the federal government also funds SwissCore (Swiss Contact Office for European Research, Innovation and Education), the liaison office for Swiss researchers and students in Brussels. Besides providing information and consulting services, SwissCore represents the interests of Switzerland's private and public sectors in questions of ERI policy vis-à-vis EU institutions and stakeholder groups in Brussels.

European Union educational and mobility programmes

International exchange and mobility contribute to strengthening the Swiss education system and labour market. The aim is to consolidate and enhance Switzerland's appeal as a location. From 2011 to 2013, Switzerland participated in EU educational, vocational and youth programmes such as "Lifelong Learning" and "Youth in Action" as an associated country. The goal of these programmes was to promote collaboration between educational and training institutions as well as the mobility of students at all educational levels in Europe. Replacing the earlier programmes, the follow-up programme Erasmus+ was launched in 2014. It runs until 2020.

Impact of the Europe debate

On 9 February 2014, the "Stop mass immigration" initiative was adopted in Switzerland. This stipulates the control of immigration by means of annual ceilings and quotas. From the perspective of the EU, this is in breach of the principle of the free movement of persons enshrined in the Free Movement of Persons Agreement.[9] This prompted the EU to review and clarify collaboration with Switzerland in the areas of education and research. Switzerland's status was relegated from "associated country" with membership rights to "third country" (Erasmus+) and "partially associated country" (Horizon 2020). For Switzerland as an education and research centre this was a step backwards which cannot be rectified by the transitional measures for Erasmus+ and Horizon 2020 implemented immediately by the Federal Council. It remains the declared aim of the federal government to re-attain full "associated country" status for Horizon 2020 and Erasmus+ at the earliest possible date. If Swiss Parliament does not ratify the protocol extending the Free Movement of Persons Agreement to Croatia (signed by the Federal Council on 4 March 2016) by 9 February 2017, Switzerland's "partial association" status for Horizon 2020 will lapse and its membership rights be downgraded to those of a third country. Conversely, if Switzerland ratifies the protocol in good time, its "associated" status will automatically be extended to the entire Horizon 2020 package with full access as an associated country as of 1 January 2017.

Innovation promotion through collaboration in European networks

Enterprise Europe Network (EEN) helps SMEs to establish collaborations, engage in KTT and forge strategic partnerships. 600 regional member organisations in over fifty countries offer individualised, confidential support. In addition to brokering contacts, EEN provides advice to SMEs on matters relevant to them in connection with transnational cooperation programmes. Switzerland is a self-funding member of EEN. Under a gradual change of direction in Switzerland from 2016 on, EEN is to provide even more direct support in the regions to SMEs initiating innovation projects with foreign partners. Backup will come from regional innovation systems already in place or under development as well as from the CTI and its partners. Responsibility for implementing the change lies with the CTI, which assumed the lead of the EEN Switzerland consortium at the beginning of 2016.[10]

3.2.2 Organisations, programmes and infrastructures for international research and innovation collaboration

In addition to participating in the European Union Framework Programmes, Switzerland is also a member country and active partner in other large intergovernmental organisations, programmes and infrastructures for international research and innovation collaboration. Being integrated into key international networks allows Swiss research and innovation actors to productively address questions together with international partners which would not have been possible alone. The tie-in with international networks also provides access to extremely costly experimental research facilities as well as to a very large pool of knowledge.

For instance, as a full member of the European Space Agency (ESA), Switzerland is entitled to take part in its programmes. It is one of the ESA founding countries and has jointly held the Agency chairmanship with Luxembourg from 2012 to 2016. ESA membership represents an R&D investment that contributes to promoting Switzerland's technological capabilities in the aerospace sector. As a return on Switzerland's membership fee, ESA contracts are

[9] As a result of the bilateral Agreement of the Free Movement of Persons concluded in 1999 between Switzerland and the EU, the basic principles of the free movement of persons as applied within the EU were also contractually agreed between Switzerland and the EU and introduced in stages.

[10] The Euresearch Association has been mandated by SERI to provide EEN services for the promotion of international innovation, while SECO-mandated Switzerland Global Enterprise (S-GE) is responsible for EEN services in the area of international business marketing support.

awarded competitively to Swiss companies and scientists in proportion to the fee. This is instrumental in developing and maintaining a specialised innovation-intensive industrial sector and creates jobs with high added value. ESA membership also promotes knowledge and technology transfer between research and industry as well as transfer out of the institutional European market into the global commercial market for aerospace technology and products.

Switzerland is also a member of the European Organization for Nuclear Research (CERN). CERN is a major basic physics research establishment. Huge particle accelerators are used to investigate the structure of matter. CERN's membership numbers 21 nations. A headcount of around 2,524 (end 2014) makes CERN the world's largest research centre in the area of particle physics. Over 10,000 guest scientists from 85 nations are working together on the various experiments. CERN's annual budget amounted to approximately CHF 1.1 billion in 2014.

An overview of the above and other examples of Switzerland's engagement in international research and innovation programmes, infrastructures and organisations can be found in the Annex.

What is more, Swiss researchers and companies can in some cases also take part in further international programmes, initiatives and infrastructures even where Switzerland is not a (full) member. Once such instance are the EU's Joint Technology Initiatives (JTIs), co funded under Horizon 2020. They are based on public-private partnerships (PPP) between the European Union and industry, focus on applied research and development and give SMEs and large corporations access to European research and cutting-edge technology. Another case in point are the EU's Joint Programming Initiatives (JPIs), which are designed to increase international collaboration by pooling the programming of national calls for proposals. The underlying rationale is to jointly address major Europe-wide social challenges that could not be tackled alone at national level.[11] The Framework Research Programmes (FPs) also encompass numerous other research and innovation initiatives, including the Future Emerging Technology Flagship Initiatives (FET Flagship Initiatives). The FET are large-scale long-term initiatives with a probable scale of action of around ten years and a budget of CHF 1 billion per flagship. Funding comes from the FPs and capital provided by the project partners and industry. Switzerland also participates in various ERA-NETs, which are likewise FP instruments. By strengthening transnational collaboration between research and innovation promotion organisations, ERA-NETs drive the networking of national and regional research and innovation programmes in specific thematic areas.

3.2.3 Bilateral research collaboration

Research collaboration with European countries is primarily under the mantle of multinational European research programmes and organisations. This Europe-centric multilateral foreign scientific policy is complemented by bilateral collaborations between Switzerland and non-European countries. Besides international scientific contacts via the ERI Network, the federal government has specific promotion programmes in place for research collaboration with priority countries. The objective of the bilateral research programmes is to strengthen scientific relations between Switzerland and the respective partner country in research areas of key strategic importance to both countries. Moreover, the international networking of Swiss tertiary and research institutions is intended to enhance their reputation abroad. Collaboration is based on the principles of scientific excellence, mutual interest and equally shared responsibility for funding. Bilateral programmes are currently ongoing with China, India, Russia, South Africa, Japan, South Korea and Brazil. In addition, various multilateral projects (with partners from China, Norway, France, USA, etc.) for the development of scientific instruments for aerospace research are being supported, plus a joint aerospace technology promotion project with partners from Austria.

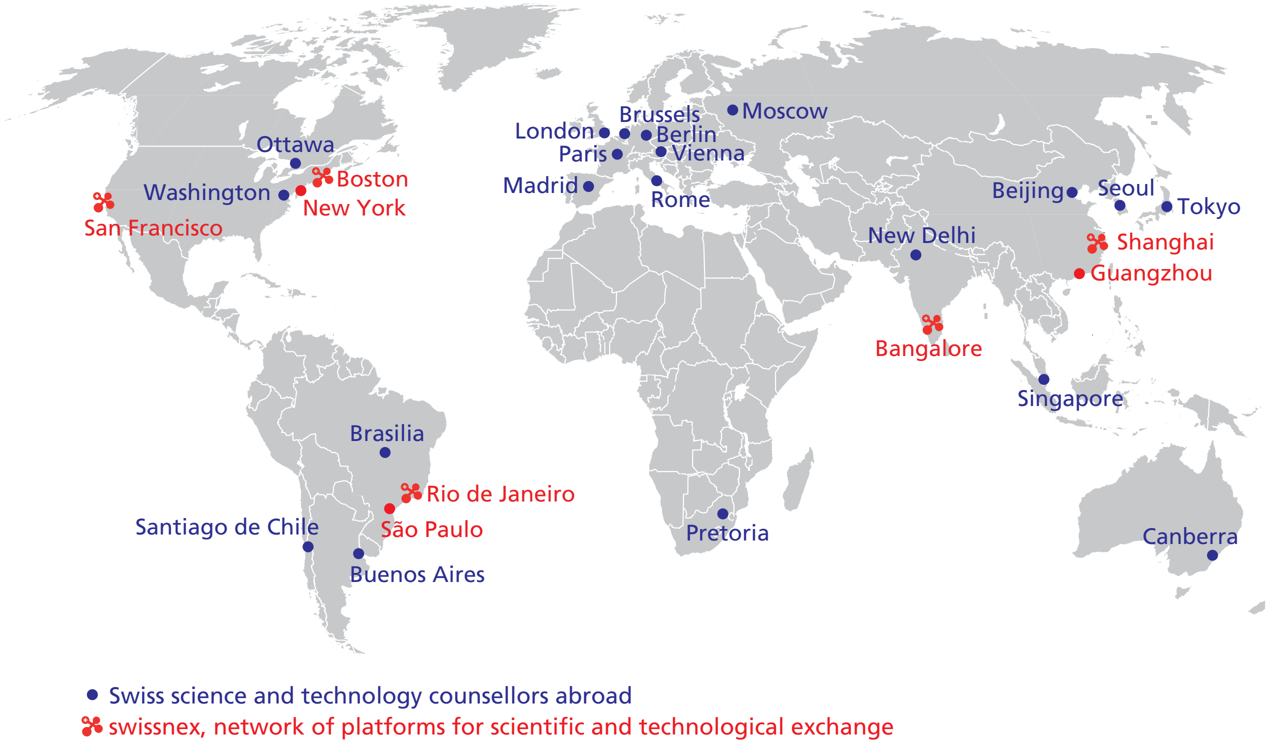
3.2.4 ERI Network and other federal tools with an international focus

In collaboration with and co-funded by the Federal Department of Foreign Affairs (FDFA), universities, the business sector, interest groups and private sponsors, SERI manages swissnex, a network of "scientific consulates" in Bangalore, Boston, Rio de Janeiro, San Francisco and Shanghai. Together with science and technology counsellors at 19 further locations worldwide, swissnex forms the ERI Network. As one of the federal government's international ERI strategy instruments, it supports and promotes the internationalisation efforts of Switzerland's universities, scientists, and companies with close links to research.

A further instrument is Switzerland Global Enterprise (S-GE), which has been mandated by the federal government to bundle service level agreements for export, import and promoting Switzerland as a business location. S-GE promotes the implementation and spread of innovations by helping SMEs looking for export outlets secure access to foreign markets. S-GE has 21 Swiss Business Hubs on four continents. Their role is to advise Swiss exporters and also to promote Switzerland as a business location abroad.

[11] Switzerland is participating in the following JPIs: Alzheimer and other Neurodegenerative Diseases (JPND); Agriculture, Food Security and Climate Change (FACCE); A Healthy Diet for a Healthy Life; More Years, Better Lives; Antimicrobial Resistance.

Figure A 3.4: ERI Network



Source: SERI

3.3 The federal government's basic stance on research and innovation policy

Given Switzerland's generally excellent positioning in the relevant global rankings, its research and innovation system appears well-structured with all the necessary core elements to ensure a high degree of effectiveness. In addition to structure, another crucial factor behind innovative leverage is the way that actors use the research and innovation system at their disposal and how they interact within it. This hinges largely on research and innovation policy, seen as the totality of promotion measures instigated by the public sector in this area.

The main focus of research and innovation policy is on the promotion of education and research in Switzerland. "Education policy is essentially built on two pillars: vocational and professional education and training (…) and academically based education (…). For the economy as a whole, this produces a good mix of different types of qualification – practical and application-oriented on the one hand, science-based and academic on the other – accommodating the realities of the business sector" (Hotz-Hart & Rohner, 2014). Research promotion places the emphasis on basic research, but does not neglect applied development. It follows in principle that the closer projects seeking funding are to the market, the less substantial state support should be. This is borne out by the fact that the annual federal contribution allocated to the SNSF is around seven times higher than the amount received by the CTI.

Unlike the EU Framework Programmes, public research and innovation funding in Switzerland does not entail direct payments to companies. What is more, there are no tax incentives for R&D activities, such as in the form of tax relief or indirectly via public procurement, as recommended by the OECD.[12]

Public research and innovation promotion decisions are informed primarily by researcher initiative, the principle of competition, and qualitative assessment criteria for applications: The bottom-up principle is predominant. Individual research teams or companies are expected to take the initiative for R&D and innovation activities and themselves assume the responsibilities and risks. Individual projects receive state funding on the basis of a competitive application process and an evaluation procedure that is focused on excellence. Applied research with a business bias generally shuns top-down programme funding. In the area of near-basic research, this does not rule out a priori a policy-led focus on key strategic themes, as the example of NCCR shows. However, key themes tend to materialise as part of a follow-up programme picking up and building on positive trends, which in turn come about as the result of bottom-up developments.

The bottom-up principle also goes hand in hand with the prevailing view that innovations are primarily the result of entrepreneurial actions and thus the archetypal task of companies. The private sector bears the main responsibility for innovation

[12] Reference is made to corporate tax reform (CTR III) under 1.1.

processes. Within a regulatory framework, it wants and should be given sufficient freedom to pursue these processes. The state limits itself to a subsidiary role, creating favourable conditions and an attractive climate for innovations, such as an effective education system and a high-calibre education and research infrastructure (enabling). State innovation promotion is directed at giving people opportunities, within their spheres of action, to develop their talents to optimum capacity and produce internationally competitive top achievements in selected areas. This includes ensuring that, measured against other countries, Switzerland enjoys great appeal as a location for innovative firms, researchers and skilled workers.

Switzerland has, in effect, a federal paradigm of innovation promotion (Hotz-Hart & Rohner, 2014). The central approaches and principles are as follows:

- The key driver of innovation is competition where the competitors are not only companies, but also universities and non-university research establishments. Innovation policy is aimed at allowing and respecting existing or newly forming competitive relationships between public and private actors in the innovation system. It ensures that state involvement in education and research distorts competition as little as possible. Recognising and upholding the autonomy of universities is a sine qua non.
- Innovation policy is directed at enhancing the flexibility and adaptability of actors in the business and university sectors, at sharpening their ability to absorb new ideas and at supporting the concomitant structural change. This includes driving the rapid implementation and dissemination of the state of the art (diffusion-oriented business policy). Given their economic significance and presumed potential to create value added and jobs, but also in light of their structurally rooted problems and bottlenecks, technology and export-oriented SMEs and start-ups are a particular target group for innovation policy measures.
- Innovations very frequently occur in networks of large corporations and SMEs, suppliers and customers, public and private research and innovation institutions, as well as education establishments, association and authorities. Innovation policy is geared to helping facilitate and improve collaboration in such networks. Good framework conditions create an important basis for research and innovation collaborations between universities and the private sector. The large majority of such collaborations come about directly between partners, without any direct federal involvement or funding.

As shown above, innovation policy touches on many policy areas, notably education and research policy, competition and labour market policy, location and regional policy, and finance policy. A further key source of momentum are sectoral policies such as the healthcare, environment, energy and transport portfolios. Innovation policy is cross-sectional and needs to factor in the connections and interactions between numerous policy areas and their actors. This calls for measures to be coordinated and synchronised.

In addition to having a materially diverse innovation policy, Switzerland's skill resources are spread across different institutions and actors, nationally over the three administrative levels of Confederation, cantons and municipalities, and internationally over states and communities. Coordination demands a considerable amount of time and expense and is one of the main obstacles to an effective innovation policy (Hotz-Hart & Kissling-Näf, 2013). Innovation policy in Switzerland is normally based on negative coordination (Scharpf, 1993), i.e. the review and avoidance or prevention of any negative influence of a decision variable on the status quo or the interests of other functionally related units.

An innovation policy founded on a universally recognised concept drawn up jointly by political and business proponents and with the explicit coordination of the actors involved does not exist in Switzerland, or only rudimentarily as recently seen in the Cleantech Masterplan, the Green Economy Action Plan or the strategy to strengthen the role of regional innovations systems (RIS Strategy) under the New Regional Policy. Any such stipulation goes beyond present practice.

Much of Switzerland's innovation promotion policy is implicit. The policies of different innovation institutions and actors reflect different priorities, e.g. economic growth, research excellence, energy efficiency, or sustainability. Since innovative activities are aimed at achieving these objectives, innovation policy is driven by a fragmented system in which various actors and institutions purse their own agendas. Efforts undertaken in different policy areas relevant to innovation output contribute indirectly to Switzerland's excellent innovative track record.

Funding from the private sector is a further hallmark of innovation promotion in Switzerland. Complementing federal grants, it is used to finance start-ups or support the scaling-up of start-ups in privately funded technoparks. Start-up launches are funded by different forms of public-private partnership, such as between the CTI (state) and CTI Invest (private).

This type of research and innovation promotion provides a solid context in the form of a strong educational and research base and attractive conditions for innovation activities, with very little state intervention and regulation by international comparison. Given the immense challenges and pitfalls that blanket coordination of the various policy areas would bring, this is most likely the optimum pragmatic approach for Switzerland.

Annex

International programmes, infrastructures and organisations with Swis participation

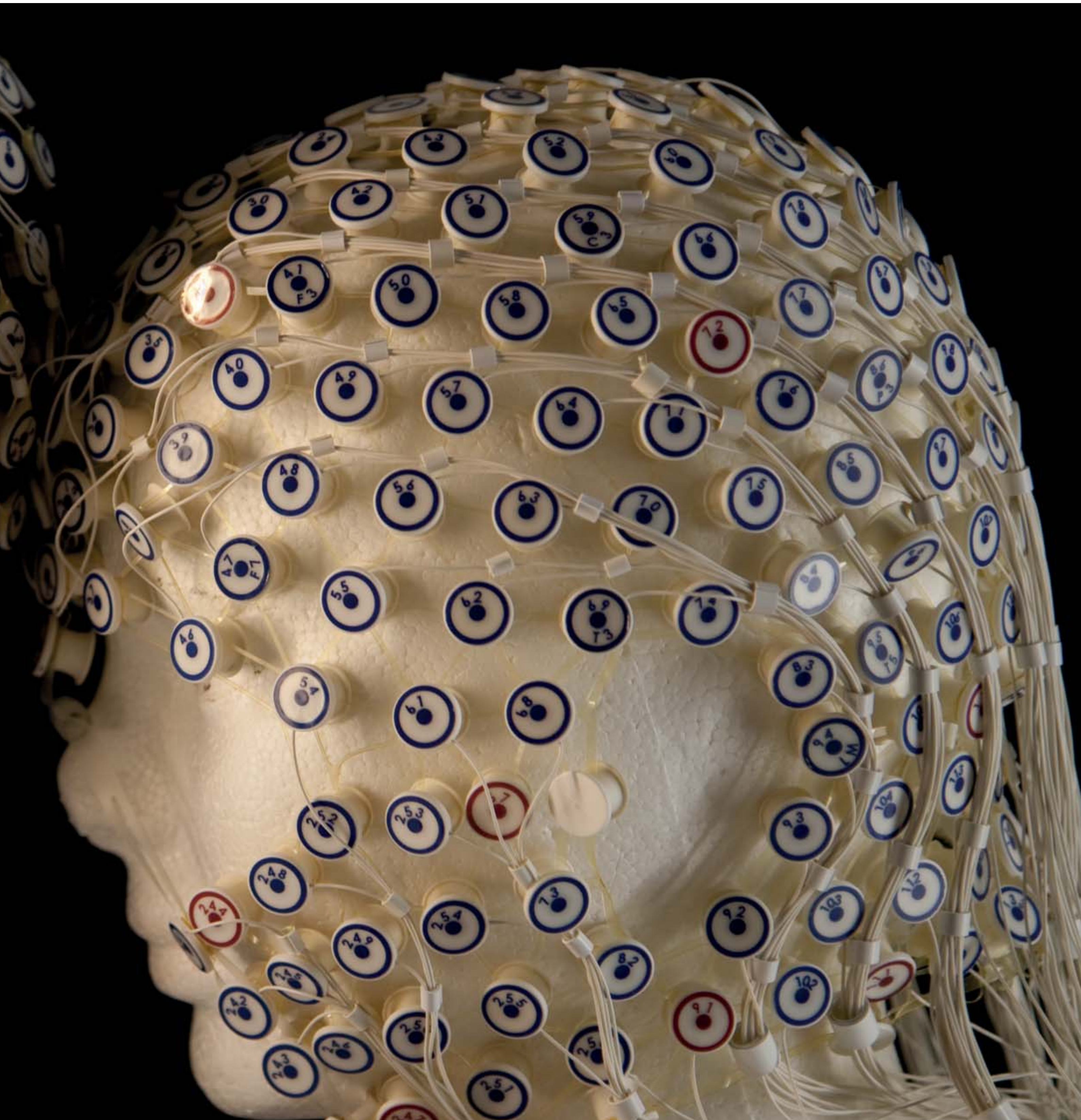
The following non-exhaustive list provides an overview of the international research and innovation programmes, infrastructures and organisations with Swiss participation mentioned in Section 3.2.2, along with further examples.

Name	**Purpose**	**Year Switzerland joined**
Multilateral research and innovation programmes (participation under an international treaty)		
EURATOM, European Atomic Energy Community , fusion research programme, Brussels (Belgium)	Coordinates national research activities for the peaceful use of nuclear energy across national borders.	1979
FP, Horizon 2020: European Union Framework Programmes for Research and Innovation, Brussels (Belgium)	The European Union's main instrument for implementing its common science and technology policy. The 8th programme generation runs from 2014 to 2020 under the title of Horizon 2020.	Different forms of participation since 1987
International research organisations (participation under an international treaty)		
CERN, European Organization for Nuclear Research, Geneva (Switzerland)	Provides facilities for European countries cooperating in nuclear and particle physics research for exclusively peaceful purposes. Through its accelerator facilities, CERN promotes advanced research in the fields of high-energy physics.	1953
EMBC, European Molecular Biology Conference, Heidelberg (Germany)	Promotion of research in molecular biology in Europe. The EMBC supports training programmes and the exchange of information between European researchers.	1969
CIESM, International Commission for the Scientific Research of the Mediterranean Sea, Monaco	Advancement of scientific cooperation by supporting the international use of national research stations.	1970
EMBL, European Molecular Biology Laboratory, Heidelberg (Germany)	Promotes European collaboration in fundamental research in molecular biology, provides the necessary infrastructures and contributes to the ongoing development of state-of-the-art instrumentation for modern biology.	1973
ESA, European Space Agency, Paris (France)	Promotes collaboration between European countries in the area of space research and technology for the purpose of advancing scientific knowledge and developing practical applications such as navigation systems and weather satellites. Switzerland jointly holds the Agency chairmanship with Luxembourg from 2012 to end 2016.	1975
ESO, European Southern Observatory, Garching (Germany)	Builds, equips and operates astronomical observatories in the southern hemisphere and promotes and organises European collaboration initiatives in the field of astronomy research.	1981
ESRF, European Synchrotron Radiation Facility, Grenoble (France)	Provides X-rays with hitherto unattained energy, intensity and precision. Such X-rays are required for structural analyses in solid-state physics, molecular biology, material sciences, for medical diagnoses and therapies as well as for special experiments in radio biology, fundamental physics and physiochemistry.	1988
ILL, Institut Max von Laue – Paul Langevin, Grenoble (France)	It serves as a reliable neutron source for research and studies in the fields of material sciences, solid-state physics, chemistry, crystallography, molecular biology as well as nuclear and fundamental physics.	1988

Name	Purpose	Year Switzerland joined
International research organisations (participation under an international treaty)		
HFSP, Human Frontier Science Program, Strasbourg (France)	International programme promoting innovative basic research around the world with a focus on the complex mechanisms of living organisms. It addresses life sciences topics ranging from molecular biology to cognitive neuroscience.	1991
SNBL, Swiss Norwegian Beamline SNX, Swiss-Norwegian Foundation for Research with X-Rays ESRF, Grenoble (France)	The SNX operates the Swiss Norwegian-Beamline (SNBL) at the ESRF in Grenoble for Switzerland and Norway. The numerous top-rank scientific publications based on the wide range of measurements taken at the SNBL enjoy an excellent reputation worldwide. Collaboration is funded in equal parts by Switzerland and Norway.	SNBL: 1998 SNX: 2004
IO, ITER Organization, Cadarache (France)	ITER is building the world's largest experimental nuclear fusion reactor (scheduled for completion by 2023), planned as the final step toward achieving nuclear fusion energy. Switzerland is an indirect participant, represented by the EU.	2007
Fusion for Energy, Barcelona (Spain)	European enterprise which prepares, processes and provides in-kind and financial contributions to ITER. Switzerland is a full member of the enterprise.	2007
European XFEL, European X-Ray Free Electron Laser Facility, Hamburg (Germany)	The facility is under construction. From 2017, it will generate short high-intensity X-ray laser flashes by accelerating electrons to high energies. This will allow scientists to map the atomic details of viruses, decipher the molecular composition of cells, take images of the nanoworld and film physical-chemical and biological reactions.	2009
ESS, European Spallation Source, Lund (Sweden)	European research infrastructure, which is building the world's most powerful neutron source. Switzerland has been involved from the outset in the planning and construction of the ESS and will also be involved in operating the facility.	2015
Intergovernmental research and innovation programmes		
COST, European Cooperation in Science and Technology, Brussels (Belgium)	It enables researchers from various research institutes, universities and companies to work together at the European level in pursuit of a broad range of R&D activities. COST complements the FPs and EUREKA. Partners in a COST network frequently later become partners in an FP project.	1971
EUREKA, initiative for European technological research cooperation, Brussels (Belgium)	Instrument designed to enhance European competitiveness. Through EUREKA, R&D projects with clear market potential are devised and carried out according to the bottom-up principle. Cooperation between companies, research centres and universities in transnational projects makes it possible to bring innovative products, processes and services to market. The initiative is particularly important for SMEs, which today constitute half of its partners. EUREKA complements the FP and COST.	1985

Name	**Purpose**	**Year Switzer-land joined**
European P2P (public-to-public) initiatives (legal form according to Art. 185 TFEU, co-funded through Horizon 2020)		
AAL, Active and Assisted Living, collaboration programme with the EU, Brussels (Belgium)	The European funding programme AAL aims to develop innovative, marketable solutions designed to enable older adults to maintain their customary quality of life and autonomy in their own home environments for as long as possible.	2007
Eurostars, Brussels (Belgium)	Support for research-intensive SMEs: SMEs can work with European research teams through Eurostars and improve their competitive capacity in the field of knowledge and innovation. Eurostars is part of the EUREKA framework. The EUREKA Secretariat in Brussels is responsible for evaluating and monitoring projects.	2008
EMPIR, European Metrology Programme for innovation and Research, Brunswick (Germany)	The European Association of National Metrology Institutes (EURAMET) and the EU Commission have jointly developed the European Metrology Research Programme (EMRP) and its successor programme, the European Metrology Programme for Innovation and Research. The goal of these programmes is to improve the international coordination of research conducted by the national metrology institutes and to strengthen their collaboration. In the EMPIR programme, seven project tenders are envisaged during the period from 2014 until 2020.	EMRP: 2009 EMPIR: 2014

PART B: SWISS RESEARCH AND INNOVATION IN INTERNATIONAL COMPARISON



The University of Geneva is home to the national centre of competence in research (NCCR) "Affective sciences – emotions and their effects on human behaviour and society", one of the leading research centres in the world dedicated to the interdisciplinary study of emotions. Researchers study the origin of affective states and emotions, control of them and their social functions. In their experiments they use electroencephalographs, which allow them to measure brain activity by means of electrodes. The results of this research helps to improve people's physical and psychological health, to increase their well-being within the family and at work and helps them to develop the ability to manage their emotions. The NCCRs are a tool financed by the Swiss Confederation and implemented by the Swiss National Science Foundation. Photo: Sophie Jarlier

Contents

This part of the report assesses Switzerland's international position in research and innovation. For this purpose, Switzerland will be compared with other industrialised countries and emerging economies. Moreover, development over time will be examined. In order to describe research and innovation activities, a variety of indicators will be presented that refer to investments, interactions and performance.

International comparison[1]

To the degree that data is available, comparisons are drawn between Switzerland and the following countries: Austria, Denmark, Finland, France, Germany, Italy, Japan, Korea, the Netherlands, Sweden, the United Kingdom (UK), the United States of America (USA) and China.[2]

These countries were chosen for comparison because they have at least one of the following characteristics:

- They occupy a leading position in science and technology.
- Their economic significance is increasing.
- They are comparable with Switzerland in terms of their size or developmental status.
- They are important economic partners of Switzerland.

The position of Switzerland in comparison with these countries will be explained in Chapters 1 through 11. All the chapters have been structured the same way as far as possible, stating the context and validity of each indicator, a comparison of Switzerland with the other countries and the development over time. A few indicators reflect only a national context and are not compared internationally.

Comparison with innovation regions[3]

In many cases, research and innovation are concentrated in relatively few regions in a country. This is a function of positive externalities (external effects of knowledge) that are encouraged by the physical proximity of the participants. Often, a large number of the researchers in a country is active in these «innovation regions», which makes them a driving force in the creation of new scientific insights and innovations.

In addition to comparisons with other countries, comparison with such innovation regions can enable a better assessment of Switzerland's international positioning, because their standards are higher. Moreover, it corresponds more closely to Switzerland's special structures – its small, open and highly specialised economy – than a comparison with large countries. The whole of Switzerland can be considered an innovation region owing to the short distances between the most important research and innovation locations, especially between the universities and the research and development departments of innovative companies. In other countries, in contrast, this function is assumed by just a few regions.

Each of the six regions considered in this analysis represents a research and innovation centre in its country. These innovation regions are as follows:

- Baden-Württemberg (Germany)
- Bavaria (Germany)
- Lombardy/Piedmont (Italy)
- The Paris metropolitan area (France)
- The London metropolitan area (UK)
- New England (USA)

The position of Switzerland in comparison with these innovation regions will be examined in Chapter 12.

Indicators and their limits

The indicators are quantitative descriptions; in this report, they deliver condensed information about research and innovation investments, interactions and performance.

However, it must be noted that these indicators should generally be interpreted with caution, especially in the field of research and innovation:

- The effects of research and innovation are only measurable over the medium or long term.
- Indicators are generally static and cannot completely capture the complexity of a national innovation system.
- It is extremely difficult to assess the effect of research and innovation on assets that are not subject to market forces, independently of whether the assets are cultural, social, political or environmental.

The indicators used below nonetheless allow us to survey Switzerland's performance in research and innovation and in their development.

[1] This section is based on groundwork carried out by Dr. Spyridon Arvanitis, Dr. Martin Wörter and Flavio Schönholzer, of the Swiss Economic Institute (KOF) at the Swiss Federal Institute of Technology Zurich.

[2] The countries are named in the order in which they appear in the OECD's tables.

[3] This section is based on a study conducted by Dr. Christian Rammer at the Centre for European Economic Research (ZEW).

1 Framework conditions of research and innovation

The innovativeness of a country is dependent on more than just its technological potential, capital or the size of its companies: framework conditions are just as important. These include public infrastructure, which is very significant for the economy, but also the laws and the availability of a well-educated workforce. In this chapter, framework conditions in various countries will be compared using especially significant indicators. The legal and economic framework was explained in detail in Part 1 of this report.

1.1 Quality of the infrastructure

An extensive, high-quality infrastructure in the areas of transport, power supply and telecommunications is a prerequisite for the efficient functioning of an economy. Such an infrastructure reduces the transaction costs in a country and supports the internationalisation of its markets.

Figure B 1.1 shows the quality of Switzerland's infrastructure in an international comparison. The data was drawn from a survey of economic leaders who assessed the quality of transport routes, electricity supply networks and telecommunications networks in their own countries. The results show only minimal differences between most of the countries compared. Switzerland, Finland and the Netherlands have the best infrastructures. In Italy and China, the infrastructure is considerably less good.

1.2 Corporate tax rate

The tax burden is a decisive factor in the choice of domicile for internationally active firms. For local firms as well, the tax burden is very important: it creates incentives to found new businesses, affects their scope for action and is a significant factor with respect to the financial resources available for innovation activities. It can especially be decisive for small and medium-sized enterprises (SMEs), which have to finance their innovation activities mainly through cash flow.

Figure B 1.2 shows the average corporate tax rate. Firms pay especially low taxes in Denmark, Switzerland and the UK, and especially high taxes in France, Italy and China. However, it should be noted that some countries known for their attractive tax environments – such as Singapore, Luxembourg or Ireland – have not been included in this comparison.

1.3 Labour market flexibility

A flexible labour market makes it easier for firms to meet their needs for skilled labour for innovation activities or to market new products. It promotes companies› technological flexibility and accelerates the implementation of technologies that increase efficiency.

Figure B 1.3 shows an international comparison of labour market flexibility, based on a survey of entrepreneurs on their hiring and dismissal practices and the role of minimum wages. Switzerland and Denmark have the most flexible labour markets, followed by the USA and the UK. In contrast, the labour markets in Italy and France are strongly regulated. Except for these extremes, the differences between the compared countries are not particularly marked.

1.4 Skilled labour with an immigrant background

Economies need skilled labour for innovative business processes and the development of new technologies and products. However, hiring qualified personnel is a big challenge for many firms, and one that will become more demanding in future owing to the demographic developments in most industrialised countries. The immigration of foreign labour can balance out the shortage of labour.

Figure B 1.4 shows the proportions of the immigrant workforce who have completed tertiary education (universities or professional education): it is high in the UK, Switzerland and the USA.

1.5 Quality of life

High quality of life in a country is a significant location factor for innovative firms. Companies find it easier at such locations to recruit a well-educated, internationally mobile workforce.

In line with one of the most well-known indicators for quality of life, cities are categorised according to their political and social environments, economic and sociocultural environments, medicine and healthcare, public services and transport, leisure opportunities, available consumer goods, housing quality and the natural environment (Figure B 1.5). Austria (Vienna) and Switzerland (Zurich and Geneva, which is somewhat further down the list but still among the top ten) were the two countries with the highest quality of life in 2015. Next in the ranking (among the compared countries) were Germany (Munich, Düsseldorf, and Frankfurt) and Denmark (Copenhagen).

1.6 Legal framework for starting a new business

The legal provisions to start a business indicate how business-friendly a country is, and thus also to what degree innovation is promoted.

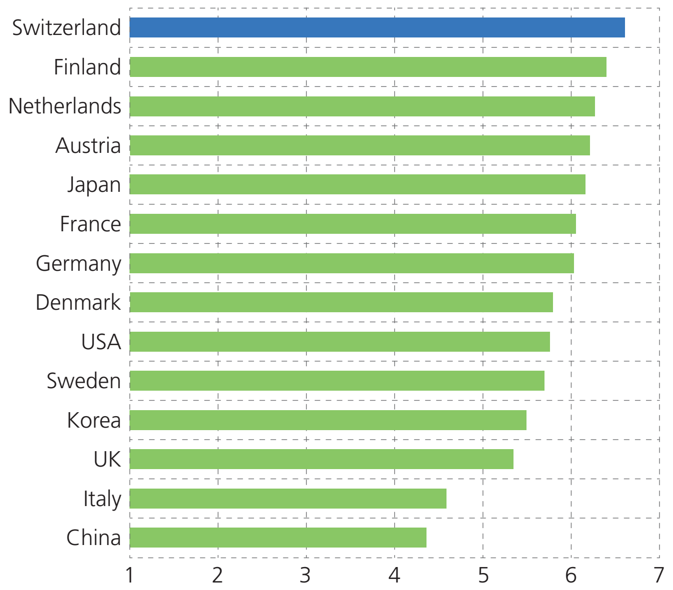
Figure B 1.6 shows the favourability of the legal provisions to create a new business. The data in this illustration are from a survey of entrepreneurs in various countries. Legal provisions to launch a business are particularly favourable in Switzerland and the Scandinavian countries. The USA, the birthplace of entrepreneurship, is in fifth place.

1.7 Time to create a new business

The time required to create a new business can be significant for the utilisation of an innovation: if a business can be started quickly, this shortens the period between the invention and the marketing of a product. The business that is first to enter a particular market has a competitive advantage and can use the patent protection term, which is always limited, for a longer period of time.

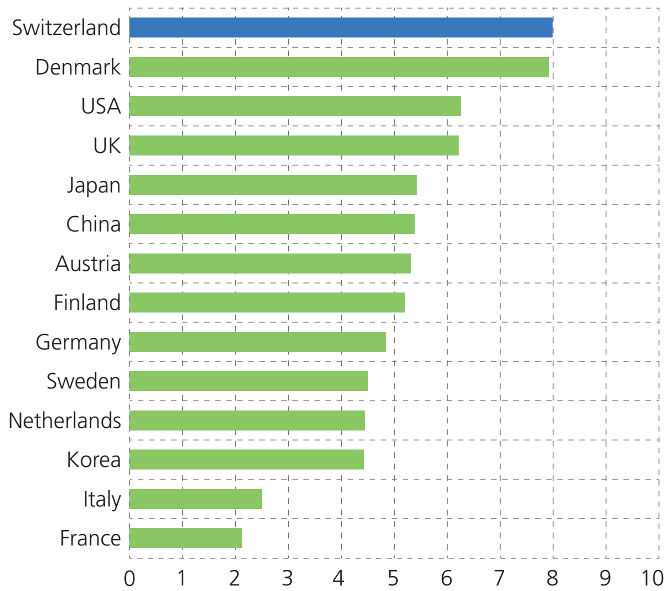
Figure B 1.7 shows the number of days required to start a business, comparing the procedures in the largest city of each country. The data comes from a survey of local experts. Where a business start-up takes less than a week in Korea, the Netherlands and France, around two weeks are needed in Switzerland.

Figure B 1.1: Quality of the infrastructure, 2014



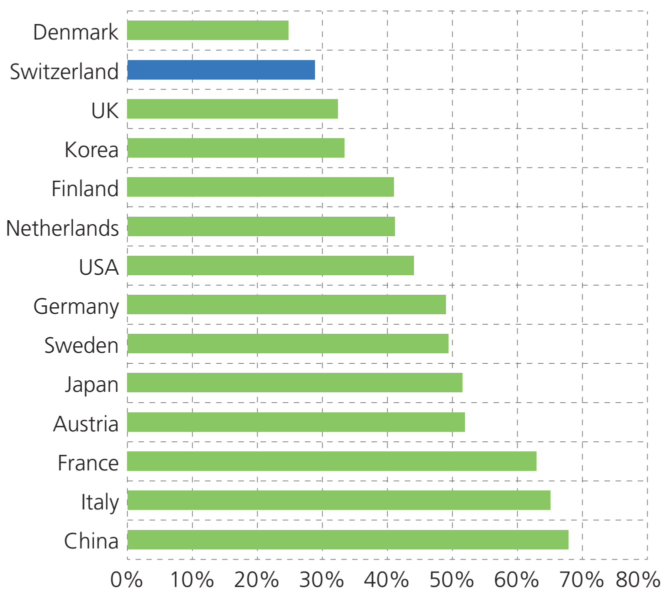
1 = extremely underdeveloped – among the worst worldwide,
7 = extensive and efficient – among the best worldwide
Source: WEF

Figure B 1.3: Labour market flexibility, 2014



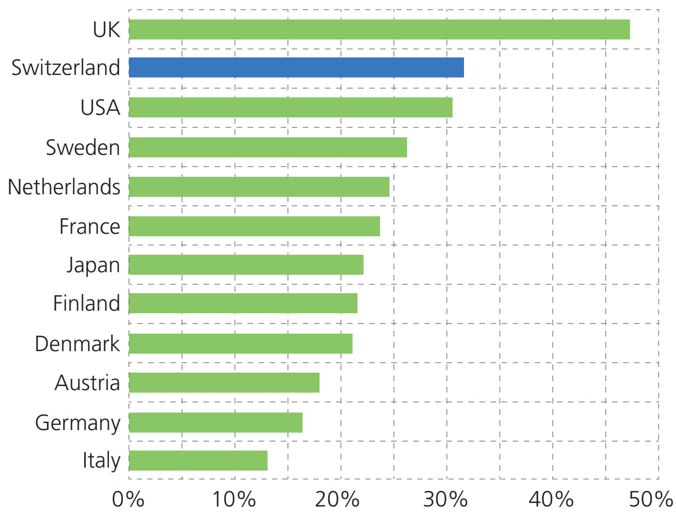
0 = less flexible or strongly regulated labour market, 10 = very flexible or scarcely regulated labour market
Source: IMD

Figure B 1.2: Total corporate tax rate, 2014



Source: World Bank

Figure B 1.4: Share of university graduates among total immigrants, 2010



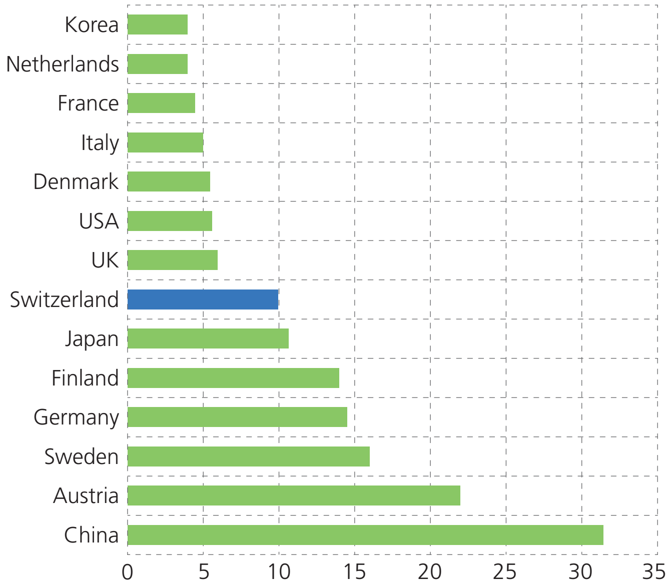
No data available: Korea, China
Source: OECD

Figure B 1.5: Quality of life according to city ranking (top 10), 2015

Rank	City	Country
1	Vienna	Austria
2	Zurich	Switzerland
3	Auckland	New Zealand
4	Munich	Germany
5	Vancouver	Canada
6	Düsseldorf	Germany
7	Frankfurt	Germany
8	Geneva	Switzerland
9	Copenhagen	Denmark
10	Sydney	Australia

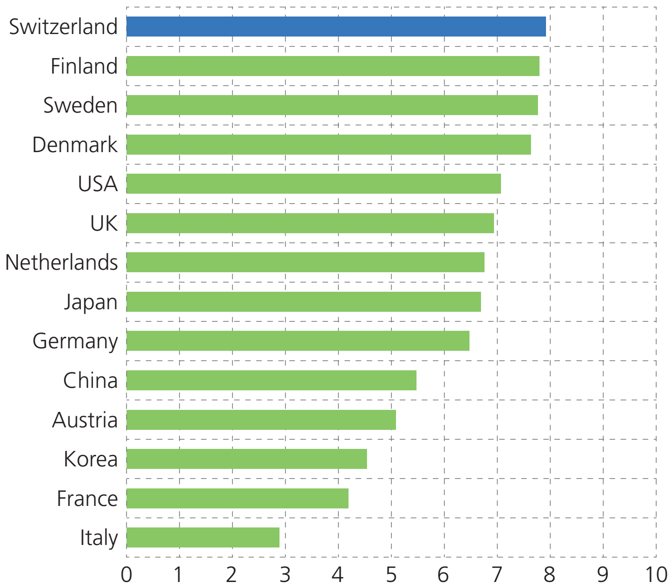
Source: Mercer

Figure B 1.7: Time to create a new business in days, 2015



Number of calendar days needed to complete the procedures to legally operate a business
Source: World Bank

Figure B 1.6: Ease of starting a new business, 2014



0 = very unfavourable legal conditions, 10 = very favourable legal conditions
Source: IMD

2 Education and qualifications

One task of education is the development and dissemination of knowledge and skills. In this area, most countries focus on higher education in conjunction with the objective of achieving higher numbers of people with school-leaving certificates. Switzerland has decided to pursue a dual strategy in which vocational and professional education and training play an important role. It is difficult to find meaningful indicators for this area, but with respect to Switzerland's innovation performance, the importance of basic training and professional education cannot be emphasised enough. Since no such indicators are available, this chapter will present the standard indicators at international level, which refer mainly to tertiary education. However, in view of the special features of the Swiss educational system, these indicators should be interpreted with caution.

2.1 Youth competence in mathematics, natural sciences and reading

The great demand for highly qualified labour has triggered a worldwide race for talent. Secondary-school pupils with very good proficiency in mathematics, science and reading are predestined to enhance a country's pool of research and innovation talent.

The Programme for International Student Assessment (PISA) measures the competence of 15-year-old pupils in mathematics, science and reading. In Switzerland, pupils are in the top group in mathematics; their proficiency in science and reading is average (Figure B 2.1). The profiles of the Netherlands and Germany are similar to that of Switzerland.

2.2 People with tertiary education

People aged 25 to 34 who have completed tertiary education (university or professional education) form a pool of highly qualified human resources that is very important for the creation and dissemination of knowledge in a knowledge-based economy and society. However, we must bear in mind that international comparisons are difficult owing to the significant differences between national educational systems.

In Switzerland, somewhat more than 40% of the population aged 25 to 34 has completed tertiary education (Figure B 2.2). This rate is markedly higher in Korea, Japan and the UK, and lower, among the compared countries, in Germany, Austria and Italy. As mentioned above, Switzerland's relatively average ranking can be explained by the high standing accorded vocational and professional education and training in our country.

Since 2000, the share of people who have completed tertiary education in Switzerland has increased strongly, while the share of those who have only completed upper-secondary education has declined correspondingly (Figure B 2.3). Apart from the rising attractiveness of tertiary education immigration, especially from the European Union (EU), is likely to play a role.

2.3 Doctoral graduates in natural sciences and technology

Given the increasing specialisation and rapid increase in scientific knowledge production, researchers with high-level research degrees have become a cornerstone of scientific and technological systems around the world. Holders of doctorates, particularly in science and technology, are generally deemed well qualified to generate research-based innovations.

In Switzerland, 44% of holders of doctoral degrees come from the natural sciences and engineering (30% from natural sciences, 14% from engineering) (Figure B 2.4). At the top of the countries ranking are France, with 59%, and China, with 54%. Austria, the UK, Denmark and Italy have values similar to those of Switzerland.

2.4 Foreign students

Firms and universities compete for the best talents in their fields, irrespective of people's origins. International students form a pool of well-educated, competent talent that can be very valuable for an economy. This is particularly true for Switzerland, which – thanks to its international students – can increase its modest share of graduates.

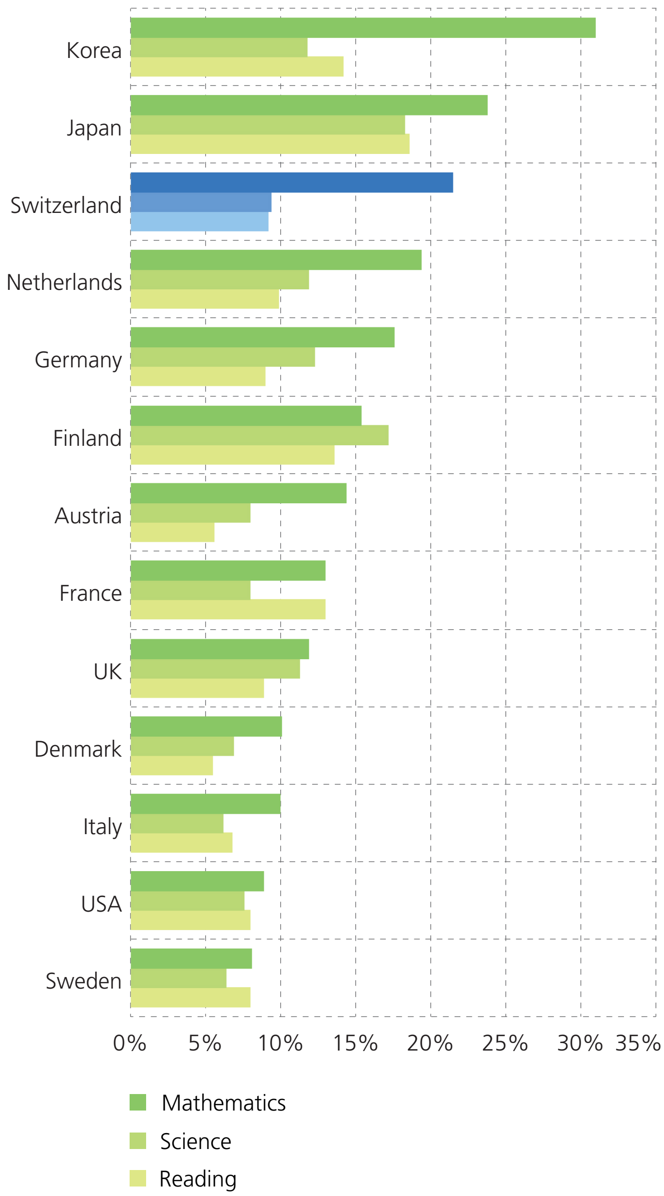
Nearly a quarter of its students are foreign, placing Switzerland top among the compared countries (Figure B 2.5), followed by the UK and Austria. At the bottom of the list are Italy and the Asian countries, with values under 5%.

The share of foreign students in Switzerland was already high at the start of the 2000s and has grown less strongly than in most of the reference countries. Only Germany is characterised by near-stability of its share of foreign students. In contrast, Korea, Italy, Finland and the Netherlands show especially strong growth.

In terms of foreign doctoral students, Switzerland is likewise at the top: this group makes up over half of all students at this level (Figure B 2.6). The UK achieves a comparable share, whereas Korea and China show the lowest rates.

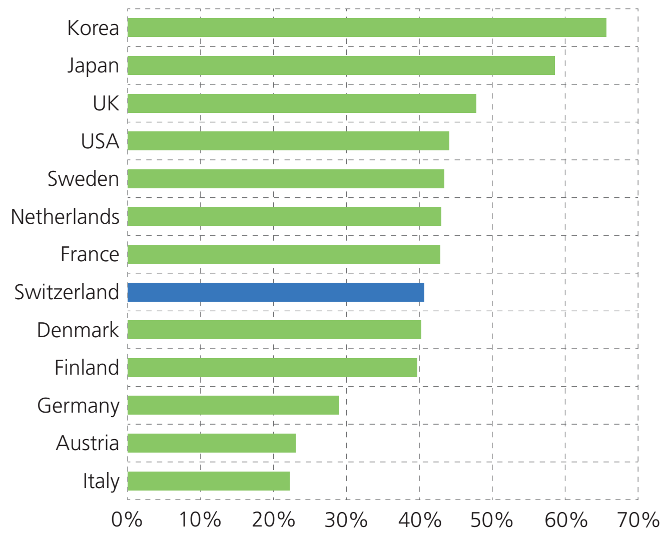
Yet the share of foreign doctoral students in Switzerland has also increased more slowly than in the other countries in the comparison.

Figure B 2.1: Share of young people with very good proficiency in mathematics, science and reading, 2012



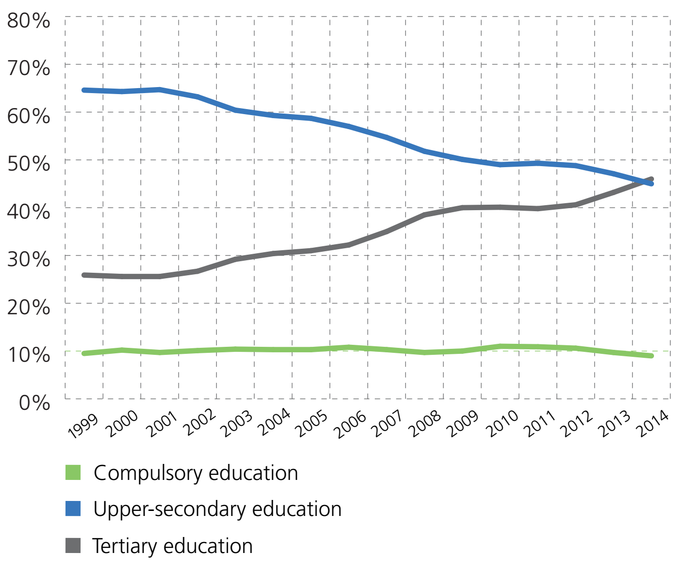
Young people aged 15 who received a PISA survey rating of 5 or 6 in the corresponding subject
No data available: China
Source: OECD

Figure B 2.2: Share of the population who have completed tertiary education, 2012



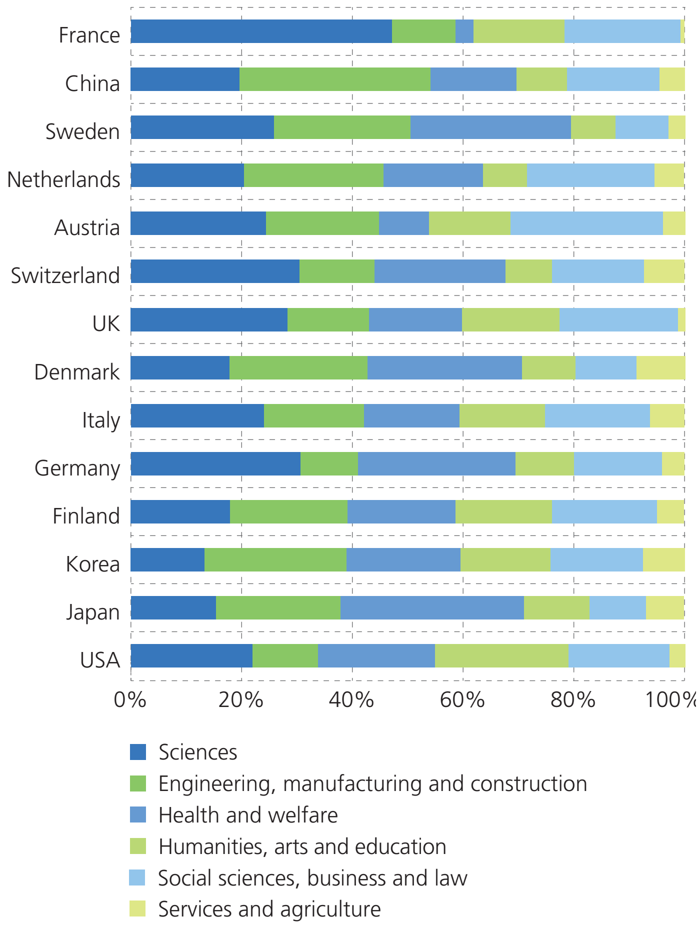
People aged 25 to 34
No data available: China
Source: OECD

Figure B 2.3: Educational level of the permanent resident population of Switzerland



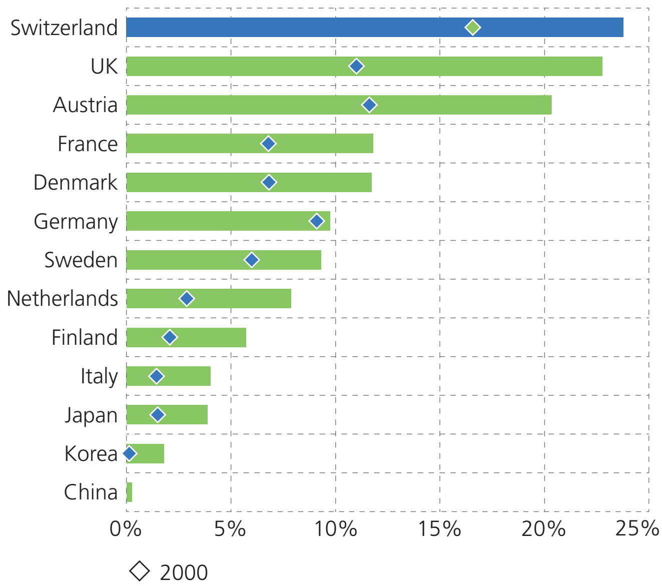
Highest level of education completed by the population aged 25 to 34
Source: FSO

Figure B 2.4: Graduates at doctoral level by field of education, 2012



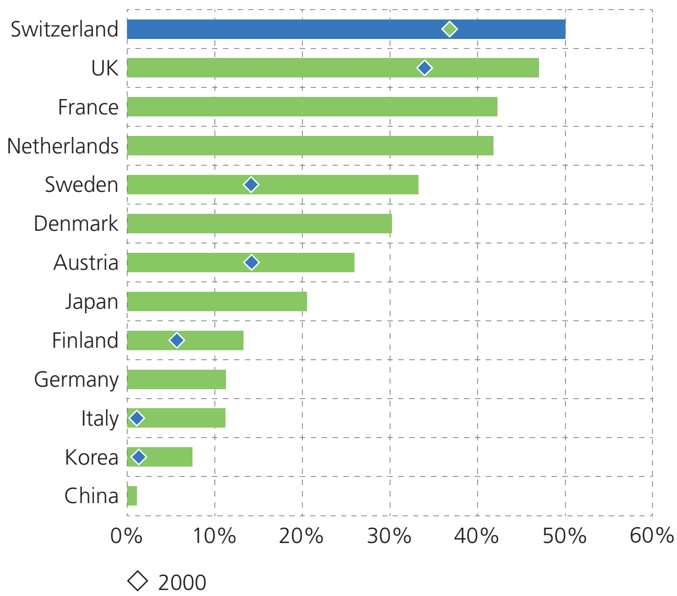
Exceptions to reference year 2012: China: 2013; France: 2009
Source: OECD

Figure B 2.5: Share of foreign students among all students at tertiary level, 2012



No data available: USA
Source: OECD, KOF calculations

Figure B 2.6: Share of foreign doctoral students among all doctoral students, 2012



No data available: USA
Source: OECD, KOF calculations

3 Personnel in research and innovation

Human resources are the driving force of research and innovation activities. High-quality research requires well-trained personnel in sufficient numbers. It is through these human factors that knowledge translates into the new products and services that are needed by the economy and society.

3.1 People employed in science and technology

People employed in science and technology are considered to be those who deal with the creation, dissemination and application of scientific and technological knowledge. More specifically, they are the professionals, including science and engineering professionals (Major Group 2 of the International Standard Classification of Occupations) and technicians and associate professionals (Major Group 3).

In Switzerland, 42% of those employed are active in science and technology (Figure B 3.1), which puts Switzerland at the top of all the countries in the comparison, followed closely by Sweden, Denmark and Finland. Italy ranks at the bottom with a share of less than 30% of its population engaged in science and technology.

In comparison with the year 2000, Austria and the UK show the highest rates of growth. The share of the workforce employed in science and technology in Switzerland has risen moderately but continuously, probably as a result of the higher numbers of graduates from universities of applied sciences (see Part C, Study 4).

3.2 Research and development personnel

Research and development (R&D) personnel means researchers (specialists working on the design and development of new insights, products, procedures, methods and systems and the management of related projects), technicians (performing scientific and technical tasks) and support personnel.

The share of R&D personnel (expressed in full-time equivalents) in the total workforces of Denmark and Finland is more than 2% (Figure B 3.2). At 1.6%, Switzerland is in the mid-field together with Korea, France and Austria. However, in terms of researchers alone, Switzerland drops toward the bottom of the ranking with a share of 0.75% of the total workforce. Only Italy and China have lower shares. Denmark and Finland, in contrast, claim an undisputed lead with a share of around 1.5% of the total workforce. Switzerland's poor ranking can be attributed in large part to the fact that the share of researchers in private enterprise is very low (FSO, 2014).

The increase in the share of R&D personnel in the total workforce in Switzerland since 2000 has been average (largely due to increases in foreign R&D personnel). China, Korea, Italy and Denmark recorded much stronger increases.

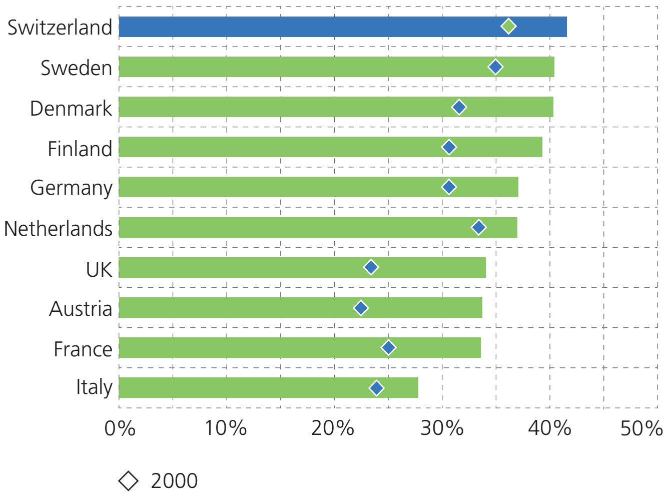
3.3 Share of women in the total number of researchers

Women have comprised the majority of tertiary-level students for some years now, but their potential in research and innovation is far from being utilised completely. This is a problem in numerous countries, but in Switzerland it is particularly acute owing to the shortage of skilled labour.

In 2012 the share of women in research teams amounted to 32% (Figure B 3.3). In international comparisons, this percentage puts Switzerland midway in the rankings, far behind the UK and Sweden, but ahead of Austria, Germany and France.

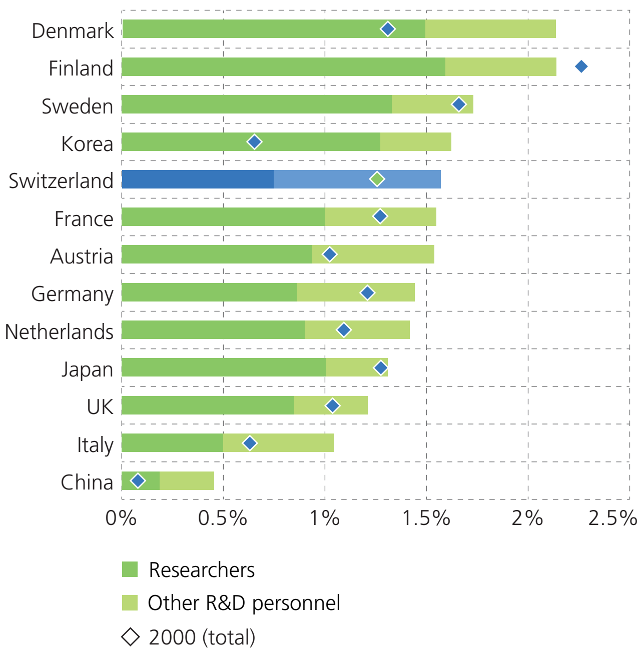
The share of women among the total number of researchers has increased most strongly since 2000 in Korea and Switzerland. In contrast, the number of women researchers in France is declining.

Figure B 3.1: Share of the workforce employed in science and technology, 2014



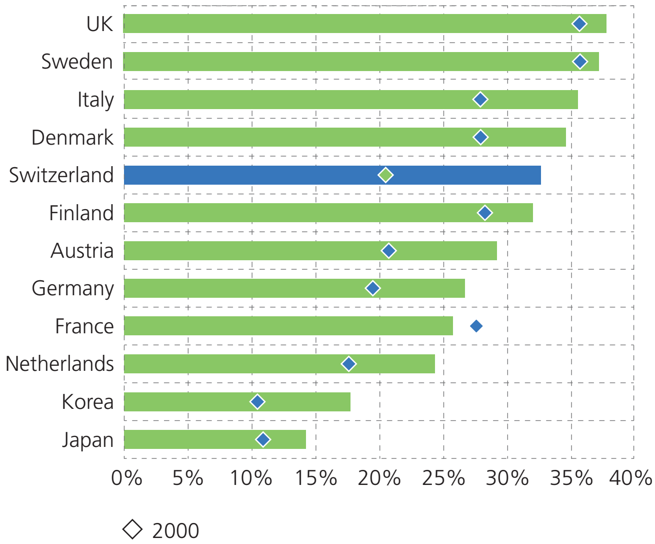
Working population aged 15 to 74 (exception: Switzerland: people aged 15 to 64)
No data available: Japan, Korea, USA, China
Source: EUROSTAT

Figure B 3.2: Share of R&D personnel in the total workforce, 2013



Exceptions to reference year 2013: Switzerland: 2012
Exceptions to reference year 2000: Sweden: 2001; Austria: 2002
No data available: USA
Source: OECD

Figure B 3.3: Share of women in the total number of researchers, 2012



Natural persons
Exceptions to reference year 2012: Austria, Germany, Sweden: 2011
Exceptions to reference year 2000: Japan, Netherlands, Sweden: 2001;
Austria: 2002; Germany: 2003; Sweden, UK: 2005
No data available: USA, China
Source: OECD, FSO

4 Expenditure on research and innovation

As the official statistics reflect only research and development expenditure and not research and innovation expenditure, the following statements apply exclusively to R&D. The innovation activity of the countries can be quantified on the basis of their R&D expenditure. High R&D expenditure is no guarantee either of high-quality research or of successful innovations, but represents a favourable prerequisite, as it enables the creation of knowledge and the development of new products and processes.

4.1 R&D expenditure as a percentage of GDP

R&D intensity (R&D expenditure relative to GDP) is a measure of the relative importance accorded by a country to investments in the creation of knowledge.

Across all sectors, in 2012 Switzerland dedicated 2.96% of its GDP to R&D (Figure B 4.1). This puts it in sixth place among the compared countries – behind Korea, Japan, Finland, Sweden and Denmark. Important industrialised countries such as the USA and France investment proportionately less in R&D than Switzerland.

R&D activities in Switzerland have developed positively during the 2000 to 2012 period; R&D intensity grew more strongly than in most of the other countries in the comparison. Only China, Korea, Austria and Denmark had higher growth.

4.2 R&D expenditure by performing sector

The shares of the different sectors in a country's R&D may reveal the strengths and weaknesses of its innovation system: high expenditure by the private sector reflects an economy›s strong participation in the utilisation of new forms of knowledge.

In most industrialised countries, the private sector performs the vast majority of R&D, and with a share of 69% coming from the private sector, Switzerland takes fifth place here behind Korea, China, Japan and the USA (Figure B 4.2). Swiss universities (universities, federal institutes of technology and universities of applied sciences) are likewise well placed, as Switzerland is among the countries in which the share of higher educational institutions in the total R&D expenditure exceeds 25%. Only the Netherlands and Denmark have higher shares in this sector. By contrast, Switzerland is the country with the lowest level of R&D activity in the public sector, with a share of less than 1%, whereas the public sector share in China, Germany and Italy amounts to just under 15%.

4.3 R&D expenditure of Swiss business enterprises

The largest volume of Swiss R&D expenditure (82%) is borne by large firms (Figure B 4.3) – an unsurprising finding given the high costs of certain research infrastructure. Although R&D expenditure by large firms climbed steeply from 2000 to 2008, it has stagnated in the most recent period. R&D expenditure among small and medium-sized enterprises (SMEs), on the other hand, has increased further.

A breakdown of intramural R&D expenditure by beneficiary industry reveals that the pharmaceutical sector is the most important user of the results of R&D activities conducted in Switzerland (CHF 5.7 billion in 2012, which equals 45% of R&D expenditure), far ahead of the mechanical engineering (15%), high-tech instruments (9%) and food (8%) sectors (Figure B 4.4).

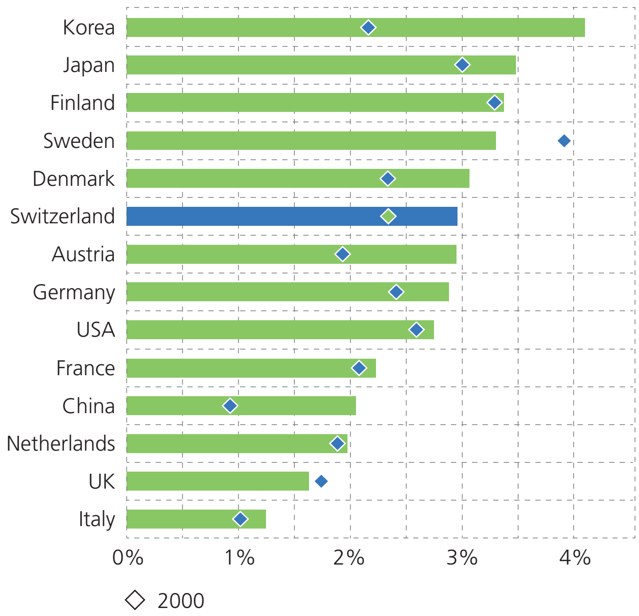
4.4 Investments in knowledge

In order to measure the knowledge penetration in an economy, the OECD has developed an indicator which adds R&D expenditure to expenditure on software and on tertiary education.

In Switzerland, these investments in knowledge amounted to 6.4% of the GDP in 2011 (Figure B 4.5), placing the country in the high mid-field, but behind Korea, the USA, Finland, Denmark and Japan. Investments in traditional capital equipment (machinery, motor vehicles, business equipment etc.) are an interesting point of comparison: they make up 9.1% of GDP in Switzerland and are thus 1.4 times higher than its investments in knowledge. This difference is greater in Switzerland than in most of the other countries in the comparison, in which investments in capital goods are only 1.1 times higher on average than investments in knowledge.

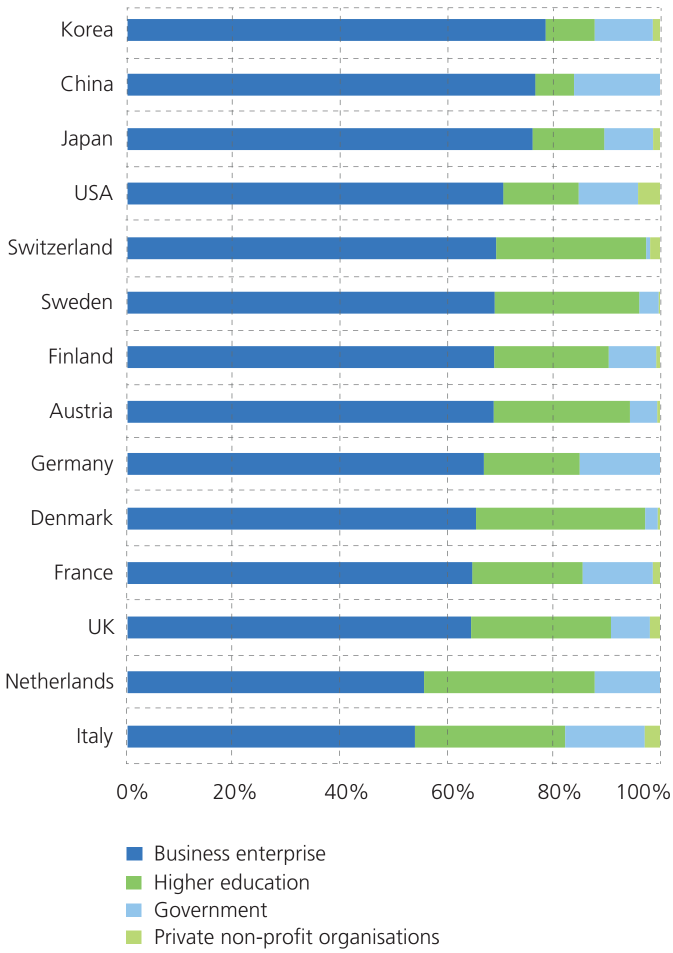
From 2000 to 2011, Swiss investments in knowledge increased more strongly than in most of the compared countries: only Korea, Denmark and Austria had higher rates of growth. Investments in capital goods in all of the countries have declined since 2000 – probably due to the economic crisis.

Figure B 4.1: R&D expenditure as a percentage of GDP, 2013



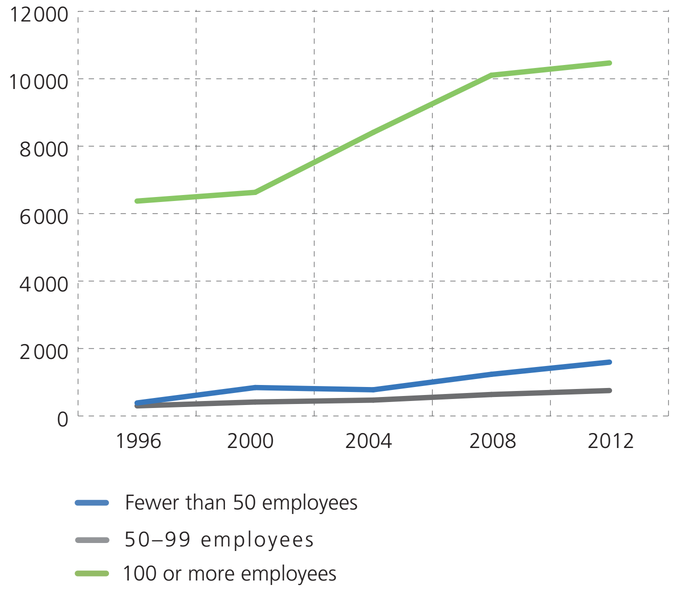
Exceptions to reference year 2013: Switzerland: 2012
Exceptions to reference year 2000: Denmark, Sweden: 2001
Source: OECD

Figure B 4.2: R&D expenditure by performing sector, 2013



Exceptions to reference year 2013: Switzerland: 2012
Netherlands: Expenditure by private non-profit organisations is included in the public sector (government)
USA: Cost of capital is not included in the R&D expenditure of business enterprises, higher education or non-profit organisations. The government sector includes only federal and/or central government
Source: OECD

Figure B 4.3: R&D expenditure of Swiss business enterprises by firm size, in CHF million at current prices



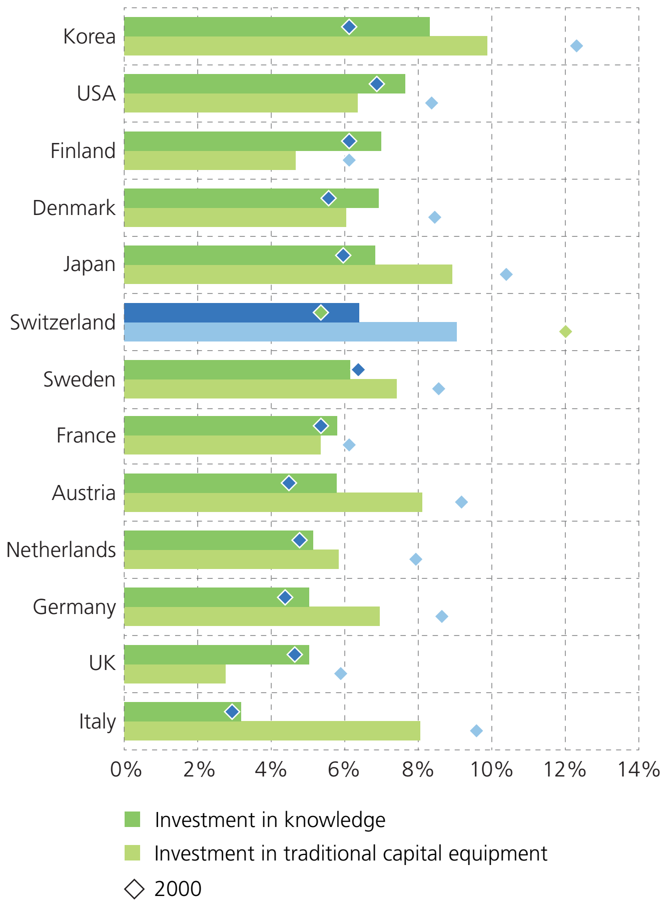
Source: FSO

Figure B 4.4: Intramural R&D expenditure of Swiss business enterprises by beneficiary industry, in CHF million at current prices, 2012

	Intramural R&D expenditure in CHF million	Share
Food	1 017	8%
Chemistry	297	2%
Pharmaceutical	5 706	45%
Metallurgy	333	3%
Machinery	1 927	15%
High-tech instruments	1 214	9%
ICT – manufacturing	310	2%
ICT – services	488	4%
Other	1 528	12%

ICT: Information and communication technology
Source: FSO

Figure B 4.5: Investment in knowledge and investment in traditional capital equipment as a percentage of GDP, 2011



No data available: China
Source: OECD, KOF calculations

5 Funding of research and innovation

Who finances research and innovation? The answer to this question gives another view, complementing the expenditure aspect (see Chapter 4). We will examine the origins of the resources which fund R&D activities (R&D funding by sector). Moreover, we will show the involvement of government in supporting R&D (government budget appropriations or outlays for R&D) and the support of investors for start-up companies (venture capital).

5.1 R&D funding by sector

Significant government funding of R&D is an expression of the political will to promote R&D. The share contributed by business enterprises demonstrates their ability to absorb new knowledge and techniques and maintain their innovativeness.

The largest part of the R&D resources in all the countries under comparison comes from the private sector (Figure B 5.1), which is not surprising if one considers how expenditure for performing R&D is distributed (see Chapter 4). In Switzerland, the share borne by the private sector is 61%. The leaders in this respect are Korea, Japan and China, with values of over 70%.

In all the countries examined, the private sector share in R&D financing is lower than its share in performing R&D. The greater the difference, the more significant the role of government support and/or foreign investments in company R&D. Austria and the UK reveal the greatest differences here, with 21 and 18 percentage points (pp), respectively. In Switzerland, the difference is 8 pp (69% vs. 61%), which is average for the countries compared. The smallest differences are found in Japan, Germany and China.

With shares of over 10%, R&D funding from foreign sources plays an especially important role in the UK, Austria, the Netherlands, Switzerland and Finland. In Switzerland, this financing amounts mainly to contributions from the EU. In contrast, the Asian countries included in the comparison receive practically no financing from other countries.

5.2 Government budget appropriations or outlays for R&D

Government support for R&D activities in a specific country can be assessed on the basis of government budget appropriations or outlays for R&D. These contributions are expressed as a percentage of GDP in order to take account of differences in the sizes of the economies of the compared countries.

Korea and Denmark lead the rankings, with public R&D financing of more than 1% of their GDP (Figure B 5.2). Switzerland spent 0.9% of its GDP in 2014 on public R&D financing, which put the country in the front of the mid-field together with Germany, Sweden and Austria.

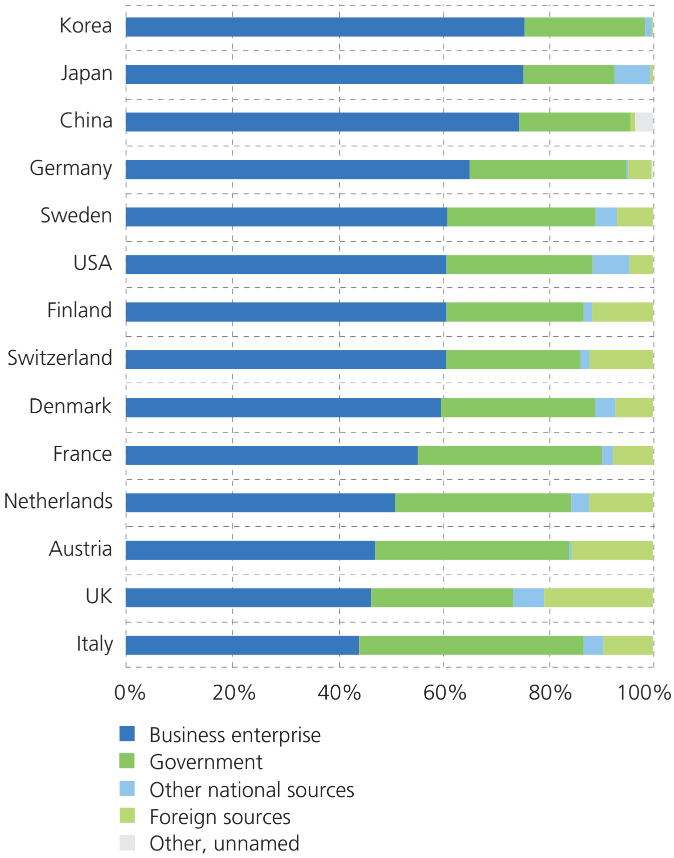
From 2000 to 2014, contributions from the public budget to R&D in Switzerland rose by an average of 2.8% per year – a rate slightly ahead of GDP growth (+2.4%). Thus the government maintained its R&D efforts regardless of economic developments and continually increased its contributions to research and innovation.

5.3 Venture capital

The financing of innovation activities is very difficult, particularly in the early stages of development. Start-up companies frequently need financially strong partners because they cannot raise the necessary capital themselves. Venture capitalists provide capital, their networks and their experience for the founding and initial development phase of innovative firms or for the creation of technologies with substantial potential for development. The availability of venture capital is thus a significant feature of a dynamic, innovation-oriented society.

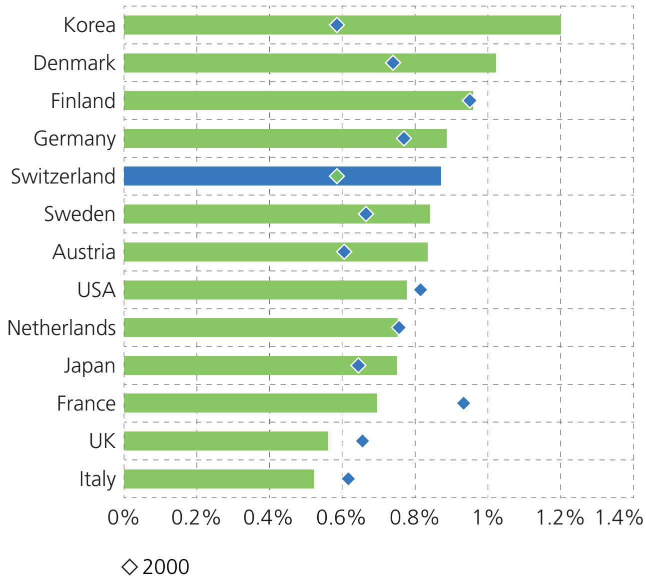
In 2014, the USA had by far the highest level of venture capital investment as a percentage of GDP, whereas Switzerland ranked in the middle (Figure B 5.3). However, since the availability of venture capital is very dependent on the economic climate with respect to volume and investment phases, these results must be viewed with caution. Under current financial conditions, venture capital funds prefer to invest in later stages of development, and for this reason there is a lack of capital available for the pre-start and start-up stages of businesses, which are riskier. In Japan, Denmark, Italy and the Netherlands, venture capital is invested primarily in the start-up stage. With more than half of its venture capital invested in the start-up stage, Switzerland ranks in the lower midfield in this context.

Figure B 5.1: R&D funding by sector, 2013



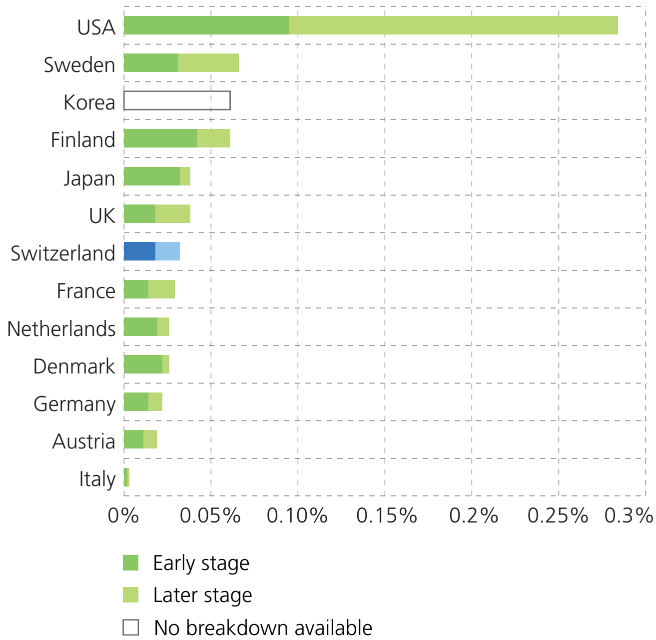
Exceptions to reference year 2013: France, Italy, Switzerland: 2012
Source: OECD, FSO

Figure B 5.2: Government budget appropriations or outlays for R&D as a percentage of GDP, 2014



Exceptions to reference year 2014: Italy, Korea, UK: 2013; Switzerland: 2012
No data available: China
Source: OECD

Figure B 5.3: Venture capital investments by stage as a percentage of GDP, 2014



Exceptions to reference year 2014: Japan: 2013
No data available: China
Source: OECD

6 Participation in EU Research Framework Programmes

Participation in international research organisations and programmes is an important factor in making scientific progress, because it offers institutions and researchers the opportunity to position themselves in international research and innovation networks.

As there are a great many of these funding instruments at international level, this chapter will concentrate on the Research Framework Programmes (FPs) of the EU. The FPs, which were launched during the 1980s, are the most important EU instruments for implementing Community policy in the areas of science and technology. For Swiss research institutions, the FPs are the second-most important source of third-party funds for scientific research, after the Swiss National Science Foundation (SNSF). Owing to the time needed to produce statistics, the data refer to the 7th FP (2007–2013) and thus mirror the situation before the popular initiative "Stop mass immigration". As the initiative jeopardised Swiss participation in Horizon 2020 (8th FP, 2014–2020), it could have a serious impact on Swiss research.

6.1 Participation in FPs

The 4269 Swiss participations in the 7th FP correspond to 3.2% of all participations (Figure B 6.1). This share puts Switzerland in seventh place among the countries in the comparison, behind the large European countries, but ahead of Austria, Denmark and Finland.

Since 1992, the number of Swiss participations in European research projects has increased continually (Figure B 6.2): Swiss firms have integrated themselves in the European research arena in ever-greater numbers. This increase coincided with an increase in the FP budgets, which is also expressed in a higher number of financed projects and thus enhanced participation opportunities.

6.2 Contributions paid as part of the FPs

Within the framework of the 7th FP, the Swiss research and innovation institutions attracted European finance worth CHF 2482 million, i.e. 4.2% of the European total (Figure B 6.3). This puts Switzerland in sixth place among the compared countries, and the figure comfortably exceeds the levels of participations quoted in the previous point. The difference between the share of participations and the share of subsidies paid is especially attributable to the fact that researchers in Switzerland are very successful with their applications for the particularly generous European Research Council (ERC) grants (see Section 6.4).

When it comes to funding allocated to Swiss researchers within the FPs, a remarkable trend can be observed (Figure B 6.4): from 1992 to 2012, these contributions increased by a factor of around nine, from an average of CHF 40 million per year during the 3rd FP to more than CHF 350 million during the 7th FP.

6.3 Success rate of project proposals

Within the 7th FP, European funding was granted for nearly every fourth project proposal; proposals from Swiss researchers have a success rate of 24%. This good result puts Switzerland in third place in the comparison, behind the Netherlands and France (Figure B 6.5), and suggests an above-average quality of Swiss project proposals overall. However, the differences between the countries are small.

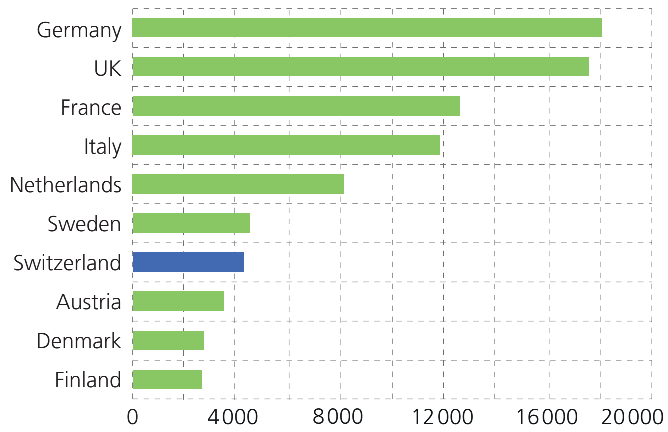
6.4 ERC Grants

As part of the FPs, the European Research Council (ERC) likewise awards grants to promising research projects. There are three main types of individual grant: a) Starting grants (for young researchers with research experience of two to seven years after completing their doctorates and whose work is very promising); b) Consolidator grants (for scientists beginning an independent career); and c) Advanced grants (for experienced researchers).

Switzerland is well represented among all three types of grants. Within the entire 7th FP, researchers active in Switzerland received 168 Starting grants (6.2% of all Starting grants awarded during the period under review), 24 Consolidator grants (7.2%) and 153 Advanced grants (7.4%) (Figure B 6.6). These values were exceeded only by relatively large countries.

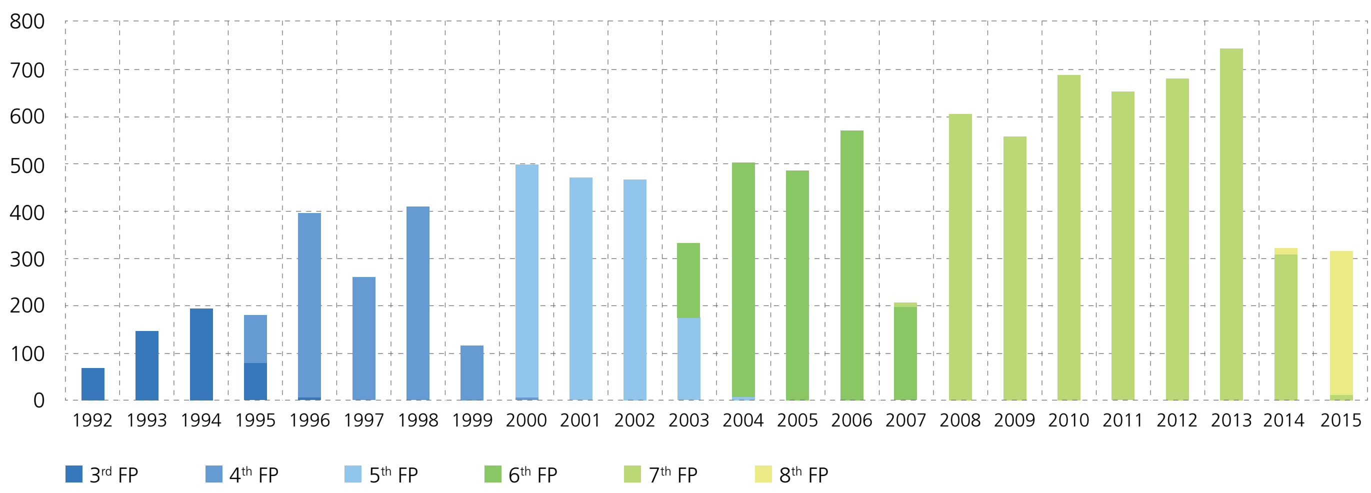
As Switzerland was excluded from the Horizon 2020 programme from February to September 2014, the SNSF resorted to temporary backup schemes which enabled excellent researchers working in Swiss institutions to apply for contributions comparable to ERC grants. Of the 145 applications that were submitted, 27 projects were granted financial support (12 in the exact sciences and engineering, 10 in life sciences and 5 in humanities and social sciences).

Figure B 6.1: Number of participations in the 7th FP, 2007–2013



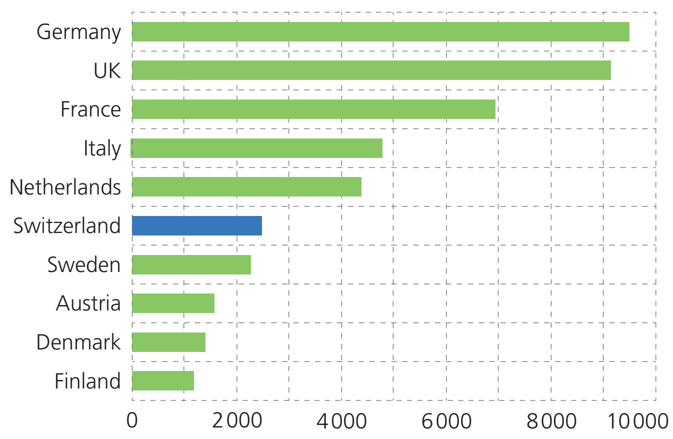
The figure includes only those comparison countries that are EU Member States or states associated with the FPs
Source: European Commission, SERI

Figure B 6.2: Number of new Swiss participations in the FPs



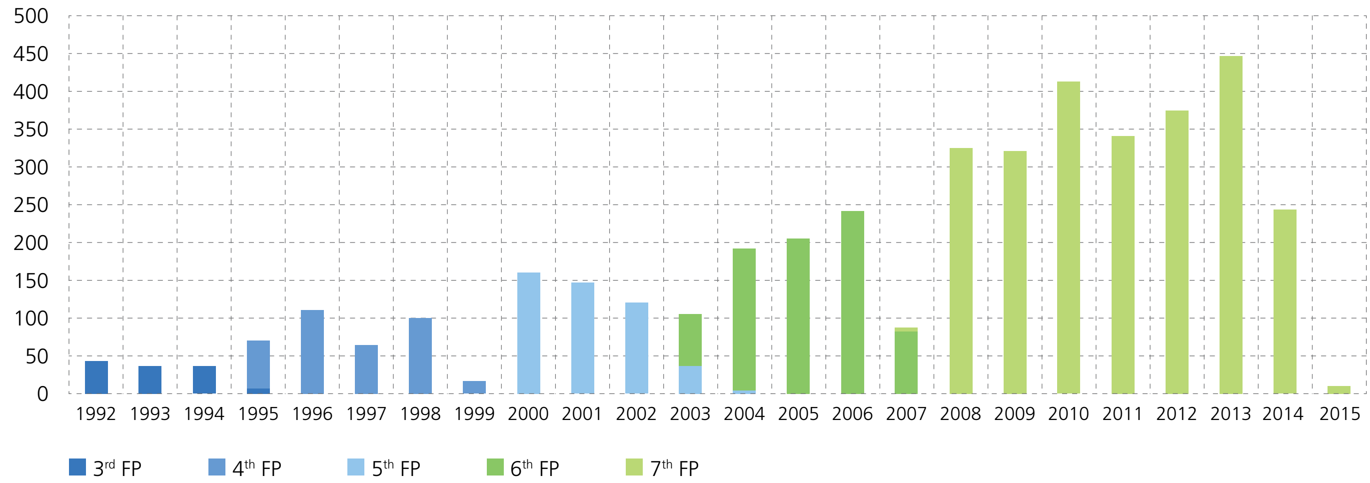
Source: European Commission, SERI

Figure B 6.3: Funds committed as part of the 7th FP in CHF million, 2007–2013



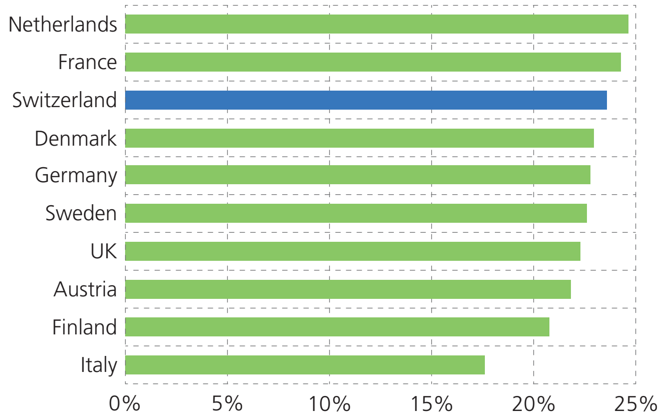
The figure includes only those comparison countries that are EU Member States or states associated with the FPs
Source: European Commission, SERI

Figure B 6.4: Funds committed as part of the FPs for active Swiss researchers in CHF million



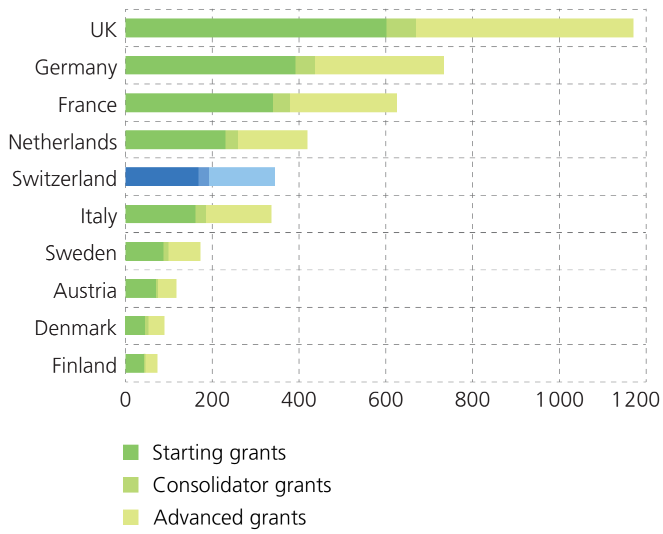
Source: European Commission, SERI

Figure B 6.5: Success rate of proposals submitted as part of the 7th FP, 2007–2013



The figure includes only those comparison countries that are EU Member States or associated with the FPs
Source: European Commission, SERI

Figure B 6.6: Number of ERC grants, 2007–2013



The figure includes only those comparison countries that are EU Member States or associated with the FPs
Source: ERC, SERI

7 Scientific publications

For researchers, the publication of articles in scientific journals is the most important means of disseminating knowledge. As a rule, scientific publications contain the best of the scientific research, as they are highly selective in what they accept for publication. They consequently reflect contributions to the knowledge and are, in many cases, the foundation of important innovations. A statistical analysis of the output of scientific articles enables the calculation of indicators of production, effect and collaboration.

7.1 Volume of publications

A first way of assessing the scientific performance of a country is to compare the volume of its publications with the entire output worldwide. An analysis per research area reveals the strengths and weaknesses of a country in the various scientific fields.

During the 2009–2013 period, the share of Swiss publications in all publications around the world amounted to 1.2% (Figure B 7.1). Other small countries in the comparison had shares of a similar magnitude. At the undisputed top of the ranking was the USA, followed by China, whose share climbed strongly. During the 2004–2008 and 2009–2013 periods, Switzerland had a high growth rate, topped only by China, Korea, Denmark and the Netherlands.

In publications per 1000 inhabitants and per researcher, Switzerland took first place and second place, in the respective periods, among the countries compared. This last indicator in particular points to above-average productivity in Swiss scientific research.

In Switzerland, the research areas life sciences (30%), the group "physics, chemistry and earth sciences" (25%, one-third for CERN in physics) and clinical medicine (20%) are most prominently represented in scientific publications (Figure B 7.2). If the portfolio of the USA is used as a measure, we see that Swiss publications deviate only slightly. Switzerland is more strongly specialised in "physics, chemistry and earth sciences" and significantly weaker in humanities and social sciences.

7.2 Impact of publications

We must consider not just the number of articles published in scientific journals, but also their quality or impact. An indicator of this is the frequency with which a publication is cited in other publications (its impact factor).

Switzerland was very well placed during the period under review as regards this indicator, coming in third behind the USA and the Netherlands (Figure B 7.3).

In a breakdown by research area, the groups "technical sciences, engineering and computer science" and "physics, chemistry and earth sciences" had the greatest impact in Switzerland (Figure B 7.4). The area "agriculture, biology and environmental sciences" and the life sciences also lay well above the global average. To a certain degree, this result probably reflects the comparatively high investments made by Switzerland in basic research, especially in the exact and natural sciences. Only the area "humanities and arts" was declining in comparison with the world portfolio, in particular the USA.

7.3 International networking as reflected in publications

The share of publications produced by several researchers from different countries is an indicator of networking or knowledge exchange.

During the 2009–2013 period, the share of publications based on international partnerships was 78% in Switzerland. This placed it at the top of the list of compared countries, followed by two other small countries, Austria and Sweden (Figure B 7.5). Since the 1999–2003 period, during which Switzerland also had the lead with a share of 74%, the share of international partnerships in Switzerland has risen only slightly. The highest growth occurred in the USA, Japan and Finland.

All research areas in Switzerland had a share of international partnerships of more than 55% during the 2009–2013 period, which likewise testifies to the strong international ties (Figure B 7.6). At the top was the group "physics, chemistry and earth sciences" (94%), followed by "agriculture, biology and environmental sciences" (71%). The areas "agriculture, biology and environmental sciences", "clinical medicine" and "life sciences" markedly increased their shares from the 1999–2003 period to the 2009–2013 period, while the shares of "technical sciences, engineering and computer science" and "humanities and arts" declined.

The limits of bibliometric analysis

Bibliometry only surveys scientific articles. However, numerous scientific disciplines disseminate their results in the form of oral reports, monographs and books (such as those in the humanities and literature) or as patents or ad-hoc reports (e.g. in applied research).

Bibliometry is also based mainly on scientific journals published in English. Thus, many articles in languages other than English (e.g. in literature and the humanities) fall outside the bibliometric databases.

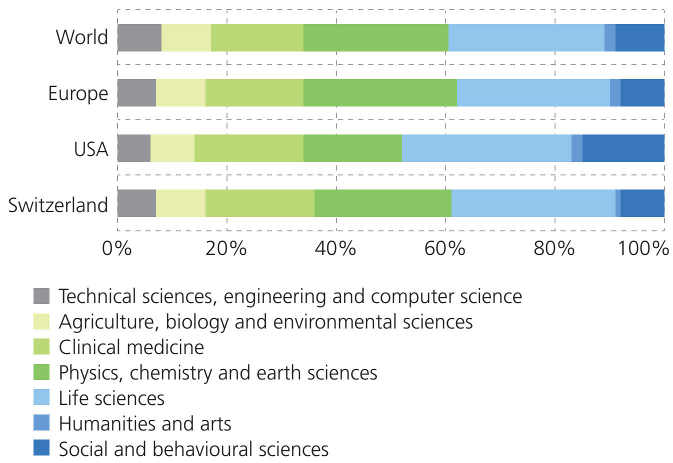
The impact of an article is measured by the frequency with which it is cited in other articles. If a publication is greeted with great resonance among researchers, the conclusion is drawn that it is significant and thus sound. However, the results can be falsified by the effects of fashions. Moreover, a scientific contribution may only gain recognition after much time has passed.

Figure B 7.1: Scientific publications, average 2009–2013

	Share of worldwide publications	Compound annual growth rate of publication volume between 2004–2008 and 2009–2013	Number of publications per 1000 inhabitants	Number of publications per researcher
Switzerland	1.2%	+5.8%	3.9	0.86
Austria	0.6%	+4.0%	1.8	0.41
Denmark	0.8%	+6.5%	3.4	0.49
Finland	0.7%	+3.2%	3.5	0.46
France	5.7%	+5.2%	2.2	0.58
Germany	5.3%	+4.5%	1.6	0.39
Italy	4.0%	+3.0%	1.7	0.93
Japan	5.0%	-0.6%	1.0	0.19
Korea	2.7%	+9.4%	1.4	0.24
Netherlands	2.3%	+6.4%	3.4	0.94
Sweden	1.2%	+3.2%	3.2	0.60
UK	5.7%	+3.5%	2.3	0.56
USA	27.1%	+3.1%	2.2	0.55
China	8.4%	+14.7%	0.2	0.16

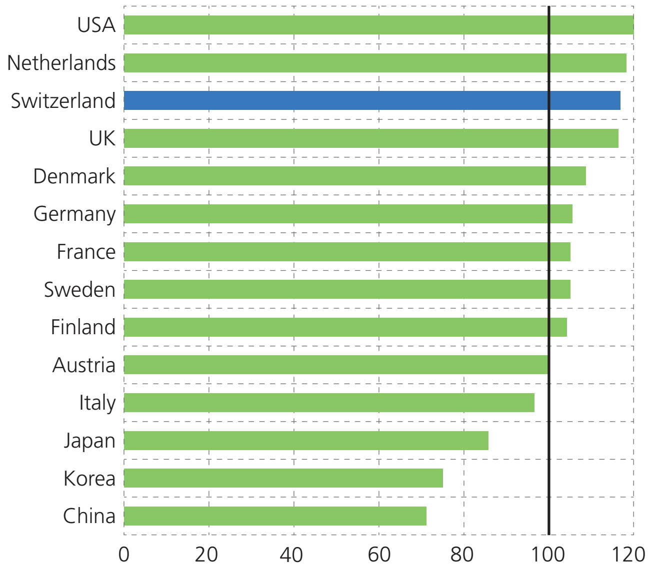
Source: SERI

Figure B 7.2: Scientific publications by research area, average 2009–2013



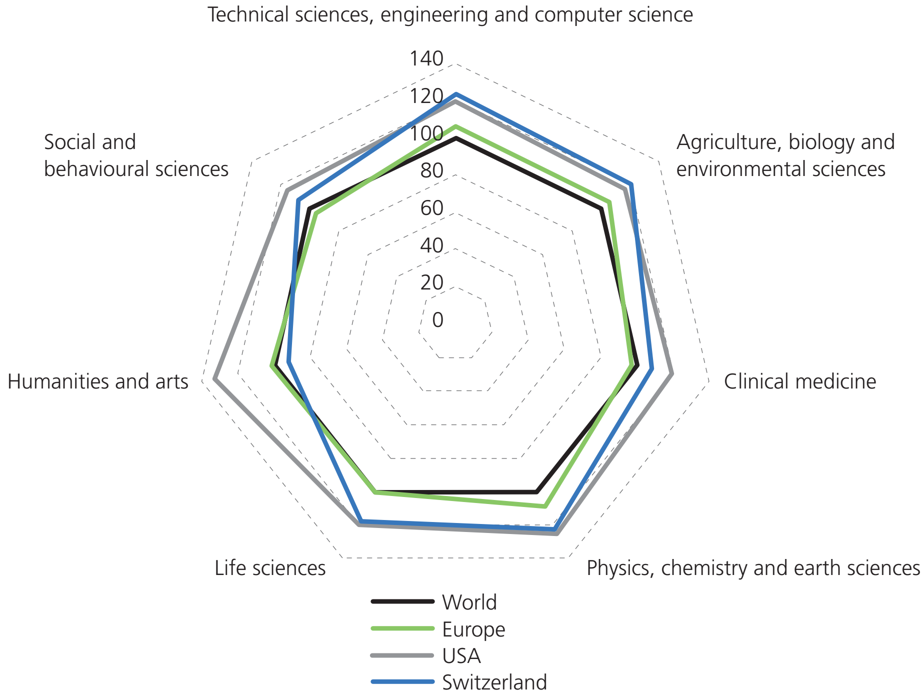
Source: SERI

Figure B 7.3: Impact of publications, average 2009–2013



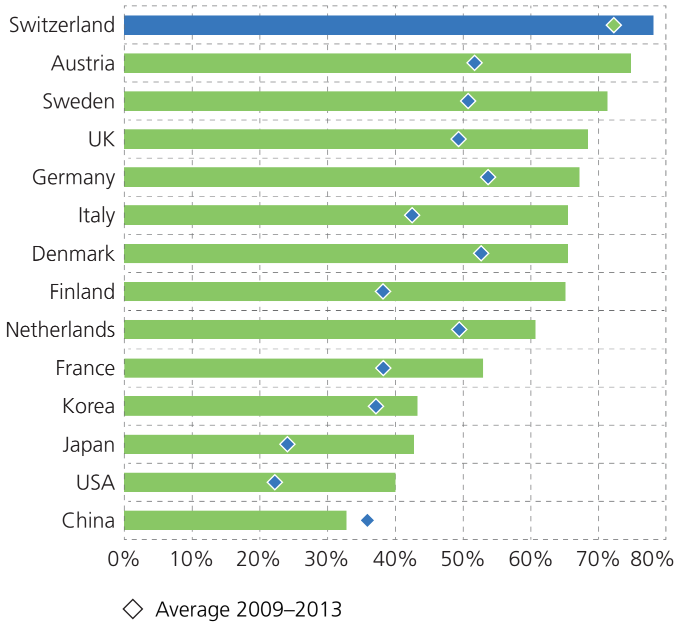
Source: SERI

Figure B 7.4: Impact of publications by research area, average 2009–2013



Source: SERI

Figure B 7.5: Share of international partnerships in the total number of jointly authored publications, average 2009–2013



Source: SERI

Figure B 7.6: Share of international partnerships in the total number of jointly authored Swiss publications by research area

	Average 1999–2003	Average 2009–2013
Technical sciences, engineering and computer science	74%	67%
Agriculture, biology and environmental sciences	54%	71%
Clinical medicine	50%	56%
Physics, chemistry and earth sciences	89%	94%
Life sciences	58%	65%
Humanities and arts	67%	64%
Social and behavioural sciences	60%	62%

Source: SERI

8 Patents

Patents are the most frequently used indicator of the knowledge output of an economy. The number of patent filings enables us to ascertain the technological and commercial utilisation of research findings. We speak of intermediate innovation, since patents allow us to observe the phase preceding the market introduction of a product.

Indicators based on patents offer the main advantage that they derive from internationally comparable data, available worldwide. Yet the usefulness of patents in individual sectors varies, depending on whether other informal strategies are available for protection against counterfeits (such as a temporal lead over competing companies or secrecy). For this reason some areas, such as software, are poorly covered by these indicators.

8.1 Number of patents per million inhabitants

Thanks to the Patent Cooperation Treaty (PCT), which is administered by the World Intellectual Property Organization (WIPO), patent protection for an invention can be sought simultaneously in a large number of countries, by filing a single "international" patent application.

Switzerland's share of the total volume of patent filings is modest (around 2% in 2013). But it is more informative to relate this value to the size of the population: with 296 PCT patent applications per million inhabitants, Switzerland is in second place, just after Japan (Figure B 8.1), and is followed by Sweden, Finland and Korea with likewise very high ratios. It must, however, be borne in mind with regard to Switzerland's outstanding position that the country is a "corporate headquarters economy": many multinationals active in R&D have their headquarters here, from which they file their patent applications.

Since 2000, the number of patent applications filed in Switzerland has grown strongly, though somewhat less markedly than in the Asian countries. In contrast, the number of filings of PCT patent applications in Sweden, Finland and the UK has declined.

8.2 Patent applications files in international collaboration

Applications for patents filed in collaboration with foreign partners indicate that an economy is integrated into the international networks. Thus it can make use of research activities conducted elsewhere and has greater access to innovative knowledge.

Swiss companies frequently apply for patent protection with foreign partners: 41% of the PCT patent applications submitted in 2012 originated from such collaborations (Figure B 8.2). Switzerland's lead is followed at some distance by the UK and Austria, and then the Scandinavian countries.

As early as 2000, Switzerland outpaced all the countries in the comparison. Since then, the number of patents applied for in international collaboration has increased yet again, which is an expression of even stronger international networking. This increase was especially marked in Finland, whereas the Asian countries recorded a decrease.

A number of different elements should be considered when interpreting these results: to begin, it is obvious that a small country will collaborate more strongly with foreign partners, which could partly explain the gap between Switzerland and Germany. Even so, there are considerable deviations between the small countries. The fact that Switzerland works with foreign partners more frequently than other small countries confirms its strong international anchor position with respect to patents.

8.3 Patent applications filed by foreign companies

Many patent applications are submitted by foreign-owned companies. This indicator reveals the scale of foreign investments in knowledge.

In Switzerland, 29% of PCT patent applications were filed by foreign companies, putting Switzerland in third place in 2012, behind the UK and Austria (Figure B 8.3). On the basis of its position, it can be assumed that Switzerland is an innovation location that attracts foreign-owned/controlled companies regardless of its size.

Switzerland's score was high as early as 2000, and has remained practically unchanged since then. Finland, the USA and Germany charted the greatest increases. A decline can be observed in the Asian countries and Austria, but at the same time, the total number of patent filings in these countries has risen (see Section 8.1).

8.4 Presence in new technologies

New technologies generally entail the development of new products or processes. Some technologies are specific, such as health-related technologies or biotechnology. Others are known as cross-cutting and can promote the creation of a broad array of products and services in different sectors. Examples include information and communication technology (ICT) as well as nanotechnology and environment-related technologies. The value of these new technologies for a country can be measured using their revealed technological advantage (RTA).

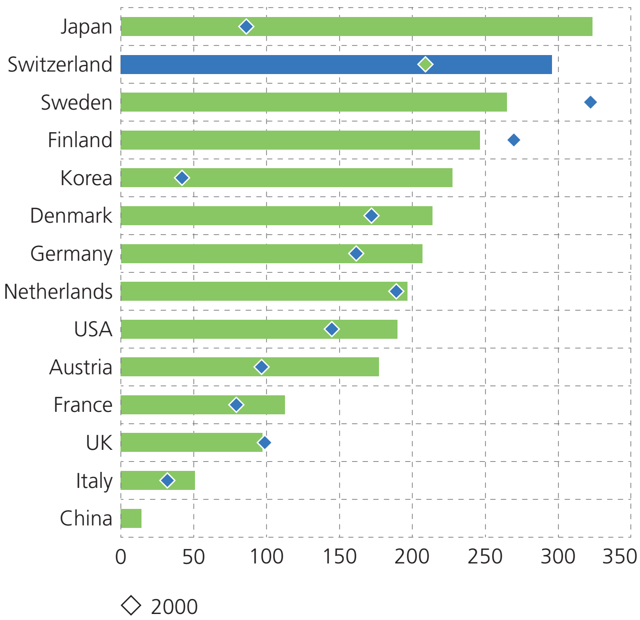
Switzerland's specialisation is above-average in health-related technologies (pharmaceuticals and medical technology) (Figure B 8.4); here it had the greatest degree of specialisation in 2012, followed by the Netherlands and Denmark. In biotechnology, Switzerland is placed in the mid-field, but above the average. In contrast, its specialisation in the other compared technologies is below average. ICT is dominated by China, Finland, Korea and Sweden. Switzerland's low score in this area is not surprising, since scarcely any manufacturers of ICT hardware are represented in the Swiss electronics industry. In nanotechnology, the USA, Korea and the UK show the most marked specialisation, and in environment-related technologies, Denmark, Germany and Japan occupy the top slots.

8.5 Forward citations

Forward citations are citations of a patent document by other patents. They can be used to measure the significance of a patented invention for subsequent inventions.

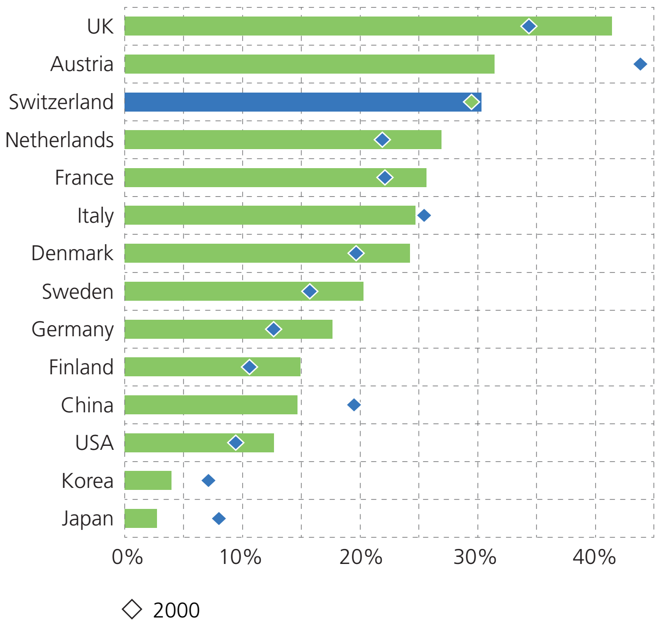
According to this indicator, European countries profit most from patented Swiss inventions: based on the most recent data, around 37% of forward citations come from this region (Figure B 8.5). Around one- quarter of forward citations are of US inventions. The significance of Swiss inventions for the USA has declined strongly, while it has increased slightly for Europe. This result underscores the relative strength of Switzerland's ties to the European research area.

Figure B 8.1: PCT patent applications per million inhabitants, 2013



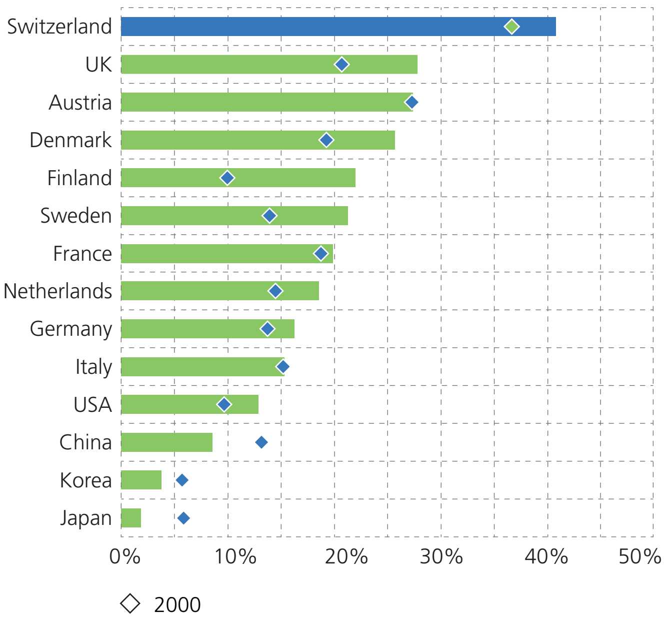
Source: OECD

Figure B 8.3 Share of patent applications filed by foreign-owned companies in all the patent applications in the country, 2012



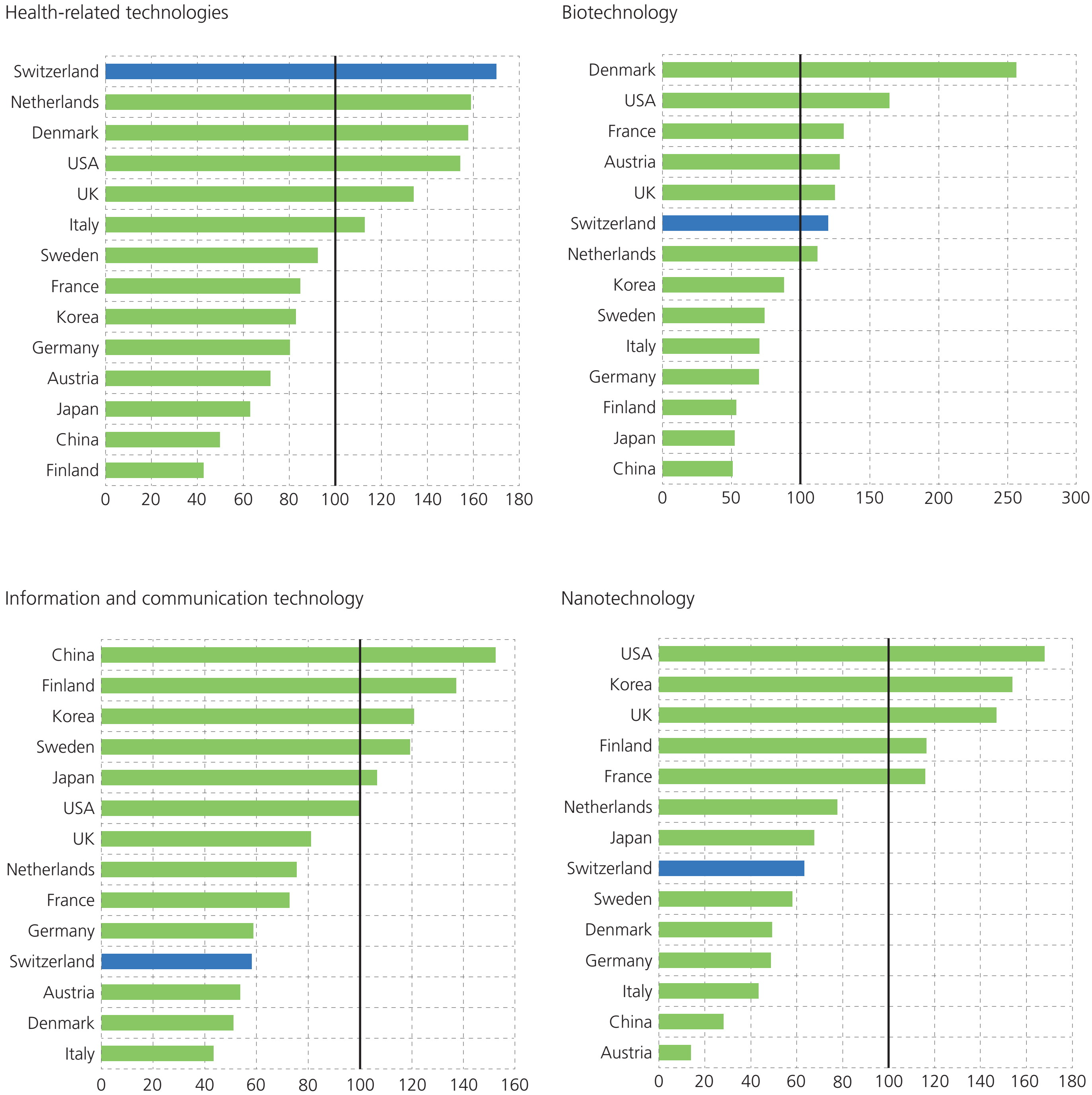
On the basis of PCT patent applications
Source: OECD, KOF calculations

Figure B 8.2: Share of patent applications filed in international collaboration in all patents, 2012

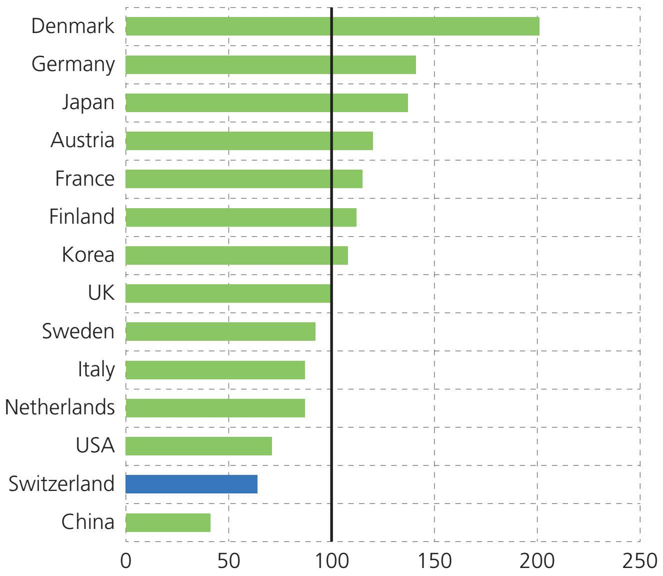


On the basis of PCT patent applications
Source: OECD, KOF calculations

Figure B 8.4: Revealed technological advantage, 2012

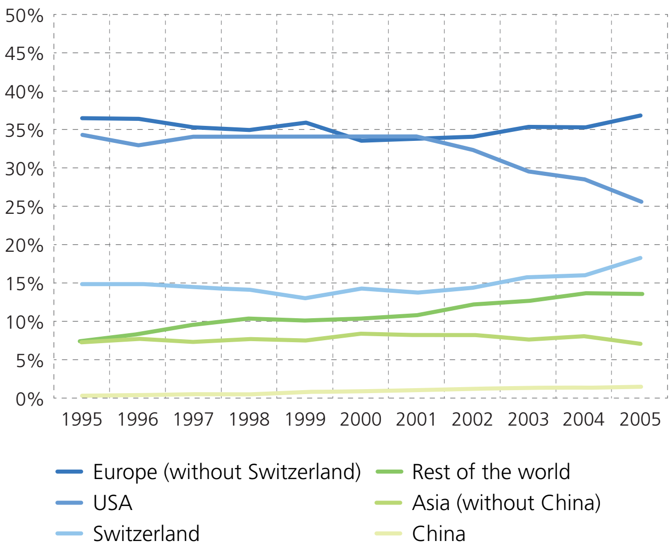


Environment-related technologies



Revealed technological advantage: the share of an economy's patents in a specific technological area relative to the share of this economy in all patents
On the basis of PCT patent applications
Source: OECD, KOF calculations

Figure B 8.5: Share of forward citations of Swiss publications by world region



On the basis of PCT patent applications
Source: OECD, KOF calculations

9 Knowledge and technology transfer

Knowledge and technology transfer (KTT) promotes innovation at the interface of research, industry and the market. It has the aim of networking firms, universities and other public research institutions in order to create an innovation-friendly environment through new collaborations. In this way, it contributes to the technological and economic utilisation of knowledge and accelerates the process of knowledge multiplication. This increases the chance that new products are developed within a relatively short time. Finally, KTT not only enables the economic utilisation of academic knowledge, it also contributes in return to the flow of practical knowledge into academic research.

As there are scarcely any comparable statistics for this area at international level, this chapter will mainly present indicators from national KTT activity based on the KOF survey of knowledge exchange and technology transfers. Since the last survey in 2011, the most recent figures refer to the 2008–2010 period. This national insight will be enhanced by an international comparison that focuses on the KTT between innovative firms and universities. Since this is a very specific sub-group of companies, these figures cannot be correlated directly with the results obtained by the KOF.

9.1 Participation of Swiss firms in KTT

During the 2008–2010 period, around one-fifth of Swiss firms were involved in KTT activities (Figure B 9.1) – a share that has not changed since the beginning of the 2000s.

At 28%, the share of industrial firms with KTT activities was somewhat higher than in the service sector (25%). The corresponding share in the building industry has seen a net decline since the 2002–2004 period and amounted to just 4% in 2008–2010.

KTT of above-average intensity can be found in the sub-sectors high-tech industry (especially "chemistry", "motor vehicles" and "electronics/instruments") and modern services. Overall, KTT activities have remained stable. However, they increased markedly in the high-tech industry and modern services sub-sectors, whereas they decreased the low-tech industry and among traditional services.

There is a striking connection between the size of a firm and its KTT activities: whereas 16% of small businesses are involved in KTT, 35% of mid-sized and 57% of large companies have such involvement. In view of the resources of large firms, especially human resources, it is not surprising that it is easier for them to coordinate and successfully utilise scientific knowledge, because large companies are more likely to have employees with completed tertiary education or training (especially in the natural sciences or engineering).

9.2 Types of KTT activity of Swiss firms

With respect to types of KTT activity, most of the firms surveyed named informal contacts and training measures as most important (Figure B 9.2). A much smaller share cited research (17%), consulting (15%) and the use of university infrastructure (14%).

Whereas informal contacts and training show a slight increase since the 2002–2004 period, the other three categories have remained practically unchanged.

9.3 KTT partners of Swiss firms

Of the firms active in knowledge transfer, 70% named one or more institutions in the ETH Domain as partners during the 2008–2010 period (Figure B 9.3). Just behind them were the universities of applied sciences (69%), whereas the cantonal universities were named significantly less often (43%). This lower value can be explained by the fact that universities do not pursue research in fields very close to the application in technical fields. Now the development of partnerships is particularly encouraged by the principle of indirect financing through collaborations with educational institutions, which is applied by the Innovation Promotion Agency CTI.

Between the 2002–2004 and 2008–2010 periods, a marked increase can be observed in the numbers of all three types of partners, which could be an effect of the economic crisis. Firms have thus increasingly pursued knowledge transfers simultaneously with partner institutions from different groups. Among the ETH Domain and the universities of applied sciences, this increase is significantly stronger than at the cantonal universities.

9.4 Swiss firms' motives for KTT

The single most important corporate motive for pursuing KTT is access to human capital (Figure B 9.4). This is followed by financial motives (which declined during the last period under review) and access to the results of research. Although institutional and organisational motives charted a slight rise compared with the 2002–2004 period, they continue to be mentioned the most infrequently.

Overall, only small changes can be noted between the 2002–2004 and 2008–2010 periods.

9.5 Obstacles to pursuing KTT among Swiss firms

Missing prerequisites on the part of the firm (53%) or the university (41%) as well as costs/risks/uncertainty (43%) are the most frequently cited obstacles to KTT (Figure B 9.5). Although organisational and institutional obstacles are named significantly less frequently, they represent the only category that recorded an increase between the 2002–2004 and 2008–2010 periods (from 25 to 31%).

A breakdown by sector or sub-sector reveals almost no differences. Firms active in high-tech industry worry more than others about a lack of information and costs/risks/uncertainty. Service companies complain more frequently of missing prerequisites on the part of the university or the firm, and this point is named most frequently in the replies of traditional service providers. Finally, large companies seem less affected by obstacles than SMEs, with the exception of organisational or institutional obstacles.

9.6 Collaboration between innovative firms and universities

During the 2010–2012 period, 17% of the innovating firms in Switzerland collaborated with universities or public research institutions – a value that places Switzerland in the mid-field in comparison with other countries in the comparison (Figure B 9.6). Germany, Sweden and the UK had comparable values, whereas Finland and Austria had significantly higher shares.

However, it should be noted that, especially in EU countries, collaboration with a university is often a condition of receiving public funding for private R&D. This rule likewise applies in Switzerland (where private R&D receives much less public funding anyway), but only for CTI funding. It explains to a large degree why the share of such collaborations is higher in most of the comparison countries. Owing to the high quality of Swiss universities and the strong growth of the universities of applied sciences, there is likely to be unused potential in Switzerland for increased collaboration between the corporate sector and the research sector.

Figure B 9.1: Frequency of knowledge and technology transfer in Switzerland

% of firms	2002–2004	2008–2010
Sector		
Industry	25.1	28.0
Construction	10.1	4.3
Services	26.7	24.6
Sub-sector		
High-tech industry	28.3	44.6
Low-tech industry	23.4	16.7
Modern services	27.2	35.2
Traditional services	26.2	10.6
Size		
Small (< 50 employees)	19.4	16.2
Mid-sized (50–249 employees)	33.7	34.7
Large (>= 250 employees)	44.9	57.3
Total	22.2	21.1

High-tech industry: chemistry, plastics, machines, electrical engineering, electronics/instruments, motor vehicles
Modern services: bancassurance, technical and non-technical services for companies
Source: KOF

Figure B 9.2: Forms of knowledge and technology transfer in Switzerland

% of firms	2002–2004	2008–2010
Informal	56.6	62.9
Infrastructure	11.9	13.9
Training	52.3	59.3
Research	17.8	17.1
Consulting	15.3	14.8

Share of companies that award a score of 4 or 5 (great or very great importance) on a scale of 1 to 5
Source: KOF

Figure B 9.3: Choice of partner for knowledge and techno-logy transfer in Switzerland

% of firms	2002–2004	2008–2010
ETH Domain (ETH Zurich, EPFL, PSI, WSL, Empa, Eawag)	57.0	70.0
Cantonal universities	38.0	42.8
Universities of applied sciences	56.0	68.6

Source: KOF

Figure B 9.4: Motives for knowledge and technology transfer in Switzerland

% of firms	2002–2004	2008–2010
Access to human capital ("tacit knowledge")	65.9	65.1
Access to research results ("codified knowledge")	29.3	28.9
Financial motives	41.1	33.0
Institutional/organisational motives	25.0	28.1

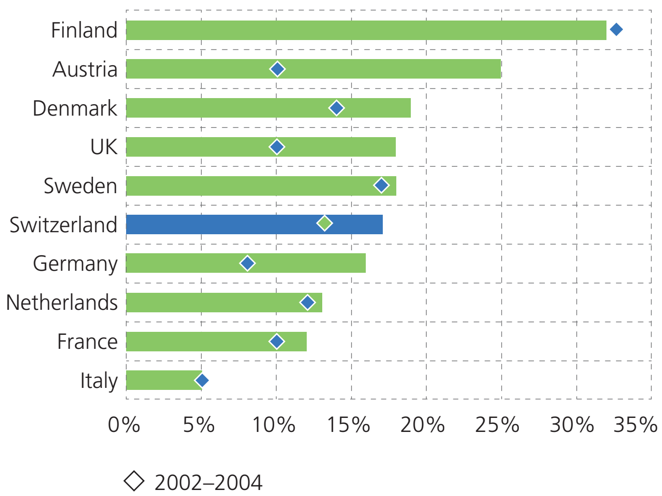
Share of companies that award a score of 4 or 5 (great or very great importance) on a scale of 1 to 5
Source: KOF

Figure B 9.5: Obstacles to knowledge and technology transfer in Switzerland, 2008–2010

% of firms	Missing information	Missing prerequisites on the part of...		Costs, risks, uncertainty	Organisational or institutional obstacles
		firm	university		
Sector					
Industry	27.8	50.4	39.6	43.4	30.3
Construction	22.3	50.2	39.9	37.7	24.4
Services	25.0	55.1	43.2	44.2	33.3
Sub-sector					
High-tech industry	31.5	47.5	42.4	49.6	35.4
Low-tech industry	25.3	52.5	37.6	39.1	26.9
Modern services	20.7	53.5	38.2	43.5	29.6
Traditional services	30.7	57.2	49.7	45.3	38.3
Size					
Small (< 50 employees)	25.6	53.4	40.9	42.6	30.2
Mid-sized (50–249 employees)	24.1	52.0	44.2	43.0	31.7
Large (>= 250 employees)	20.9	39.4	37.8	38.3	31.6
Total 2008–2010	25.2	52.7	41.4	42.6	30.5
Total 2002–2004	24.1	49.2	42.0	42.4	24.5

Share of companies that award a score of 4 or 5 (great or very great importance) on a scale of 1 to 5
Source: KOF

Figure B 9.6: Share of innovative firms that collaborate with universities among all innovative firms, 2010–2012



Exceptions to reference years 2002–2004: Switzerland: 2003–2005
No data available: Japan, Korea, USA, China
Source: Eurostat, KOF/SECO

10 Innovation activities of firms

Even if numerous patents have been filed and scientific articles published, they are only of use to an economy if they translate into innovative products and processes. This poses the question of the innovativeness of an economy and the firms active in it. In their innovation strategies, companies tend to combine the introduction of new products with the adoption of new production, organisation and marketing methods. However, this chapter will refer mainly to product innovations in accordance with the definition in the Oslo Manual (see Introduction).

10.1 New enterprise creations

New businesses are often viewed as the engine of an economy, as they stimulate competition, the creation of new jobs and increases in production capacity. Although they cannot be used as a direct measurement of innovation activities, business start-ups offer an indication of the dynamism of an economy.

In Switzerland, where nearly 4% of all those aged 18 to 64 have founded a new business, the rate of start-ups is at the front of the mid-field (Figure B 10.1). China is the absolute leader, followed at a great distance by the Netherlands, the UK, the USA and Korea. The rate of new business creation has remained stable in Switzerland since 2005, but has climbed strongly in the Netherlands and the UK.

Economic renewal is intensified even more when newly founded firms launch new products for their customers, and in this respect Switzerland, together with Sweden and Finland, is in the lower mid-field with a share of 44% (Figure B 10.2). Italy, China and Denmark have significantly higher values. Here as well, development in Switzerland is stable, while Italy and China chart particularly strong growth.

10.2 Innovative firms

The more innovative the firm, the more its competitiveness increases. However, innovation is not merely a function of young companies. Thus it is necessary to look at all the firms in a country.

By their own assessment, around half the industrial companies in Switzerland are product and/or process innovators (Figure B 10.3), which puts Switzerland in second place in the comparison – behind Germany and ahead of Finland and the Netherlands. At the beginning of the 2000s, the share of industrial firms with innovations in Switzerland was still nearly 70%, but the 2008–2010 period saw a marked decline, probably as a result of the economic crisis. Only Denmark manifested a comparable development. German industry succeeded in maintaining its share.

In the service sector, Switzerland has a share of 41% among firms with product or process innovations, thus taking fourth place in the comparison after Germany, Sweden and the Netherlands (Figure B 10.4). In this sector, too, the share of Swiss firms with innovations declined notably, first at the beginning of the 2000s and once again during the 2008–2010 period. Only Finland charted a comparable decrease (during the 2008–2010 period). Switzerland was thus affected very strongly by the crisis. This could be attributable in particular to the importance of its financial sector.

10.3 Innovation-related revenue

With respect to the share of product innovations in revenue, Denmark and Finland performed the best in 2010 among industrial firms (Figure B 10.5). Switzerland, with a revenue share of 25%, shared third place with Italy. In comparison with 2005, the share of innovative products in the revenue of industrial companies in Switzerland and Sweden dropped strongly and in Germany somewhat less strongly. In contrast, Denmark and Italy had especially pronounced increases.

In the service sector, Switzerland leads among the countries in the comparison (Figure B 10.6), followed at a considerable distance by Italy, the Netherlands and Denmark. Switzerland also had the strongest growth compared with 2005. In conjunction with the slide in the share of innovative firms, this result suggests that those service companies which continued to be innovative began, over time, to concentrate on this type of activity.

If only SMEs are considered, we see that both industrial and service firms in Switzerland are very keen on innovation (Figure B 10.7), which confirms that product innovations are widespread in the Swiss economy. Only Italian SMEs show higher revenue in connection with innovations, and then only in the industrial sector.

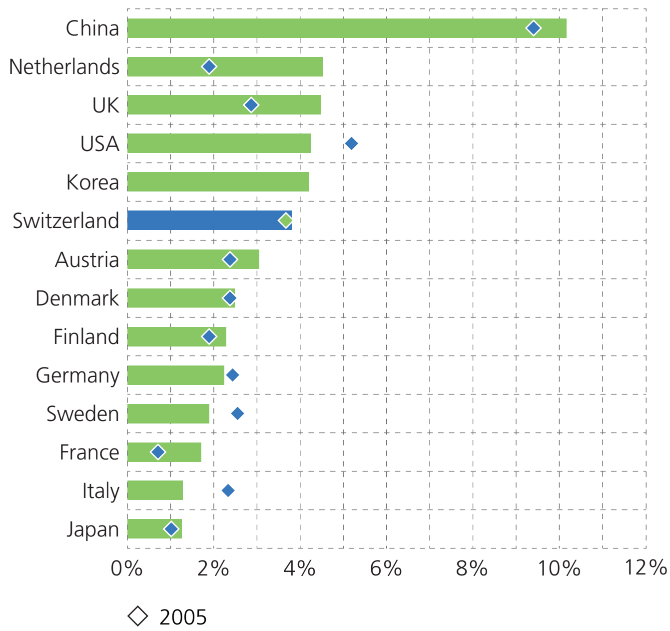
10.4 Firm and market novelties

An innovative product can be a novelty for the firm that produces it (firm novelty) or also for the market (market novelty). A novelty has greater potential in the latter case, since it is directed at a wider segment. Thus it is worth examining the relation between these two categories.

Market novelties have a somewhat higher share of revenue in Swiss industry than firm novelties (Figure B 10.8). Finland and Denmark show the greatest share of market novelties, which points to the great innovation potential of the Finnish and Danish industries. Germany takes last place in market novelties, with a share that has clearly declined since 2005, but on the other hand it boasts the highest share of revenues from firm novelties.

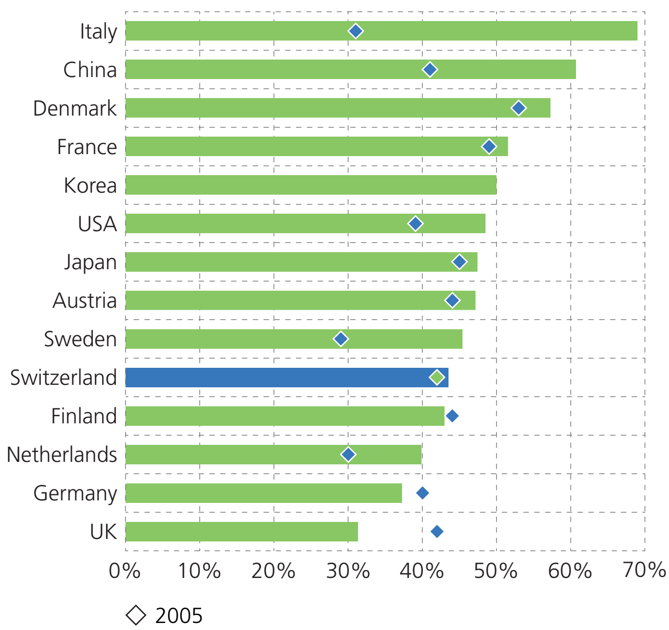
In the service sector, too, the share of revenue from market and firm novelties is well-balanced in Switzerland: in both cases, there has been strong growth since 2005 (Figure B 10.9). This puts Switzerland in first place among the compared countries, followed by Italy (market novelties) and the Netherlands (firm novelties).

Figure B 10.1: New business ownership rate, 2014



Share of 18–64 population who started a new business (which existed for 3 to 42 months)
Exceptions to reference year 2014: Korea: 2013
Source: GEM

Figure B 10.2: Share of new firms which launched products that are new to at least some customers, 2014



Share of 18–64 population who started a new business (which existed for 3 to 42 months)
Exceptions to reference year 2014: Korea: 2013
Source: GEM

Figure B 10.3: Share of innovative firms, manufacturing

%	1998–2000	2002–2004	2004–2006	2008–2010	2010–2012
Switzerland	68	67	67	57	53
Austria	53	57	53	50	44
Denmark	52	58	56	47	41
Finland	49	49	55	52	50
France	46	36	n.a.	n.a.	42
Germany	66	73	70	70	62
Italy	40	37	37	45	45
Netherlands	55	42	42	53	50
Sweden	47	54	51	51	48
UK	n.a.	44	44	n.a.	39

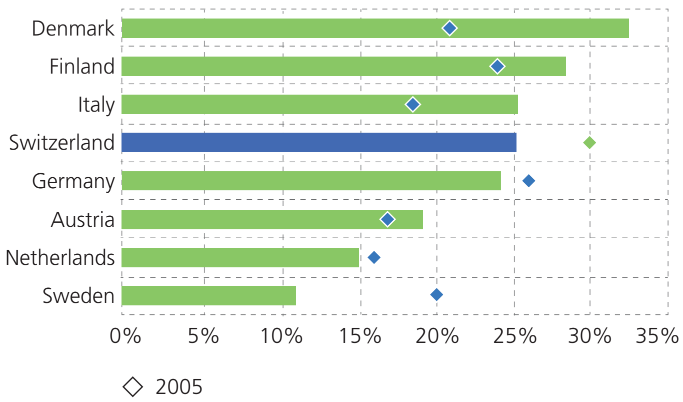
Product and/or process innovations
Exception to reference years 1998–2000, 2002–2004, 2004–2006, 2008–2010: Switzerland: 2000–2002, 2003–2005, 2006–2008, 2009–2011
No data available: Japan, Korea, USA, China
Source: Eurostat, KOF/SECO

Figure B 10.4: Share of innovative firms, services

%	1998–2000	2002–2004	2004–2006	2008–2010	2010–2012
Switzerland	67	51	51	44	41
Austria	45	48	49	39	36
Denmark	37	46	40	40	37
Finland	40	37	47	41	40
France	34	29	n.a.	n.a.	32
Germany	58	58	57	58	48
Italy	25	33	28	31	34
Netherlands	38	29	32	44	42
Sweden	46	46	39	47	43
UK	n.a.	42	34	n.a.	31

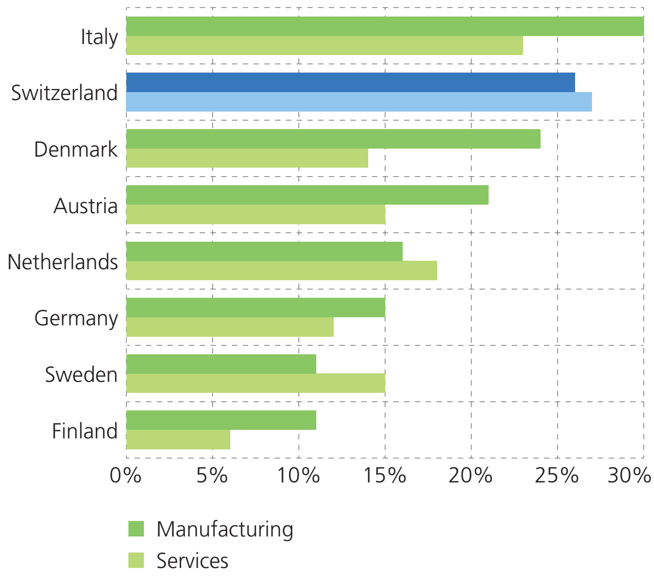
Product and/or process innovations
Exception to reference years 1998–2000, 2002–2004, 2004–2006, 2008–2010: Switzerland: 2000–2002, 2003–2005, 2006–2008, 2009–2011
No data available: Japan, Korea, USA, China
Source: Eurostat, KOF/SECO

Figure B 10.5: Revenue share of innovative products, manufacturing, 2010



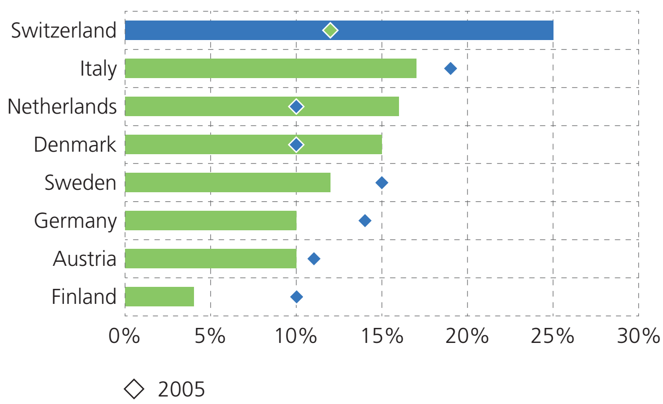
Percentages refer to innovative firms
Exceptions to reference year 2005: Switzerland: 2004
No data available: France, Japan, Korea, UK, USA, China
Source: Eurostat, KOF/SECO

Figure B 10.7: Revenue share of innovative products of SMEs, 2010



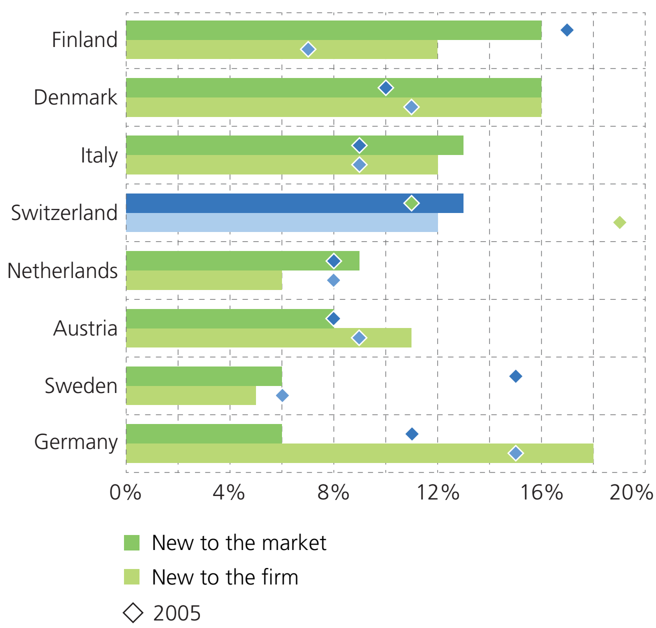
Percentages refer to innovative firms
No data available: France, Japan, Korea, UK, USA, China
Source: Eurostat, KOF/SECO

Figure B 10.6: Revenue share of innovative products, services, 2010



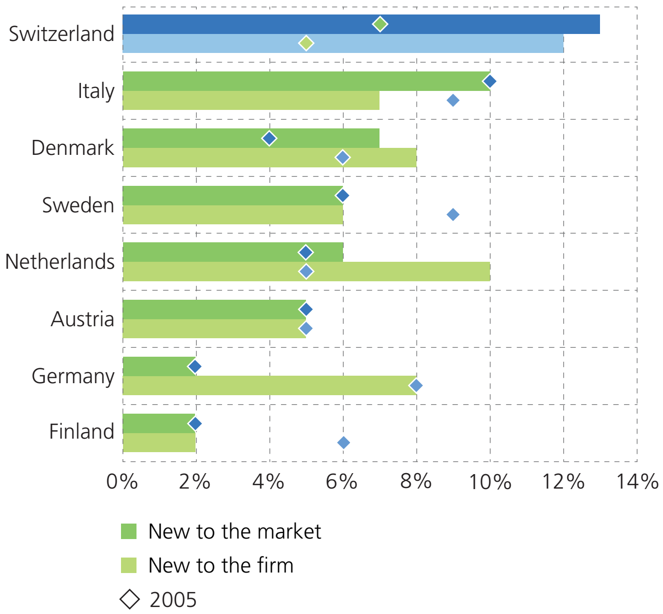
Percentages refer to innovative firms
Exceptions to reference year 2005: Switzerland: 2004
No data available: France, Japan, Korea, UK, USA, China
Source: Eurostat, KOF/SECO

Figure B 10.8: Revenue share of innovative products that were new to the market or to the firm, manufacturing, 2010



Percentages refer to innovative firms
Exceptions to reference year 2005: Switzerland: 2004
No data available: France, Japan, Korea, UK, USA, China
Source: Eurostat, KOF/SECO

Figure B 10.9: Revenue share of innovative products that were new to the market or to the firm, services, 2010



Percentages refer to innovative firms
Exceptions to reference year 2005: Switzerland: 2004
No data available: France, Japan, Korea, UK, USA, China
Source: Eurostat, KOF/SECO

11 Economic performance

An important component of an economy's innovation capacity is its ability to respond actively to new market developments, utilise the potential of technological transformation and react to structural changes in demand and competition. This innovation capacity is expressed in particular in changes to the sectoral structure; that is, shifts in the significance of the individual economic activities. A typical feature of the most advanced economies is the increasing importance of research- and innovation-intensive sectors.

In this regard, international statistics tend to differentiate between two groups of economic sectors: technology-intensive industrial sectors (high-tech and medium-high-tech) and knowledge-intensive services. In the case of the latter, we will distinguish between market-oriented services and public services (education, healthcare, arts, entertainment and leisure activities).

11.1 Sectoral structure

Changes in the shares of each sector or economic field in national added value are an expression of structural change in a country. The larger the share of the most innovative areas (high-tech industry and knowledge-intensive service categories), the more future-oriented the economy.

In Switzerland, the contribution of industry to national added value fell by 0.2 percentage points from 1998 to 2010 (Figure B 11.1). Except for Germany, all the other countries in the comparison also charted declines, with the trend particularly marked in Finland, France, Sweden and the USA. This decline affected the low-tech segments of the industrial sector in particular, but in numerous countries (especially France, the USA and Sweden), the share of the high-tech segment in value creation fell, too. Germany, Austria and Switzerland were among the few countries in which the high-tech segment's share rose (in Switzerland from 13.9% in 1998 to 15.8% in 2010). Thanks to this increase in productivity, Swiss industry was able to maintain its value creation share, despite the decline among the low-tech segments.

The value creation share in services increased between 1998 and 2010 in all the economies in the comparison, with the greatest growth rates in the USA, Denmark, France and Finland. These very substantial gains came mainly from modern services. In Switzerland, the share of modern services remained constant, as it was already comparatively high in 1998. In some countries (such as Denmark and Finland), the strong improvement can be explained by the need to catch up.

High-tech industry and modern knowledge-based services can be combined into a single main category: the "knowledge-intensive sector" (Figure B 11.2). In Switzerland, its share rose from 46.6% in 1998 to 48.6% in 2010, putting the country in third place in the comparison, behind the USA and Germany, and underscoring the knowledge orientation of the Swiss economy. The USA and Denmark had the highest rates of growth during the 1998 to 2010 period.

11.2 Exports of high-tech and medium-high-tech products

Research and innovation should enable the production and export of goods and services with high added value. A large share of exports among high-tech and medium-high-tech products thus suggests a good knowledge-based performance in an economy.

Taken together, high-tech and medium-high-tech products make up 75% of Swiss exports (Figure B 11.3), which puts Switzerland at the top of all the countries in the comparison. Japan, Korea, Germany, France and the USA were also above-average.

High-tech products dominate Swiss exports; their share has risen strongly from 2000 to reach 50% in 2014. This rise affected pharmaceutical products and electronics/instruments (including clocks and watches) in particular. During the same period, the share of medium-high-tech products in Swiss exports declined. In most of the countries in the comparison, the reverse was true: exports of high-tech products decreased and exports of medium-high-tech products increased, outstripping the export of high-tech products in every country but China.

Knowledge investments pay off: Swiss industry achieves substantial earnings through its exports, which confirms its competitiveness.

Definitions

High-tech industries: pharmaceuticals; manufacture of computer, electronics and optical products; aerospace industry

Medium-high-tech industries: chemical industry; manufacture of weapons and ammunition; manufacture of electrical appliances; manufacture of machinery and equipment not classified elsewhere; automotive industry; other transport equipment construction (except shipbuilding and aerospace construction); manufacture of instruments and supplies for medical and dental use

Knowledge-intensive service segments: information and communication; financial and insurance services; professional, scientific and technical services

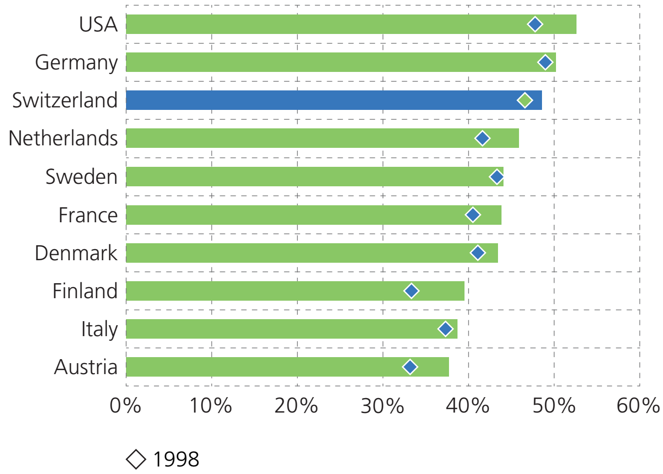
Figure B 11.1: Share of the sectors in nominal value creation

%	Switzerland		Austria		Denmark		Finland		Germany	
	1998	2010	1998	2010	1998	2010	1998	2010	1998	2010
Industry	25.5	25.3	28.2	27.0	26.6	20.1	38.6	28.9	33.3	33.4
Low-tech industry	11.6	9.5	17.1	14.5	14.9	9.1	22.4	15.4	14.6	12.8
High-tech industry	13.9	15.8	11.1	12.5	11.7	10.9	16.2	13.5	18.8	20.5
Energy	4.5	2.9	5.3	4.7	5.0	4.8	4.3	5.9	4.5	5.4
Construction industry	7.1	7.4	11.8	9.9	8.7	7.7	9.1	11.2	8.7	6.9
Services	62.9	64.4	54.7	58.2	59.5	67.4	48.0	54.0	53.4	54.2
Traditional services	30.2	31.6	32.6	32.9	34.0	34.8	27.7	28.0	24.3	24.6
Modern services	32.8	32.7	22.0	25.3	25.5	32.5	20.3	26.0	29.1	29.6
Total	100	100	100	100	100	100	100	100	100	100

%	France		Italy		Netherlands		Sweden		USA	
	1998	2010	1998	2010	1998	2010	1998	2010	1998	2010
Industry	25.6	17.5	31.3	25.4	23.3	19.4	33.5	26.5	26.2	19.2
Low-tech industry	14.9	10.5	19.8	15.6	14.3	11.7	16.3	12.2	12.9	9.4
High-tech industry	10.7	7.0	11.5	9.8	9.0	7.7	17.2	14.3	13.2	9.8
Energy	4.4	4.0	3.4	4.0	3.4	5.0	4.7	5.9	4.5	3.5
Construction industry	7.9	10.3	7.5	9.6	8.3	8.3	6.8	8.1	6.1	5.8
Services	62.0	68.1	57.8	61.1	64.9	67.4	54.9	59.4	63.2	71.6
Traditional services	30.1	31.2	33.1	32.2	32.3	29.2	28.8	29.6	31.0	28.8
Modern services	31.9	36.9	24.7	28.9	32.6	38.2	26.1	29.8	32.2	42.8
Total	100	100	100	100	100	100	100	100	100	100

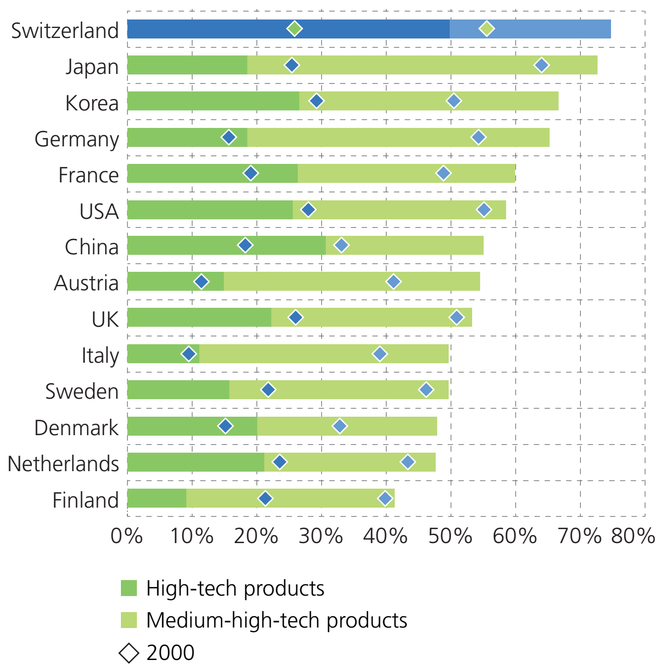
No data available: Japan, Korea, UK, China
Source: OECD, FSO, KOF calculations

Figure B 11.2: Share of knowledge-intensive sector in nominal value creation, 2010



No data available: Japan, Korea, UK, China
Source: OECD, FSO, KOF calculations

Figure B 11.3: Share of high-tech and medium-high-tech products in total goods exports, 2014



Exceptions to reference year 2014: Austria, Korea: 2013
Source: OECD

12 Switzerland in comparison with leading innovation regions

This chapter compares the position of Switzerland in research and innovation with that of selected innovation regions in other countries. The regions were chosen according to two criteria: they should be comparable to Switzerland in terms of size and economic power, and they should represent centres of research and innovation within their countries.

Six regions are included in the analysis:
- Baden-Württemberg (Germany)
- Bavaria (Germany)
- Lombardy and Piedmont (Italy)
- The Paris metropolitan area (Ile-de-France; France)
- The London metropolitan area (Greater London, Eastern England, South East England; UK)
- The core New England states (Connecticut, Massachusetts, Rhode Island; USA)

The comparison regions have a size similar to Switzerland (apart from the Paris metropolitan area and Bavaria), but a population that is 20 to 160% greater with an economic power that is 15 to 45% lower (GDP per capita; Figure B 12.1).

Switzerland's position was examined using five indicator groups that correspond in the main to the indicators used in previous chapters:[4]
1) R&D expenditure
2) scientific publications
3) patent applications
4) innovation activities of firms
5) importance of research- and knowledge-intensive activities

Figure B 12.1: Key figures on the comparison regions

	Surface area (km²)	Population (2012, million)	GDP (2011, EUR billion)	GDP per capita (2011, EUR)
Baden-Württemberg	35 751	10.814	385.4	35 800
Bavaria	70 550	12.633	459.3	36 500
Lombardy and Piedmont	49 251	14.114	463.2	32 800
Paris metropolitan area	12 012	11.948	608.6	51 200
London metropolitan area	40 572	22.188	798.6	36 000
New England	45 695	11.175	497.6	44 500
Switzerland	*41 285*	*7.997*	*474.7*	*60 000*

Source: Eurostat, ZEW calculations

[4] Owing to the use of difference sources, the results stated here sometimes deviate from results stated in previous chapters.

12.1 R&D expenditure

At 2.96%, the R&D intensity of Switzerland – that is, the GDP share of expenditure for R&D – was only average in 2012 in comparison with the innovation regions considered here (Figure B 12.2). Two regions – Baden-Württemberg and New England – achieved much higher values, with 5.0% and 4.8%, respectively. Bavaria's R&D share is similar to Switzerland's, with the Paris metropolitan area just below that of Switzerland. This somewhat relativises Switzerland's good position in the country comparison (see Chapter 4): there, Switzerland is ahead of France, the USA and Germany, but does not reach or only barely reaches the level of R&D expenditure in the especially innovation-oriented and similarly sized regions within these countries.

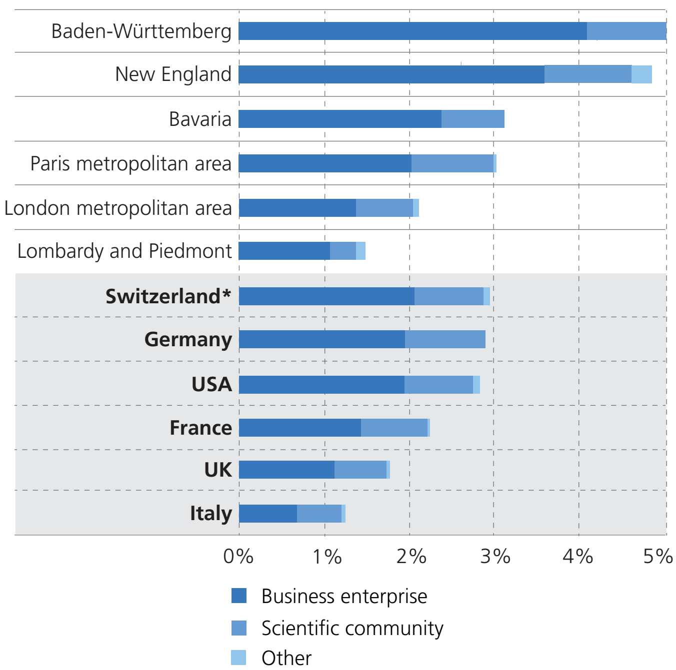
At 2.08%, the GDP share of the private sector's R&D expenditure in Switzerland is clearly lower than in the two German regions, Baden-Württemberg and Bavaria, and the US region of reference (Figure B 12.3). However, it is somewhat higher than in the Paris metropolitan area and much higher than in the regions of reference in Italy and the UK. With respect to R&D expenditure by the scientific community (universities and government), New England, Baden-Württemberg and the Paris metropolitan area are ahead of Switzerland, whereas Bavaria and the London metropolitan area are slightly behind.

Between 2000 and 2012, Switzerland's R&D expenditure climbed by 0.48 percentage points (pp) – the third-highest value in the comparison behind Baden-Württemberg (+1.23 pp) and New England (+0.81 pp). In the Paris and London metropolitan areas, this proportion has even dropped since 2000, an effect primarily attributable to the low dynamism of R&D expenditure in those economies. At a deeper level, account must be taken of the process of deindustrialisation affecting these two regions that has led to a reduction of their R&D capacities. With respect to R&D expenditure by the scientific community, Switzerland stands out, with growth of +0.22 pp. Only New England scored higher, with an increase of +0.39 pp. In terms of private-sector R&D expenditure, by contrast, Baden-Württemberg has charted the most significant increase since 2000 (+1.06 pp compared with +0.39 in New England and +0.25 in Switzerland).

The composition of R&D expenditure in Switzerland differs in two points from that of the other regions (Figure B 12.4). Firstly, Switzerland has the highest share of R&D expenditure at universities: at 28.1% (2011), it even tops the values of the two metropolitan areas Paris (17.9%) and London (24.0%), where substantial parts of the university research capacities of France and the UK are concentrated. Secondly, the government share is considerably lower: with the exception of New England, the innovation regions show values of between 8 and 15% for the state, mainly comprising government research facilities outside universities. If the R&D shares of universities and government are added together, in Switzerland they total 29%. This is higher than in the German, Italian and US regions and quite close to the values of the Paris (32%) and London (33%) metropolitan areas.

Changes to the composition of R&D expenditure based on performing sector are predominantly uniform: in almost all the regions, the share of the business sector in total R&D expenditure has declined since 2000, with the sole exception of Baden-Württemberg. The share of universities has risen across the board: the increase visible in Switzerland (+5.3 pp) is exceeded slightly only by the London metropolitan area (+5.5 pp). The government share has fallen in most regions, except for Bavaria and New England.

Figure B 12.2: R&D expenditure as a percentage of GDP, 2011



Notes: see Figure B 12.3
* 2012
Source: Eurostat, Swiss National Science Foundation, ZEW calculations

Figure B 12.3: R&D expenditure of business enterprises and scientific community as a percentage of GDP, 2011, and change since 2000

	Business enterprise		Scientific community[1)]		Overall	
	2011	ΔPP_{2000}[2)]	2011	ΔPP_{2000}[2)]	2011	ΔPP_{2000}[2)]
Baden-Württemberg[3)]	4.07%	+1.06	0.97%	+0.16	5.05%	+1.23
Bavaria[3)]	2.40%	+0.08	0.73%	+0.12	3.13%	+0.20
Lombardy and Piedmont	1.06%	+0.08	0.32%	+0.02	1.48%	+0.19
Paris metropolitan area	2.02%	–0.23	0.96%	–0.04	3.02%	–0.26
London metropolitan area	1.34%	–0.16	0.70%	+0.04	2.11%	–0.06
New England	3.58%	+0.39	1.02%	+0.39	4.85%	+0.81
Switzerland[4)]	*2.08%*	*+0.25*	*0.82%*	*+0.22*	*2.96%*	*+0.48*
Germany	1.96%	+0.22	0.94%	+0.20	2.89%	+0.42
Italy	0.68%	+0.16	0.53%	+0.01	1.25%	+0.21
France	1.44%	+0.09	0.78%	+0.01	2.25%	+0.10
UK	1.13%	–0.03	0.62%	+0.02	1.78%	–0.01
USA[5)]	1.95%	–0.06	0.81%	+0.16	2.84%	+0.18

GDP on the basis of the European system of national and regional accounts (ESA95)
1) Higher education and government
2) Change in percentage points between 2000 and 2011
3) Business R&D expenditure in 2000 estimated on the basis of data for 1999 and 2003
4) 2012 instead of 2011 and change between 2000 and 2012; GDP for 2012 estimated on the basis of ESA95
5) Includes R&D expenditure not allocated to any of the sectors
Source: Eurostat, National Science Foundation, ZEW calculations

Figure B 12.4: Distribution of R&D expenditure by performing sector, 2011, and change since 2000

	Business enterprise		Higher education		Government		Other	
	2011	ΔPP_{2000}[1)]	2011	ΔPP_{2000}[1)]	2011	ΔPP_{2000}[1)]	2011	ΔPP_{2000}[1)]
Baden-Württemberg[2) 3)]	80.7%	+1.9	10.9%	+0.6	8.4%	–2.5	0.0%	+0.0
Bavaria[2) 3)]	76.5%	–2.6	13.9%	+1.2	9.6%	+1.4	0.0%	+0.0
Lombardy and Piedmont[3)]	72.0%	–5.0	16.8%	+2.1	4.6%	–3.7	6.6%	+6.6
Paris metropolitan area	66.8%	–1.7	17.9%	+2.2	13.8%	–0.9	1.5%	+0.4
London metropolitan area	63.7%	–5.6	24.0%	+5.5	9.3%	–2.9	3.0%	+3.0
New England[4)]	73.9%	–5.1	17.6%	+4.6	3.4%	+0.8	5.1%	–0.3
Switzerland[5)]	*69.3%*	*–4.7*	*28.1%*	*+5.3*	*0.8%*	*–0.6*	*1.8%*	*–0.1*
Germany[3)]	66.9%	–3.4	18.3%	+2.2	14.8%	+1.2	0.0%	+0.0
Italy[3)]	54.5%	+4.4	28.6%	–2.4	13.7%	–5.2	3.1%	+3.1
France	64.2%	+1.7	20.8%	+2.1	13.7%	–3.6	1.2%	–0.2
UK	63.4%	–1.5	26.5%	+5.9	8.2%	–4.4	1,.%	+0.0
USA[6)]	68.7%	–6.7	18.7%	+4.3	8.5%	+1.9	4.1%	+0.6

1) Change in percentage points between 2000 and 2011
2) Business R&D expenditure in 2000 estimated on the basis of data for 1999 and 2003
3) The "Other" category in Germany (2000, 2011) and Italy (2000) is largely included in the government sector
4) Tertiary institutions include Federally Funded Research Centers; government includes R&D expenditure of the US federal states
5) 2012 instead of 2011 as well as change between 2000 and 2012
6) "Other" includes R&D expenditure not allocated to specific performing sectors
Source: Eurostat, National Science Foundation, ZEW calculations

12.2 Scientific publications

The number of scientific publications in specialist international journals[5] is an important indicator of the performance of a scientific system. With 1.29 publications per researcher[6] per year, Switzerland leads the regional comparison by a slim margin over New England (Figure B 12.5).

Publications from scientists working in Switzerland also have a higher impact than publications from most of the reference regions (Figure B 12.6); only New England outperforms Switzerland, with 9.8 citations per publication (Switzerland: 7.3). Numbers of publications in Switzerland have climbed sharply in recent years: an increase of nearly 60% between the two periods 2000–2006 and 2007–2013 puts Switzerland in the lead among all the regions together with Lombardy/Piedmont. Reasons for this strong growth are not only the greater publication output of the individual researchers, but also increasing collaboration between researchers from different institutions. As a single publication is counted multiple times when researchers from several institutions publish jointly, this alone ensures a rise in publication numbers.

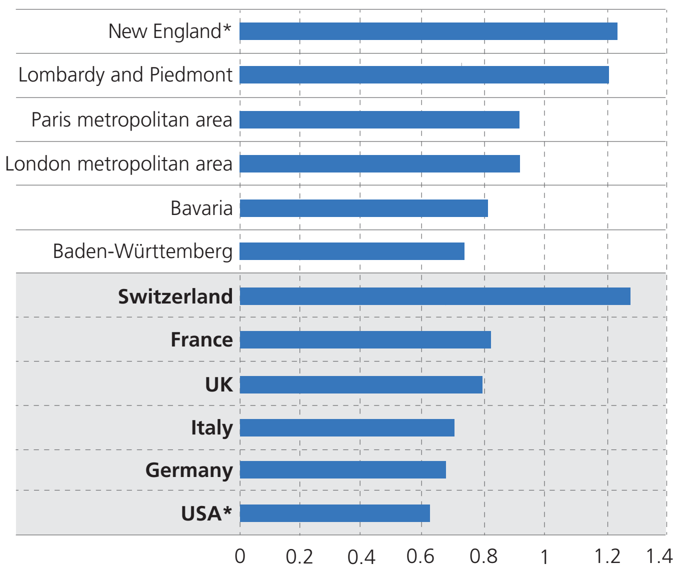
The distribution of publications by research area shows a profile for Switzerland similar to most of the other regions (Figure B 12.7). All the regions show a greater share of publications in the areas of clinical medicine and life sciences than the worldwide average, but the share of publications in engineering and computer science is consistently below average.[7] Compared with the other regions analysed, Switzerland has a particularly high share of publications in agriculture/biology/environmental sciences. Its share of publications in social and behavioural sciences is likewise higher than in most of the other regions, but significantly lower than in the London metropolitan area and in New England, which produce especially high numbers of publications in this scientific field. The distribution of publications by research area in Switzerland is well balanced compared with the worldwide distribution, but other regions set clearer priorities. New England and Lombardy/Piedmont are especially heavily oriented toward clinical medicine, while the Paris metropolitan area and Bavaria focus on physics/chemistry/earth sciences.

[5] This comprises publications recorded in the Web of Science (WoS) database, Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) or Arts & Humanities Citation Index (AHCI) in the categories Article, Letter, Note and Review. A publication is allocated to a region if at least one of the authors works in an institution located in the region ("full counting"). If a publication has authors from several institutions in the same region, it is counted only once.

[6] Only researchers at universities and government research institutions, in full-time equivalent terms.

[7] The distribution of publications by research area provides only an incomplete picture of a research area's relative importance in terms of scientific publications. Natural sciences and medicine show much higher numbers of publications than the humanities, social sciences or engineering. This is because joint publications by authors from different institutions are very common in the natural sciences and medicine, where the number of authors per publication is significantly higher than in other areas of research. Finally, important forms of publication in the humanities, social sciences and engineering (such as books or conference proceedings) are only partly included in the publication database used here.

Figure B 12.5: Number of scientific publications per researcher in the scientific community, average 2007–2013



Researchers at universities and in government, in full-time positions
* Values estimated
Source: WoS: SCIE, SSCI, AHCI, Fraunhofer-ISI and ZEW calculations

Figure B 12.6: Scientific publications, average 2007–2013

	Share of worldwide publications[1]	Rate of change in number of publications, 2000–2006 to 2007–2013	Impact (citation rate[2])
Baden-Württemberg	0.89%	+41.8%	6.5
Bavaria	0.88%	+41.2%	6.7
Lombardy and Piedmont	0.95%	+59.7%	6.1
Paris metropolitan area	1.77%	+50.1%	6.5
London metropolitan area	2.86%	+33.8%	7.3
New England	2.40%	+42.9%	9.8
Switzerland	*1.21%*	*+59.4%*	*7.3*
Germany	5.46%	+42.5%	5.8
Italy	3.98%	+56.0%	5.5
France	4.79%	+53.6%	5.6
UK	5.65%	+33.4%	6.4
USA	23.93%	+35.7%	7.2
World	100%	+62.7%	5.1

[1] Proportionate number of publications with authors from different regions/countries
[2] Citation of publications during the 2007–2011 period; citation rate checked for varying citation frequency by research area
Source: WoS: SCIE, SSCI, AHCI, Fraunhofer-ISI and ZEW calculations

Figure B 12.7: Scientific publications by research area, average 2007–2013

%	Engineering/ computer science	Agri-culture/ biology/ environ-mental sciences	Clinical medicine	Physics/ chemistry/ earth sciences	Life sciences	Humanities/ arts	Social/ behavioural sciences
Baden-Württemberg	8.9	6.6	22.9	26.1	29.3	0.8	5.4
Bavaria	8.0	7.6	22.9	27.6	28.4	0.7	4.7
Lombardy and Piedmont	9.0	6.4	29.7	21.4	29.1	0.6	3.7
Paris metropolitan area	8.1	6.2	23.7	26.8	29.4	1.5	4.2
London metropolitan area	6.9	8.1	25.7	16.7	28.1	2.6	11.9
New England	5.0	6.7	27.5	14.0	33.2	1.3	12.3
Switzerland	*8.4*	*10.6*	*23.5*	*23.0*	*27.6*	*0.8*	*6.2*
Germany	8.6	8.9	21.2	27.6	27.2	0.9	5.6
Italy	9.1	7.8	25.0	27.2	26.8	0.7	3.5
France	10.7	9.4	21.2	27.3	27.0	1.1	3.5
UK	7.6	9.0	25.0	17.4	25.9	2.5	12.5
USA	7.4	9.9	24.4	16.7	28.1	1.4	12.1
World	11.1	11.0	20.8	23.8	24.8	1.0	7.5

Source: WoS: SCIE, SSCI, AHCI, Fraunhofer-ISI and ZEW calculations

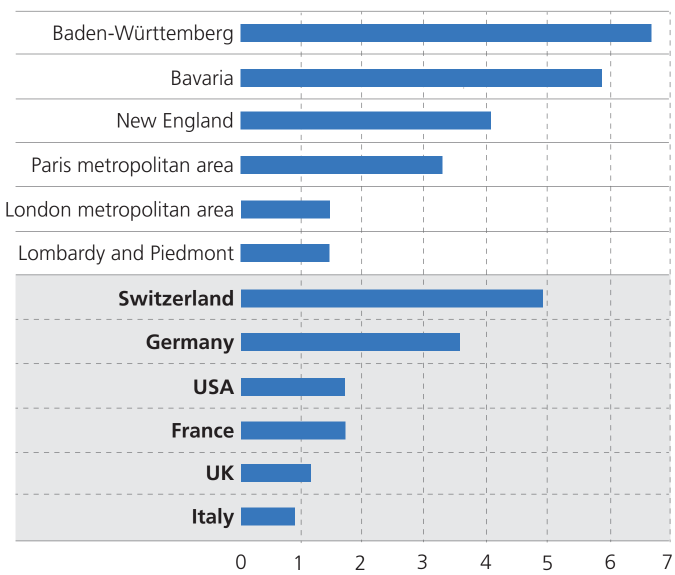
12.3 Patent applications

The number of patent filings is an important measure of the performance of application-oriented R&D (aR&D), which is pursued by firms in particular. In 2011, Switzerland was ahead of most of the other regions with a patent intensity (number of filings with the European Patent Office EPO or via the PCT process) of 4.89 per 10,000 inhabitants (Figure B 12.8). A higher patent intensity is found only in the two German regions, Baden-Württemberg (6.69) and Bavaria (5.83).

Patent intensity around the world has increased slightly over the last decade, measured by the number of EPO/PCT applications (Figure B 12.9). This is particularly attributable to the growth of filings from emerging economies and newly industrialised nations such as Korea or China, but Switzerland also increased its number of international patent applications between 2000 and 2011, with a rise in patent intensity of 0.40 percentage points (pp). Among the comparison group, only Baden-Württemberg (+0.48 pp) has a value much higher than Switzerland. The increase in Bavaria was modest, at +0.24 pp while, in the other four regions, patent intensity diminished. Except for the London metropolitan area, all the regions increased their patent intensity during the first half of the 2000s, yet between 2005 and 2011, all exhibited a decline which was moderate in Bavaria, Switzerland and the Paris metropolitan area, and quite strong in the other regions.

The distribution of Switzerland's patent applications by technology field differs in some points from the other innovation regions (Figure B 12.10): Switzerland has a particularly high share (22%) of patents in the area of instruments (optical technology, measurement technology), topped only by New England (24%). Moreover, patent applications from Switzerland are oriented more closely to the technological field of chemistry than in the other regions. However, Switzerland's share of ICT patents is below average, representing only 11% of Swiss patents. The largest proportion of Swiss patent filings is for patents in mechanical engineering and electrical engineering (23%), but other regions, such as Baden-Württemberg (40%), Bavaria (35%) and Lombardy/Piedmont (31%) are much stronger in this area. In pharmaceuticals/biotechnology, almost 9% of patent applications originate in Switzerland. This is more than in the other European regions, but considerably less than in New England (21%). The German, Italian and French regions have above-average shares of patent filings in motor vehicle construction, whereas Switzerland is less strongly represented here with a share of 9%. On the whole, Switzerland's technology portfolio is much more balanced than that of most of the other regions.

Figure B 12.8: Number of international patent filings per 10,000 inhabitants, 2011



On the basis of patent filings at the EPO and via PCT; EPO: European Patent Office; PCT: filing route based on the Patent Cooperation Treaty
Source: EPO: Patstat, ZEW calculations

Figure B 12.9: Number of international patent filings per 10,000 inhabitants

	2000	2005	2011	ΔPP_{2000}[1)]
Baden-Württemberg	6.21	7.76	6.69	+0.48
Bavaria	5.60	5.95	5.83	+0.24
Lombardy and Piedmont	1.64	1.87	1.45	–0.20
Paris metropolitan area	3.40	3.55	3.30	–0.10
London metropolitan area	2.24	2.06	1.49	–0.75
New England	5.31	5.33	4.06	–1.25
Switzerland	*4.49*	*5.24*	*4.89*	*+0.40*
Germany	3.43	3.87	3.54	+0.10
Italy	0.84	1.06	0.89	+0.05
France	1.53	1.78	1.71	+0.17
UK	1.51	1.40	1.16	–0.36
USA	1.99	2.26	1.73	–0.26
World	0.25	0.30	0.32	+0.07

Based on patent filings at the EPO and via PCT
[1)] Change in percentage points between 2000 and 2011
Source: EPO: Patstat, ZEW calculations

Figure B 12.10: Distribution of patent filings by technology field, average 2007–2011

%	ICT[1)]	Instruments	Pharmaceuticals/ biotechnology	Chemistry	Machines/ electrical engineering	Vehicles	Other
Baden-Württemberg	11.2	16.6	2.7	10.4	39.6	12.5	7.0
Bavaria	16.9	14.8	2.9	10.7	34.6	11.7	8.4
Lombardy and Piedmont	8.9	11.3	6.4	13.7	31.1	13.3	15.2
Paris metropolitan area	22.5	16.1	8.4	11.3	22.1	12.2	7.4
London metropolitan area	25.7	19.2	13.2	11.3	16.2	5.8	8.6
New England	17.1	24.0	20.8	13.5	17.5	3.4	3.6
Switzerland	*11.1*	*21.6*	*8.6*	*17.3*	*23.4*	*8.5*	*9.5*
Germany	11.7	14.9	4.3	15.4	33.6	11.6	8.5
Italy	19.0	14.6	7.3	14.7	24.0	12.2	8.3
France	19.2	19.1	9.5	13.3	21.1	7.0	10.7
UK	8.9	12.5	6.6	12.4	30.2	12.9	16.5
USA	26.3	20.2	11.7	14.9	16.0	4.6	6.2
World	24.2	16.8	6.9	14.4	22.9	7.3	7.4

Based on patent filings at the EPO and via PCT
Allocation of patents to technology fields using the International Patent Classification (IPC) on the basis of the Schmoch classification (2008)
[1)] Information and communication technology
Source: EPO: Patstat, ZEW calculations

12.4 Innovation activities of firms

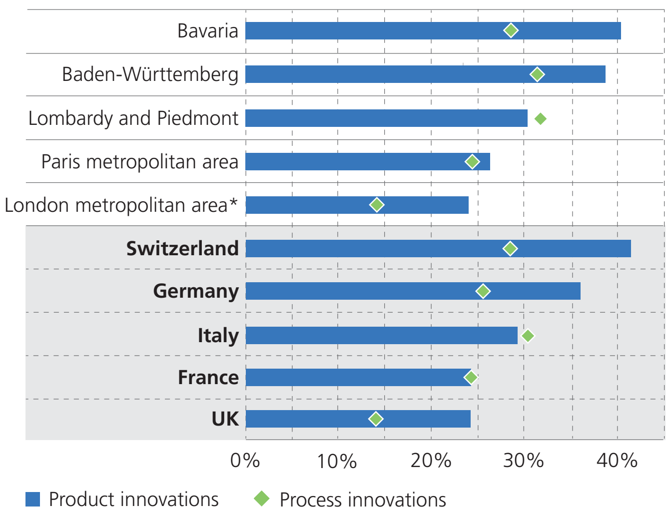
The innovation orientation of Swiss firms is very high not just in a comparison of countries, but in a comparison of leading innovation regions as well. At 41%, their share of creators of innovative products is higher than in every other European region of reference (Figure B 12.11).[8] The two German regions reach nearly the same level as Switzerland, but the three other regions have considerably lower shares of creators of innovative products. However, this does not translate into a lead for Switzerland with respect to the share of firms that have introduced product innovations: at 29%, Switzerland holds a middle position, behind north-western Italy (32%) and Baden-Württemberg (31%) and similar to Bavaria. The share of companies with process innovations is much lower in the two metropolitan areas, Paris and London, which is attributable partly to the sectoral structure (lower share of industrial companies, higher share of knowledge-intensive service companies).

An uneven picture is revealed when it comes to further indicators of innovation activity (Figure B 12.12). At 17%, the share of Swiss firms with market novelties approximates to the values of the other European regions for which data are available, but if one considers the "total innovator ratio", which is the share of companies that have introduced product, process, marketing or organisational innovations, Switzerland has a significant lead at 77%. The share of Swiss firms that show ongoing R&D activities is lower – 18% – than in Baden-Württemberg, but higher than in Bavaria and the Paris metropolitan area.

The innovation expenditure of the Swiss economy proves to be much higher than the other regions (Figure B 12.13). The total innovation expenditure as a share of revenue is higher than in all the other regions, but it must be borne in mind that this phenomenon is due to a few major projects at large firms. Expenditure for R&D, which is more stable in the long term, and less dependent on special factors, shows a lower value – also measured in revenue – for Switzerland (3.1%) than for Bavaria (3.8%), but a higher value than for Baden-Württemberg (2.7%). The revenue contribution from new products is no higher in Switzerland than in the other regions, and at 3.5%, the share of revenue from market novelties is actually lower. However, it must be remembered that market novelties do not necessarily refer to world market novelties: instead, they can be limited to novelties for regionally limited markets. This proviso applies in particular to services, since here only a few firms are globally active, and their key markets are more often geographically restricted. The revenue share of product novelties that are only new for the firm is comparatively high in Switzerland at 14.9%. Only Bavaria shows a higher value (17.7%). The success of product innovations is not recorded in CIS. The German Innovation Survey shows that Baden-Württemberg and Bavaria (at 4%) had a significant lead over Switzerland (1%) when it comes to the cost reduction share achieved through process innovations.

The indicators of the openness of innovation processes show that Swiss firms have an outward orientation that is similar to companies in the other regions (Figure B 12.14): around 10% of Swiss companies utilised external knowledge through R&D assignments. This is similar to the German regions, but lower than the Paris metropolitan area. At 11%, the share of Swiss firms with R&D collaborations is similar to Bavaria and somewhat lower than Baden-Württemberg and the Paris metropolitan area. Collaborations with universities are scarcer among Swiss firms than in companies from the German regions, but the share of Swiss companies cooperating in R&D with private or government research institutions outside universities is higher. In patent exploitation, Switzerland trails the two German regions with a share of around 6%, but has a higher value than firms in the London metropolitan area.

Figure B 12.11: Share of innovative firms, 2010–2012



* Values estimated
Source: EPO: Patstat, ZEW calculations

[8] Indicators of corporate innovation activities are only available for European countries in the European Commission's Community Innovation Survey (CIS). The values presented here refer to the business sector stated in the CIS; that is, companies with ten or more employees in the manufacturing industry (industry sectors 5 to 39) and selected service sectors (industry sectors 46, 49 to 53, 58 to 66, 71 to 73), and thus deviate from the values presented in Chapter 10.

Figure B 12.12: Penetration of innovation activities in the business sector, 2010–2012

% of firms	Market novelties	Total innovations[1]	Ongoing R&D activity
Baden-Württemberg	16	69	21
Bavaria	16	65	15
Lombardy and Piedmont	n.a.	58	n.a.
Paris metropolitan area	19	57	17
London metropolitan area[2]	n.a.	51	n.a.
Switzerland	*17*	*77*	*18*
Germany	14	56	17
Italy	17	54	9
France	16	51	15
UK	12	44	n.a.

All data refer to firms with ten or more employees in the NACE sections B, C, D, E (industry, including mining and quarrying, power generation and distribution, water supply, and waste disposal) as well as 46, H, J, K and 71–73 (wholesale trade, transport, information and communication, financial and insurance services, engineering services, research and development, advertising)
[1] Product, process, marketing or organisational innovations
[2] Values estimated
Source: Eurostat, ZEW, KOF, BIS, ISTAT, INSEE, ZEW calculations

Figure B 12.13: Innovation expenditure and successes in the business sector, 2010–2012

% of revenue	Innovation expenditure[1]	R&D expenditure	Market novelties	Firm novelties	Cost reductions through process innovations[2]
Baden-Württemberg	4.7	2.7	5.4	13.3	4.2
Bavaria	6.5	3.8	5.4	17.7	4.4
Lombardy and Piedmont	1.3	n.a.	n.a.	n.a.	n.a.
Paris metropolitan area	1.6	1.4	5.9	6.5	n.a.
London metropolitan area[3]	n.a.	n.a.	6.7	9.7	n.a.
Switzerland	*8.1*	*3.1*	*3.5*	*14.9*	*1.0*
Germany	2.8	1.4	3.0	10.0	3.3
Italy	1.1	0.6	5.1	5.9	n.a.
France	2.0	1.6	6.3	7.2	n.a.
UK	0.8	0.5	5.4	8.7	n.a.

All data refer to firms with ten or more employees in the NACE sections B, C, D, E (industry, including mining and quarrying, power generation and distribution, water supply, and waste management) as well as 46, H, J, K and 71–73 (wholesale trade, transport, information and communication, financial and insurance services, engineering services, research and development, advertising)
[1] Product, process, marketing or organisational innovations
[2] This indicator is recorded only in Swiss and German innovation surveys
[3] Values estimated
Source: Eurostat, ZEW, KOF, BIS, ISTAT, INSEE, ZEW calculations

Figure B 12.14: Organisation of innovation activities in the business sector, 2010–2012

% of firms	External R&D	R&D collaborations[1]	Collaborations with universities	Collaborations with research institutions	Patent exploitation[2]
Baden-Württemberg	11	16	9	6	8
Bavaria	11	11	7	5	9
Lombardy and Piedmont	n.a.	6	n.a.	n.a.	n.a.
Paris metropolitan area	14	15	4	3	7
London metropolitan area[3]	6	n.a.	n.a.	n.a.	4
Switzerland	*10*	*11*	*6*	*10*	*6*
Germany	11	13	8	5	9
Italy	5	5	2	1	2
France	13	13	4	3	n.a.
UK	5	23	7	4	3

All data refer to firms with ten or more employees in the NACE sections B, C, D, E (industry, including mining and quarrying, power generation and distribution, water supply, and waste management) as well as 46, H, J, K and 71–73 (wholesale trade, transport, information and communication, financial and insurance services, engineering services, research and development, advertising)

[1] Countries compared: R&D or innovation collaborations, i.e. including collaborations in innovation projects at firms without their own R&D activities

[2] Switzerland: filing of a patent application during the previous three years. All other countries: patents were of great significance in securing the competitiveness of the innovations introduced by the firm during the previous three years

[3] Values estimated

Source: Eurostat, ZEW, KOF, BIS, ISTAT, INSEE, ZEW calculations

12.5 Importance of research- and knowledge-intensive activities

Research- and knowledge-intensive sectors are of growing importance for the most advanced economies, as they offer favourable growth perspectives given the shift in demand toward goods and services from these sectors. In addition, research and innovation in these industries play a crucial role, and successful innovations here promise high gains in competitiveness.

In 2012, the share of research- and knowledge-intensive sectors of total employment in Switzerland (not including public/charitable services) was 22.6% (Figure B 12.15) – a very high proportion in comparison with other countries. Yet it is lower than most of the innovation regions considered here. Only New England has a lower share. In a comparison of the innovation regions, the share of industries using medium technology (including mechanical engineering, automobile manufacture, electrical engineering and chemicals) in Switzerland is much lower than in the German and Italian regions, which is partly a function of the importance of automobile manufacturing in these regions. Switzerland's share of jobs in high-tech industries (pharmaceuticals, electronics/instruments and aircraft construction), on the other hand, is the second-highest among the regions at 2.5%, topped only by Baden-Württemberg with 3.0%. At 16.6%, Switzerland's share of the workforce employed in market-oriented knowledge-intensive services (such as ICT services, financial services, engineering services and corporate consulting) is much higher than that of the neighbouring regions Baden-Württemberg, Bavaria and Lombardy/Piedmont, but lower than the Paris and London metropolitan areas and New England.

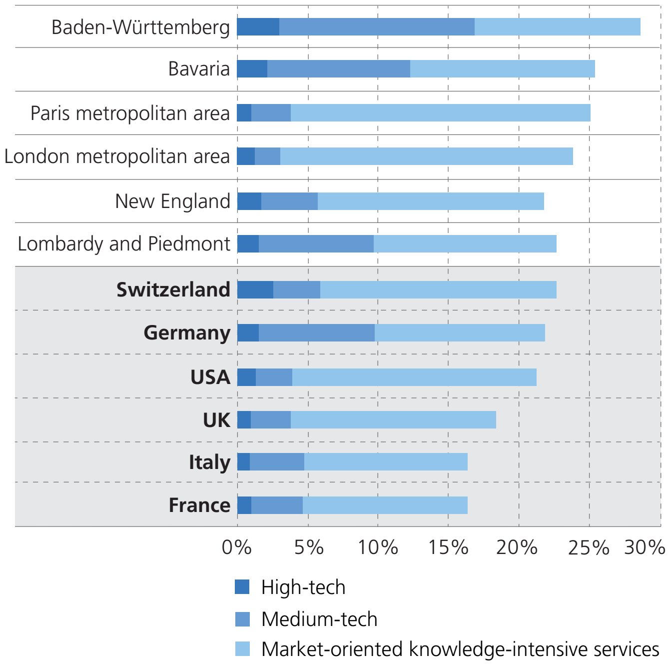
Change in the share of research- and knowledge-intensive sectors between 2008 and 2012[9] was surprising. Market-oriented knowledge-intensive services increased their share of employees in Switzerland by 1.0 percentage points (pp; Figure B 12.16). This climb was even steeper in the Paris and London metropolitan areas: +1.5 and +2.1, respectively. The share of employees in research-intensive industries declined in Switzerland by 0.5 pp (of which 0.2 was attributable to high-tech industries). In contrast, it rose in Baden-Württemberg, Bavaria and Lombardy/Piedmont, favouring the high-tech industries in Baden-Württemberg and the medium-tech industries in the other two regions.

The background to this shift was the financial and economic crisis of 2008/09, which resulted in differences in employment dynamics in the individual regions. In Switzerland and Germany, employment between 2008 and 2012 rose significantly on the whole, but fell in the USA, Italy and France. In the UK, employment in 2012 was at the same level as 2008. In the research- and knowledge-intensive sectors, however, France and the UK have both charted employment gains since 2008 – a trend that also applies to the two metropolitan areas, although London achieved above-average growth in a national comparison and Paris lay below the average. In Switzerland, employment in the research- and knowledge-intensive sectors increased by 7.4 pp between 2008 and 2012. This is somewhat less than in the two German regions, but more than in all the other innovation regions considered here. The Swiss economy's orientation toward the research- and knowledge-intensive sectors was thus strengthened in the wake of the financial and economic crisis.

In addition to market-oriented knowledge-intensive services, public or charitable services such as education, healthcare and social work as well as the arts and entertainment grew in importance in the structural transformation toward more strongly knowledge-based economic activities (Figure B 12.17). Overall, in 2012 around 37.5% of those employed in Switzerland worked in knowledge-intensive services in the broad sense – a share that is markedly higher than in the neighbouring innovation regions of Baden-Württemberg, Bavaria and Lombardy/Piedmont (27 to 31%), but much lower than in the Paris and London metropolitan areas or New England (between 41 and 47%). Among the knowledge-intensive services, financial services and healthcare and social work are more strongly represented in Switzerland than in most of the regions (with the exception of the London metropolitan area for financial services and New England for healthcare and social work). When it comes to information and communication services (including software programming, telecommunication, publishing, film and broadcasting), and arts, entertainment and leisure, Switzerland has the lowest share of all of the innovation regions examined here. The employee share in education, on the other hand, is the third-highest after the London and Paris metropolitan areas. Among the liberal professions, scientific and technical services (including legal, tax and corporate consulting, engineering services, advertising, architecture and design), Switzerland shows a higher share than the neighbouring innovation regions in Germany and Italy, but trails the Paris and London metropolitan areas and New England.

[9] A comparison that extends further into the past is not possible owing to the 2008 conversion of the industrial classification.

Figure B 12.15: Share of employees in research- and knowledge-intensive sectors, 2012



Sector definitions: see Figure B 12.16
Source: Eurostat, US Census Bureau, ZEW calculations

Figure B 12.16: Employment changes in the research- and knowledge-intensive sectors between 2008 and 2012

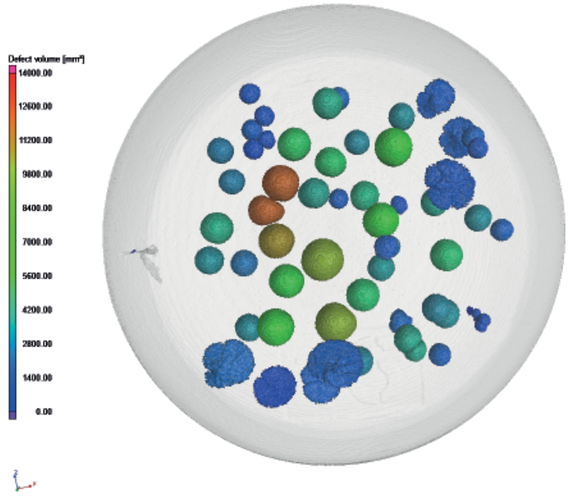
	High-tech[1]		Medium-tech[2]		Market-oriented, knowledge-intensive services[3]		RKI sectors[4]	Overall[5]
	ΔPP_{2008}[6]	$\Delta\%_{2008}$[7]	ΔPP_{2008}[6]	$\Delta\%_{2008}$[7]	ΔPP_{2008}[6]	$\Delta\%_{2008}$[7]	ΔPP_{2008}[6]	$\Delta\%_{2008}$[7]
Baden-Württemberg	+0.5	+23.1%	–0.2	+1.9%	–0.1	+2.0%	+8.3	+3.2%
Bavaria	+0.0	+6.9%	+0.2	+7.2%	+0.7	+11.4%	+10.2	+5.4%
Lombardy and Piedmont	–0.2	–11.2%	+0.7	+7.9%	–0.7	–7.0%	–2.4	–1.8%
Paris metropolitan area	–0.3	–22.2%	–0.5	–17.1%	+1.5	+6.8%	+3.3	–0.9%
London metropolitan area	–0.4	–21.1%	–0.6	–22.2%	+2.1	+12.9%	+6.8	+1.6%
New England[8]	+0.0	–5.8%	–0.4	–20.5%	–2.5	–14.9%	–14.7	–3.1%
Switzerland	*–0.2*	*–2.7%*	*–0.3*	*–5.0%*	*+1.0*	*+10.8%*	*+7.4*	*+4.3%*
Germany	+0.0	+3.7%	–0.2	+1.4%	+0.9	+12.5%	+10.5	+3.8%
Italy	–0.1	–10.6%	+0.0	–2.1%	–0.2	–4.1%	–5.1	–2.2%
France	–0.2	–15.8%	–0.5	–11.5%	+1.0	+8.6%	+4.2	–0.5%
UK	–0.2	–12.8%	–0.6	–18.3%	+1.2	+9.0%	+5.8	+0.1%
USA[8]	–0.1	–12.6%	–0.2	–11.8%	+0.1	–3.3%	–5.1	–4.1%

[1] NACE divisions/groups 21 (pharmaceuticals), 26 (electronics/instruments) and 30.3 (aircraft construction)
[2] NACE divisions/groups 20 (chemistry), 25.4 (weapons), 27 (electrical engineering), 28 (mechanical engineering), 29 (automobile manufacturing), 30 without 30.1 and 30.3 (railway construction, manufacture of two-wheeled vehicles), 32.5 (medical technology)
[3] NACE sections J (information and communication), K (financial services), M (freelance, scientific and technical services)
[4] Research- and knowledge-intensive sectors: total of high-tech, medium-tech and market-oriented knowledge-intensive services
[5] Whole economy
[6] Change in share of employees in percentage points between 2008 and 2012
[7] Rate of change in number of employees between 2008 and 2012
[8] Allocation of sector groups according to NAICS
Source: Eurostat, US Census Bureau, ZEW calculations

Figure 12.17: Share of employees in knowledge-intensive services in the broad sense, 2012

%	Information/ communica-tion[1]	Financial services[2]	Professional, scientific and technical services[3]	Education[4]	Healthcare/ social services[5]	Arts/ entertain-ment[6]	Total
Baden-Württemberg	3.9	2.8	5.1	6.3	11.2	1.4	30.7
Bavaria	4.0	3.7	5.3	5.7	10.8	1.6	31.0
Lombardy and Piedmont	3.3	3.5	6.0	5.7	7.3	1.2	27.0
Paris metropolitan area	6.5	5.6	9.3	7.0	10.3	2.4	41.0
London metropolitan area	5.8	6.2	8.9	11.1	11.4	2.7	46.0
New England[7]	4.7	7.0	9.0	5.9	19.1	1.8	47.3
Switzerland	*3.1*	*5.7*	*7.8*	*6.7*	*13.0*	*1.2*	*37.5*
Germany	3.9	2.8	5.1	6.3	11.2	1.4	30.7
Italy	2.4	2.8	5.9	6.5	7.8	1.2	26.7
France	2.9	3.2	5.5	7.0	13.6	1.5	33.6
UK	3.9	4.1	6.5	10.4	13.4	2.5	40.9
USA[7]	4.0	5.2	8.3	3.0	15.9	1.8	38.0

[1] NACE section J
[2] NACE section K
[3] NACE section M
[4] NACE section P
[5] NACE section Q
[6] NACE section R
[7] Allocation of sector groups according to NAICS
Source: Eurostat, US Census Bureau, ZEW calculations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11200.00
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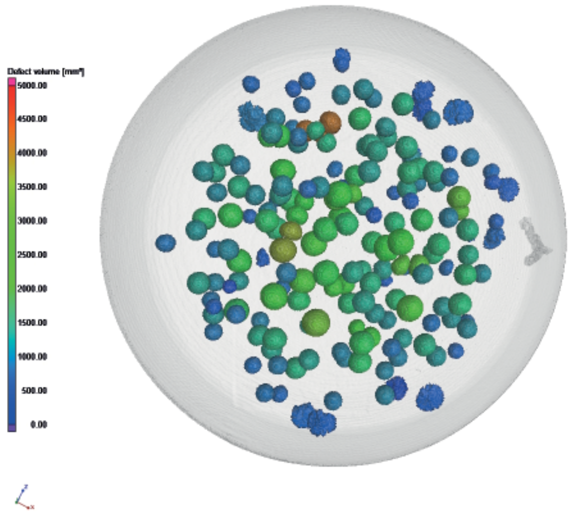
Defect volume [mm³]
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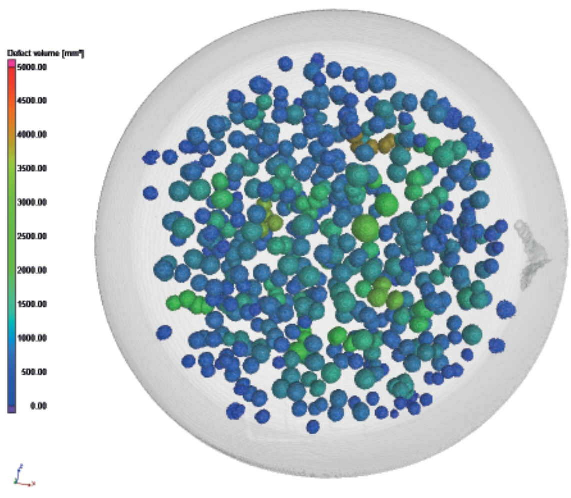
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PART C: SPECIFIC TOPICS

Agroscope – the Swiss centre of excellence for agricultural research – is affiliated with the Federal Office for Agriculture. By making an important contribution to a sustainable agriculture and food sector, Agroscope contributes to an improved quality of life. The cheese research group, for example, has shown that microscopic particles of plant matter that get into the milk during the milking process trigger the formation of holes in the cheese. The number of holes in the cheese can be precisely controlled by adding around ten milligrams of these plant particles per tonne of milk, a particularly important discovery for Swiss cheese. Photo: Agroscope

The aim of Part C is to examine overarching or intersecting questions of central importance to the Swiss research and innovation system.

The following topics were selected in coordination with the support and expert groups (see Annex 3):

- Study 1: Research and innovation activities of small and medium-sized enterprises in Switzerland
- Study 2: Research and innovation activities of multinationals in Switzerland
- Study 3: Supply and demand in public innovation promotion
- Study 4: Universities of applied sciences in the Swiss research and innovation system

The four studies were carried out by experts from the scientific community. The process was supported by project groups (see Annex 3).

Part C contains a short version of the studies. The complete studies appear in the series published by the SERI.

PART C: STUDY 1

Research and innovation activities of small and medium-sized enterprises in Switzerland

The following text is an abridged version of a study conducted by Dr. Heiko Bergmann and Prof. Thierry Volery (University of St. Gallen). This summary has been approved by the various groups that have supported the elaboration process. The full version of the study was published in the SERI publication series (www.sbfi.admin.ch).

Contents

1 Research and innovation activities of small and medium-sized enterprises in Switzerland

1.1 Introduction

1.1.1 Background and research questions

Innovations are regarded as one of the keys to the success of small and medium-sized enterprises (SMEs). The prevailing opinion is that SMEs rely on their flexibility and innovativeness to compete with large firms. This study investigates innovation by SMEs in Switzerland, their unique traits and the influences at play.

The key questions addressed in this study are: How innovative are SMEs in Switzerland in different sectors and by international standards? Why and when do SMEs invest in research and innovation activities? What role do collaborations play? Where do the obstacles to, and potential for research and innovation activities lie?

The research questions were answered on the basis of scientific literature and an analysis of secondary data, in particular the KOF Innovation Survey and the Swiss Federal Statistical Office (FSO) survey on research and development in the private sector. In addition, we carried out our own written survey of innovation at 144 SMEs in four selected sectors – with the support of the respective trade associations. The following industry groups or trade associations were involved, each of which have different innovation profiles: Chemistry/pharmacy (scienceindustries), engineering/manufacture of electrical equipment (Swissmem), food industry (fial) and ICT services (swissICT). The written survey was carried out with two focus groups: group discussions involving representatives of the ICT services and food industries and telephone interviews with representatives of the mechanical engineering sector.

1.1.2 Definitions of key terms

For the purposes of this study, small and medium-sized enterprises (SMEs) are firms with fewer than 250 employees. Firms with fewer than ten employees are described as micro-enterprises, firms with between ten and 49 employees are referred to as small enterprises and those with between 50 and 249 employees are called medium-sized enterprises. Large enterprises are those with 250 or more employees.

1.1.3 Types of innovation

In keeping with the Oslo Manual, (OECD & Eurostat, 2005), a distinction is made between product, process, marketing and organisational innovations. In the past, only product innovations (i.e. technologically new or significantly improved products from the firm's perspective) and process innovations (i.e. the first use of technologically new or significantly improved production/process technologies for the manufacture of goods or the provision of services) were considered to be innovations. Latterly, however, the realm of research has increasingly embraced marketing and organisational innovations. A marketing innovation is the introduction of a new marketing/sales method that has not previously been used by the firm. An organisational innovation is the introduction of a new organisational method at the firm..

1.1.4 Innovation processes at SMEs

Size is not the only respect in which SMEs differ from large enterprises; there are also a number of qualitative features that are typical of SMEs. In most cases, SMEs are run by an owner-manager who frequently has professional or technical training rather than a business background and, at small enterprises in particular, is heavily involved in the day-to-day running of the business. There is a greater reliance on improvisation and intuition than is the case at large enterprises, the latter having better-developed information processes and more sophisticated planning methods. Short decision-making channels and close proximity to the customer are common traits of SMEs. On the other hand, there is the risk of the owner holding too many roles at once and there is little scope for compensatory measures if the wrong decisions are made (Fueglistaller et. al., 2007; Mugler, 2008).

Studies of innovations and innovation management at SMEs and firms in general often take a process-dominated view. From a theoretical perspective, the innovation process was originally regarded as linear, emanating from a sequence of different activities. However, these simple, linear models soon proved too abstract, as the individual activities do not usually occur in succession; in reality, there is a lot of feedback and a great many actors are involved. This led to the development of more complex models such as the "chain-linked model" (Kline & Rosenberg, 1986) or the "stage-gate model" (Cooper, 1994).

Furthermore, the concept of "open innovation" has come to the fore in recent years, referring to the further opening up of the innovation process. In light of the accelerating pace of innovation coupled with shrinking R&D budgets, innovations must not only be generated internally but also be masterminded outside the company, in collaboration with or drawing on external knowledge sources (Gassmann et. al., 2010; Gassmann & Enkel, 2006). According to one empirical study, medium-sized enterprises are more likely to open up their innovation process than small enterprises; the biggest challenge when opening up the processes lies in problems with the business culture at SMEs, as external contacts swell their lean and manageable structures (van de Vrande et al., 2009).

1.2 The extent of research and innovation activities at SMEs in Switzerland

1.2.1 Product and process innovations

Share of innovative SMEs

A company's innovation activities depend on its size. Regardless of the indicator used, the impression is that large enterprises are more innovative than SMEs (Arvanitis et. al., 2013). The presence or absence of a product or process innovation in the last three years is widely used as an indicator of a firm's innovativeness. Based on this simple yes/no indicator, large enterprises are more innovative than SMEs. This is chiefly a matter of economies of scale: large enterprises are usually involved in a number of product areas, making them more likely than an SME to produce an innovation within a given period of time. There were no indications to suggest that a company's innovativeness increases disproportionately the bigger the firm (Arvanitis, 1997). On the contrary, indicators that measure a firm's innovativeness in relation to turnover show SMEs to be at least as innovative, or even more so, than large enterprises. We will discuss this in more detail below.

Since the mid-1990s, there has been a steady decline in the number of firms in Switzerland engaging in product or process innovation (Figure C 1.1). This downturn is more starkly apparent at SMEs than at large enterprises, at which there has been no decline since 2005. In other countries, there has not been such a marked downturn in innovation since 1996. The decline in Switzerland has both structural and economic roots (Arvanitis et al., 2013). Despite this, the share of innovative SMEs in Switzerland remains high by international standards (Figure C 1.6), although the other countries are closing the gap.

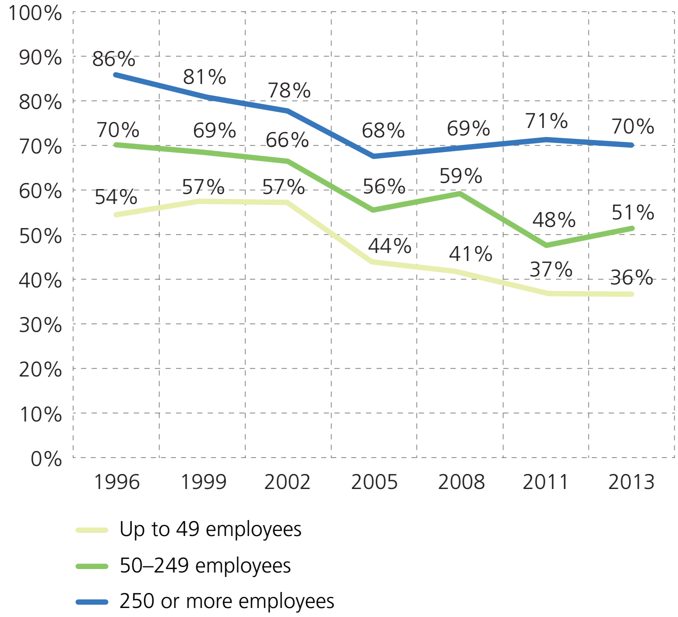
When interpreting the figures below, it should be borne in mind that the share of firms at which there have been product or process innovations is just one possible indicator of innovation. The share of turnover attributable to innovative products is an alternative indicator. Over the period under review, this figure has either remained fairly constant or even increased slightly (Arvanitis et al., 2014). This suggests that, while innovation is concentrated in the hands of fewer companies these days, each of those firms generates higher turnover from innovative products. This development is due in part to rising innovation expenditures at innovative firms.

Innovation by sector

Sectors are typified by specific technological "regimes" that are path-dependent and yield varying innovation output (Pavitt, 1984). The extent of innovation within a sector depends on a number of factors, chiefly technological developments, the knowledge base and the opportunity to utilise the returns on innovations (Castellacci, 2008).

Therefore, the values shown in Figure C 1.1 reveal significant differences between sectors. Across all size categories, the highest share of innovative firms according to the indicator used here is

Figure C 1.1: Firms with product and/or process innovations by size



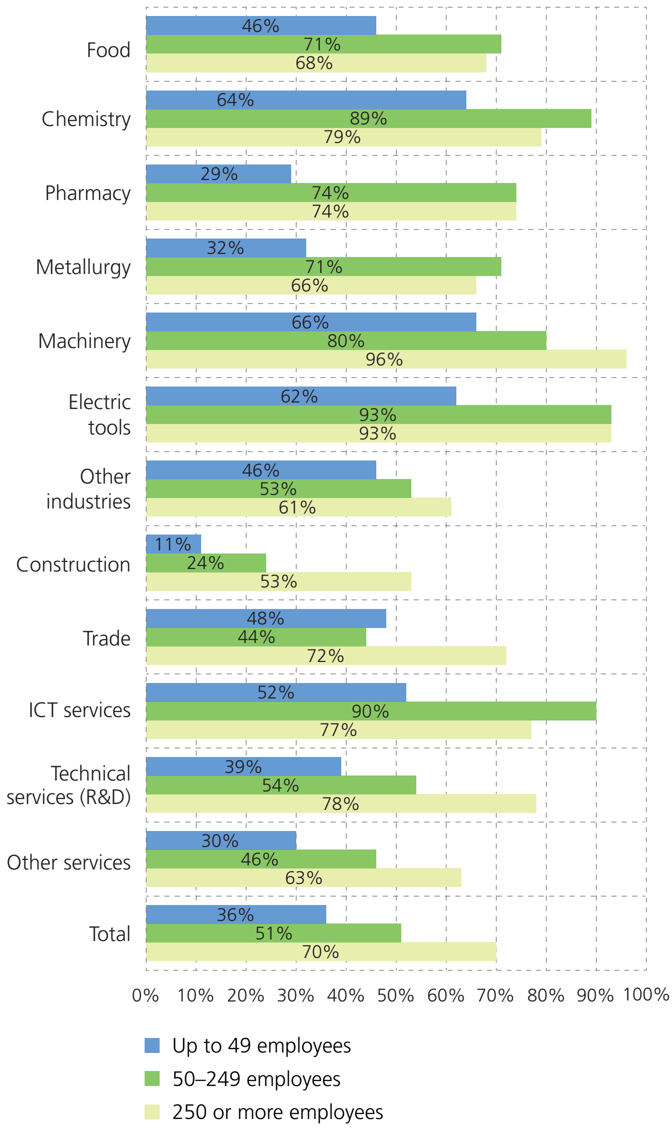
Source: KOF Innovation Surveys 1996–2013

to be found in the chemistry, mechanical engineering, electronics/instruments and ICT services sectors (Figure C 1.2). Although three quarters of all medium-sized enterprises and large enterprises in the pharmaceutical sector are innovative, only a small percentage of small enterprises have introduced product or process innovations. This finding illustrates the dominance of large enterprises in innovation in this sector, due primarily to the very high product development costs and long product life cycles. In the other sectors listed here, product and process innovations are generally more evenly distributed across the size categories.

According to this indicator, the construction sector is the least innovative, especially in the SME segment. Innovation is also below average at small enterprises in the metallurgy sector, in stark contrast to medium-sized enterprises, which are often more innovative. Presumably this can be explained by the capital-intensive nature of this sector. ICT services are the most innovative service sector.

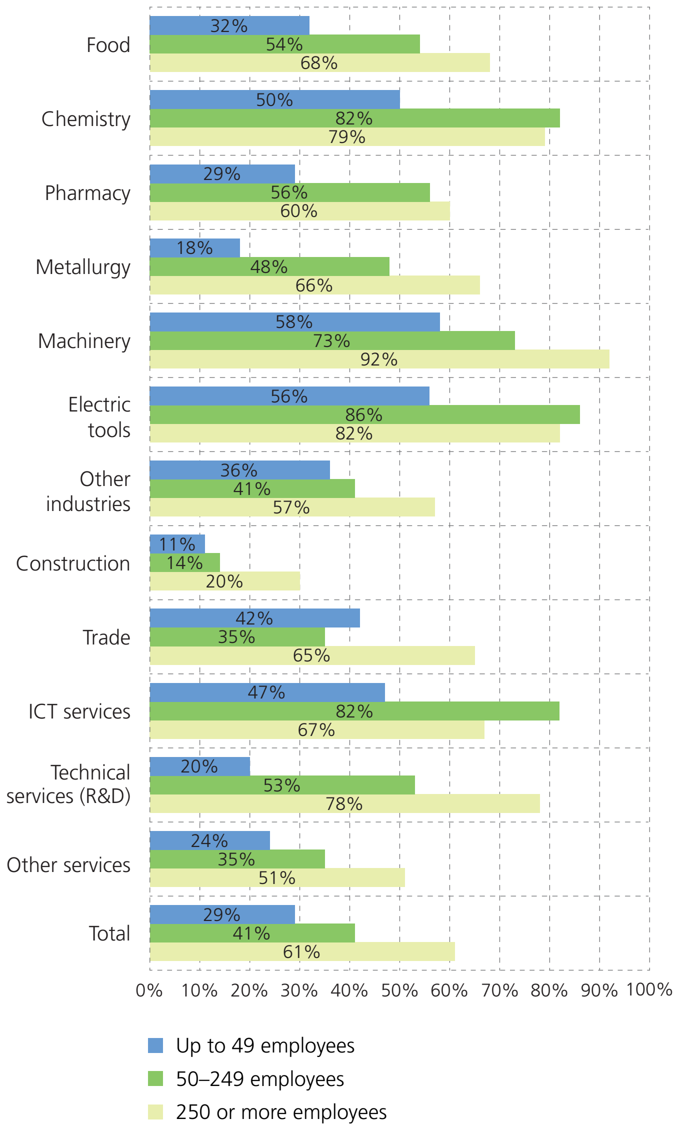
Figure C 1.3 and Figure C 1.4 show the share of innovative firms separately by product and process innovations. Overall, product innovation is more widespread at Swiss SMEs than process innovation. The frequency of product innovation by sector and firm size presents a very similar picture to innovation in general. There are, however, more marked differences for process innovations, which are less common than product innovations at SMEs. At large enterprises, there is relatively little difference in the frequency of the two types of innovation. Presumably, their small size is the reason why process innovation is less common at SMEs, since they invest little or less frequently in machinery and technolog-

Figure C 1.2: Firms with product and/or process innovations by sector and size



Source: KOF Innovation Survey 2013, calculations by the University of St. Gallen (KMU-HSG)

Figure C 1.3: Firms with product innovations by sector and size



Source: KOF Innovation Survey 2013, calculations by the University of St. Gallen (KMU-HSG)

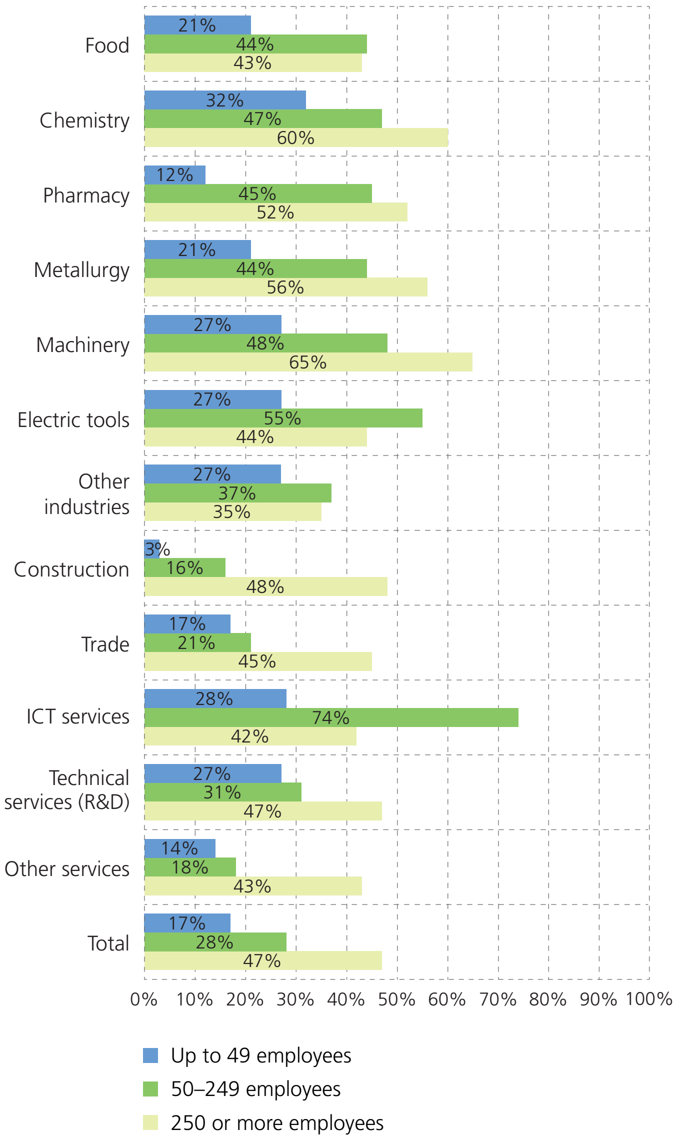
ical processes that yield such innovations (Hall et al., 2009). As one would expect, manufacturing companies tend to introduce a greater number of process innovations than service companies. An exception to this are ICT providers, which are able to programme and introduce process-optimising IT solutions themselves.

Share of turnover from innovative products

The share of turnover from innovative products is an alternative indicator of firm innovativeness. In contrast to the above indicators, this indicator records the relative significance of innovative products at each company.

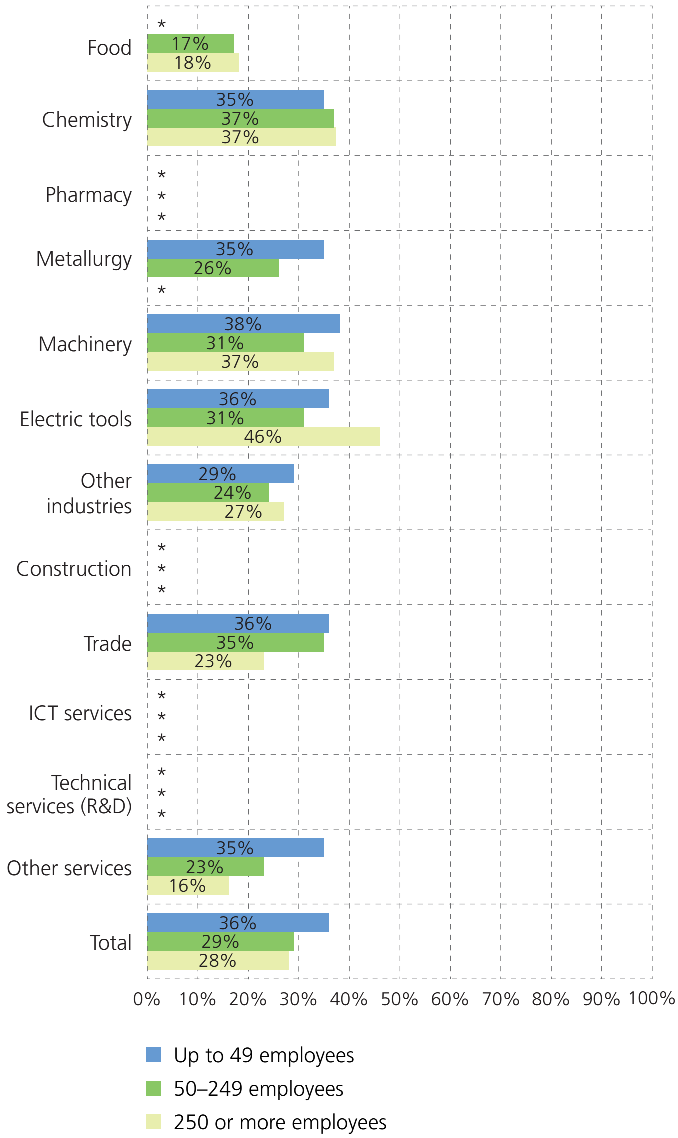
Share of turnover from innovative products is inversely related to the size of the firm (Figure C 1.5). While small enterprises generate an average of 36% of their turnover from innovative products, that proportion for medium and large enterprises is below 30%. This finding supports the argument that large enterprises are not more innovative than SMEs, relative to their size. However, this analysis disregards the novelty of innovative products. R&D-driven innovations are often highly novel and can therefore be sold on the market for many years, one example being pharmaceutical products. However, this indicator only takes account of products that are no more than 3 years old, meaning there is a tendency

Figure C 1.4: Firms with process innovations by sector and size



Source: KOF Innovation Survey 2013, calculations by the University of St. Gallen (KMU-HSG)

Figure C 1.5: Share of turnover from innovative products by sector and size



*No value can be shown, as there are fewer than 10 cases
Source: KOF Innovation Survey 2013, calculations by the University of St. Gallen (KMU-HSG)

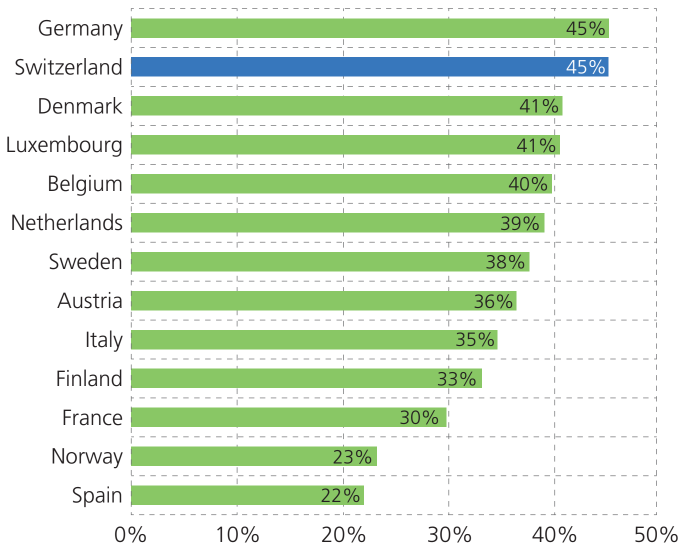
to underestimate the qualitative significance of products that are highly novel.

This indicator also differs significantly by sector and, because of the small number of cases, the values for some sectors cannot be shown. The clear differences between the sectors can be ascribed to varying times to launch, product life cycles and degree of capital intensity.

In industry (mechanical engineering, electronics and other industry) there is often a U-shaped correlation, whereby the share of turnover attributable to innovative products is higher at small and large enterprises than at medium-sized firms. Small and large enterprises are therefore relatively more successful on the market with innovative products than medium-sized companies. Presumably, this is because many small enterprises consistently pursue a (successful) niche strategy, whereas large enterprises can efficiently exploit economies of scale. It may be that, due to their size, medium-sized firms cannot consistently pursue a strategy, so find themselves in a "stuck in the middle" situation (Porter, 1980).

In contrast to the share of firms with product or process innovations (Figure C 1.1), the share of turnover from innovative products has increased slightly since the 1990s. This development is chiefly attributable to a rise in the service sector. (Arvanitis et al., 2014).

Figure C 1.6: Share of innovative SMEs



Values for selected countries for 2010/11 or the most recent year available; only internally generated innovations or innovations produced jointly with other firms
Source: Innovation Union Scoreboard 2014

Innovative firms: Findings of the new survey

The number of innovative firms and the reasons for the big differences between sectors were also discussed in interviews conducted with SMEs in selected sectors. The owners ascribe the major differences to the varying quality and scalability of innovations. They believe, for example, that the high level of innovation measured at ICT providers can be explained by the fact that they develop programming solutions for their customers, but only on a project basis. These, they argue, are not new products in the proper sense, i.e. they are not of interest to other companies and are therefore not scalable. They also believe that the high wage level in Switzerland enables a relatively prosperous ICT industry because, in this climate, it is worth achieving a high degree of automation and this creates demand for adapted software solutions.

In mechanical engineering, SMEs operate mainly in niches. The high costs compel firms to "always be at the forefront", meaning they must continually come up with fresh ideas. "Innovation is practically a must here; without technological market leadership, you won't succeed". The opinion is that collaborating with customers, universities or other partners also enables small enterprises to develop innovative solutions and successfully launch them on the market.

Product and process innovation in international comparison
Compared with other European countries, Switzerland has a very high percentage of SMEs with at least one product or process innovation. 45% of all SMEs have introduced a product or process innovation in the last three-year period (Figure C 1.6).[1] The value for Switzerland is on a par with Germany and ahead of all other European countries under consideration. Thus Switzerland is a country in which innovation is broadly based and SMEs are also heavily engaged in innovation.

When comparing the international situation, it should be borne in mind that firms always assess their own innovativeness in relation to the market in which they operate. Consequently, countries in which many companies only serve a regional market can appear highly innovative (Arundel et al., 2013). This is why we compare the value for Switzerland only with the values for selected European countries.

[1] For the international comparison, only SMEs with ten or more employees are taken into account, which explains the difference compared with the top value given for Switzerland. The latest Innovation Union Scoreboard (European Commission, 2015) gives a significantly lower value for Switzerland. However, as this development is not shown in the data for the KOF Innovation Survey, on which the Innovation Union Scoreboard is actually based, we cannot verify this figure and will not consider it further here.

1.2.2 Marketing and organisational innovations

Whereas in the past innovation research focused only on product and process innovations, for a number of years market and organisational innovations have also been considered, as alternative forms of innovation. This development was borne of the observation that, rather than product or process innovations, it is often new and innovative business models that yield success for companies (Johnson et al., 2008). Moreover, it can be argued that firms also need innovative marketing and organisational solutions in order to achieve significant success on the market with new products.

Marketing innovations involve the introduction of significantly altered designs for products/services, the introduction of new advertising techniques or media, the launch of brands, the launch of new sales channels or the introduction of new forms of pricing policy. Organisational innovations are a) the introduction of new methods for organising business processes, b) the introduction of new forms of labour organisation and c) the introduction of new forms of external relations with other firms or institutions (e.g. alliances, cooperation agreements, supplier integration). Typically, these innovations are closely bound up with process innovations.

Both marketing and organisational innovations are rather more widespread across firms in all size categories than the product and process innovations that were previously considered (Figure C 1.7 and Figure C 1.8). Moreover, the differences between sizes of company are less marked. Small enterprises in particular achieve comparatively high percentages that are around two thirds the level of large enterprises. The difference between small and large enterprises is far more marked where product and process innovations are concerned. These findings show that, at small firms in particular, marketing and organisational innovations can be more easily achieved than traditional and often technology-driven product and process innovations, and present an opportunity for an innovative market presence.

Marketing innovations are very widespread, particularly in parts of the service sector and in the business-to-consumer (B2C) segment (e.g. foods, retail), whereas the construction industry and technical service providers – i.e. classic business-to-business (B2B) sectors – make less use of this form of innovation. In contrast, the distribution of organisational innovations seems to be less sector-dependent. Here too, SMEs in the construction industry are the least likely to implement such innovations.

A study of the different types of innovation clearly illustrates that, in many cases, these are not introduced in isolation, but in combination. At SMEs, product innovations are often introduced along with marketing innovations, while process innovations tend to be combined with organisational innovations. Conversely, however, there are many SMEs that introduce marketing or organisational innovations that are not accompanied by new products and processes. This clearly demonstrates the originality of these two forms of innovation.

1.2.3 Research and development activities by sector

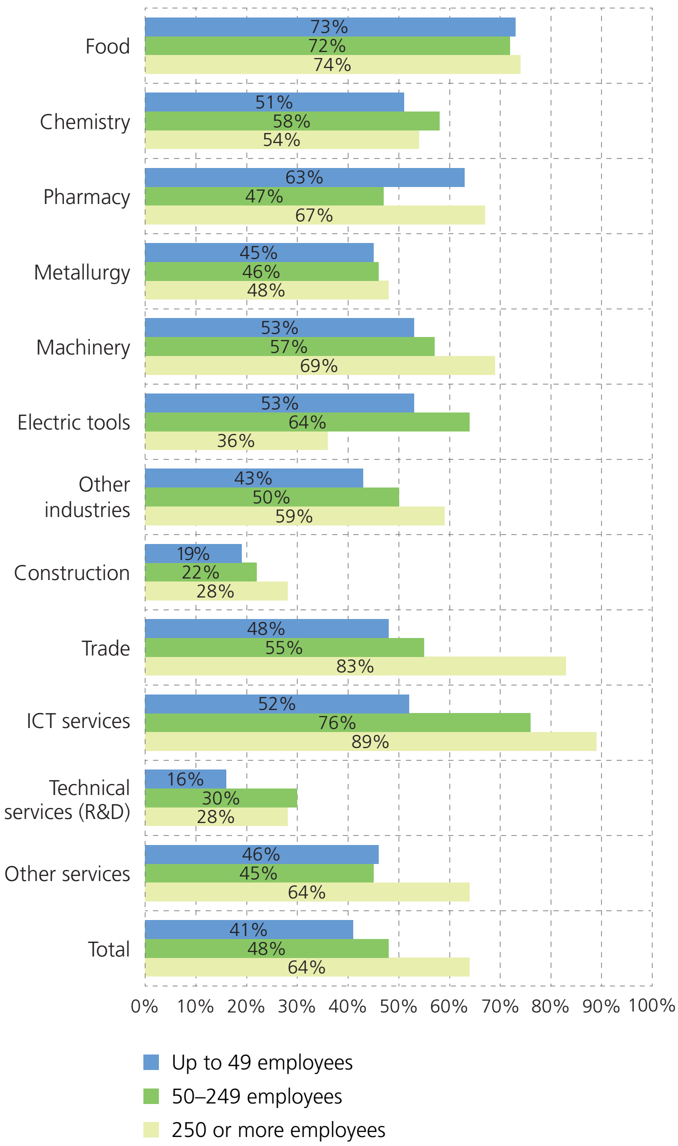
In this section we discuss the input aspects. In particular, we consider how frequently research and development activities are undertaken by each sector. Chapter 1.5 again focuses on expenditure on innovation as a whole and the financing of innovation.

The information available on the number of firms in Switzerland that engage in research and development (R&D) varies depending on the definition. The Federal Statistical Office uses a rather narrow definition of R&D, which only includes activities such as the design and monitoring of development projects, the construction and testing of prototypes and the construction and operation of test facilities. Based on this definition, there are around 2,500 firms engaged in R&D in Switzerland (FSO & economiesuisse, 2014). Of that number, 88% are SMEs with fewer than 250 employees. The number of SMEs as a share of all firms engaged in R&D is highest for ICT services and among firms that carry out R&D activities on behalf of other firms. The smallest share is in the food and the pharmaceutical industry. (Figure C 1.9).[2]

However, an entirely different picture emerges if one considers expenditure on R&D activities: As expected, large enterprises spend significantly more on R&D than SMEs. Just 28% of all expenditure on R&D is incurred at SMEs and 72% at large enterprises. The comparatively minor significance of R&D expenditures at SMEs is probably attributable to the following two reasons. Firstly, SMEs sometimes lack the independent resources to finance risky R&D activities. Secondly, for fear of a loss of control, many family-controlled companies are unwilling to raise external funds, because they want to retain control of their business (Duran et al., 2015; Mishra & McConaughy, 1999). The concentration of research expenditures at large enterprises is particularly apparent in the pharmaceutical industry. In this sector, SMEs account for a mere 4% of expenditures. Furthermore, the big Swiss pharmaceutical companies invest very heavily in R&D. Overall, the pharmaceutical industry is responsible for 30% of R&D expenditures in the Swiss private sector (FSO & economiesuisse, 2014). Relatively speaking, expenditures among SMEs are highest in ICT services and in the metallurgy industry (Figure C 1.10). In these two sectors, 50% or more of R&D expenditures are incurred by SMEs, meaning that R&D activity is distributed across firms of all sizes. The relatively high significance of SMEs also reflects the absence in Switzerland in these two sectors of dominant large enterprises with high R&D expenditures. While the number of SMEs engaging in R&D activities has tended to decline in recent years, their R&D expenditures have risen overall; R&D activities are thus increasingly concentrated at a small number of SMEs. R&D activities are also recorded in the KOF Innovation Survey. In contrast to the FSO survey, the KOF survey records the number of firms with R&D activities on the basis of a simple question that is incorporated in the general innovation survey. Therefore, the number of firms actively involved in R&D

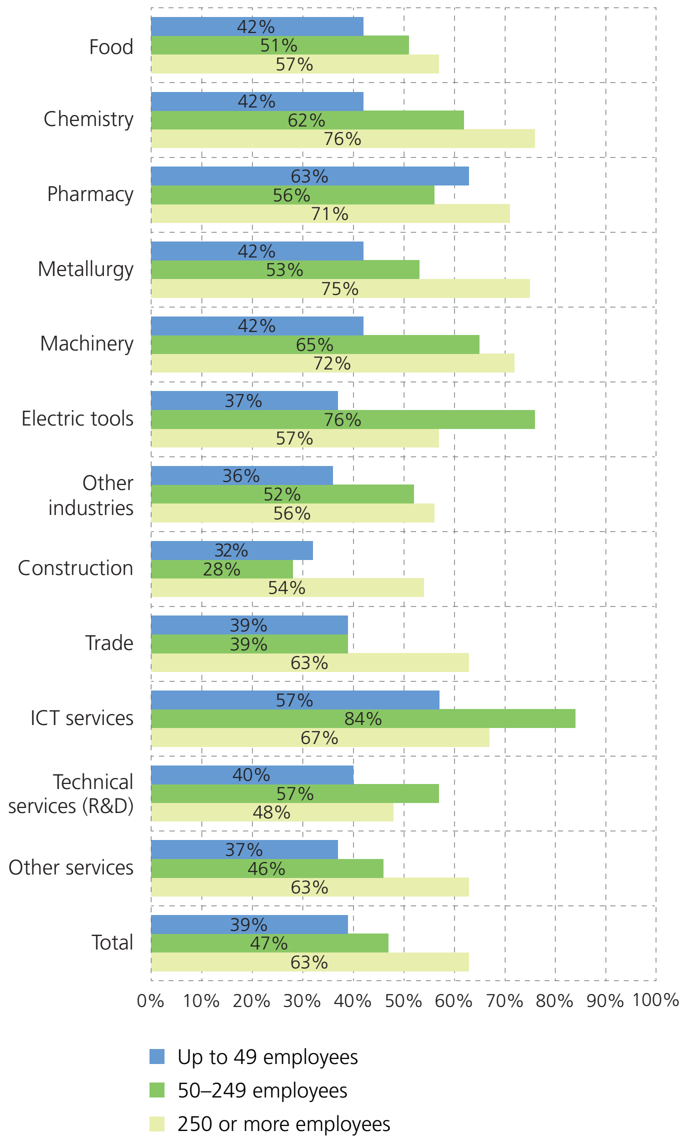
[2] It should be pointed out that the FSO survey concentrates on firms that do engage in R&D activities. Consequently, no statements can be made as to the share of firms overall or by sector that engage in R&D.

Figure C 1.7: Firms with marketing innovations by sector and size



Source: KOF Innovation Survey 2013, calculations by the University of St. Gallen (KMU-HSG)

Figure C 1.8: Firms with organisational innovations by sector and size

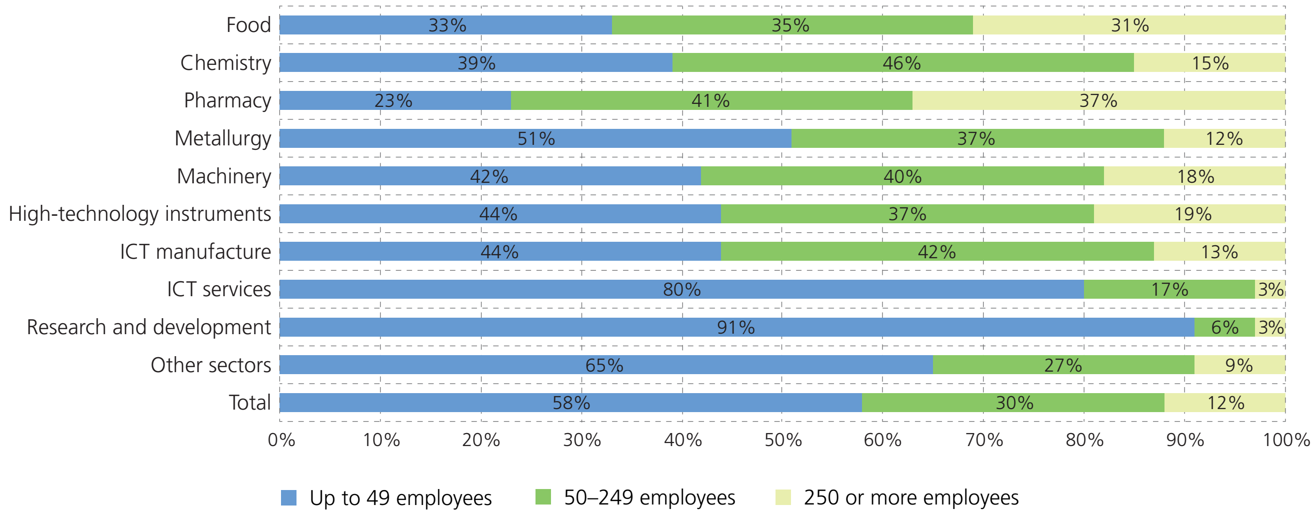


Source: KOF Innovation Survey 2013, calculations by the University of St. Gallen (KMU-HSG)

according to this survey is significantly greater. As it is mainly the data of the Federal Statistical Office that are used for international comparisons, we will not give any further consideration here to the findings of the KOF innovation survey.[3]

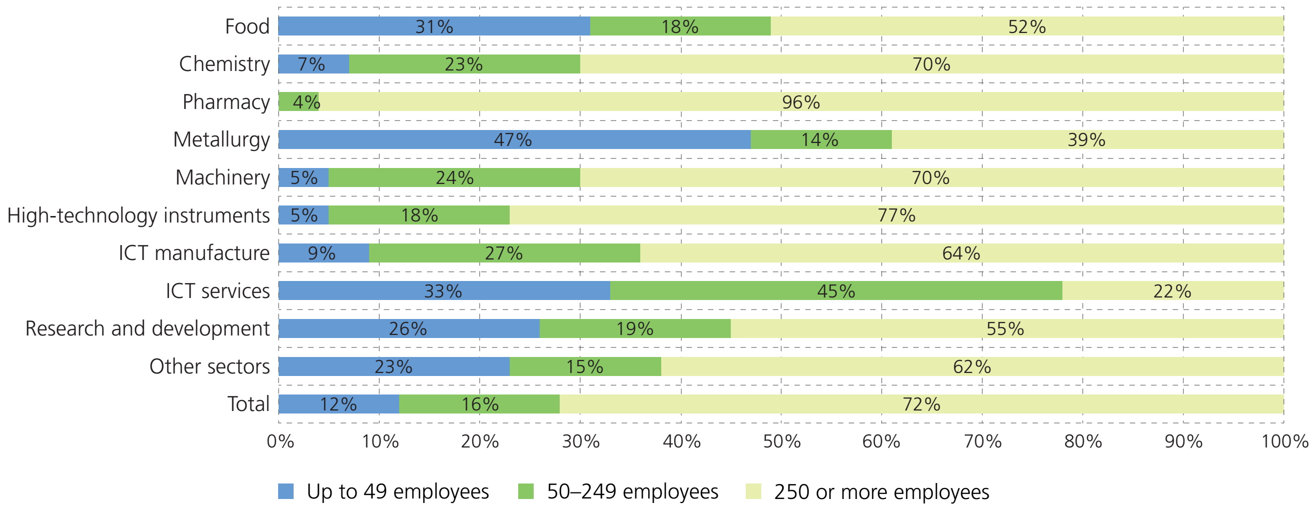
[3] The KOF indicates that 20% of firms are actively engaged in R&D (companies with more than 5 employees), which equates to around 20,000 businesses (share of firms with up to 49 employees that are actively engaged in R&D: 17.9%; companies with between 50 and 249 employees: 28.2%; firms with 250+ employees: 41.1%). The reasons behind the varying figures on the number of companies with R&D activities in the two sets of statistics are twofold: Firstly, the two surveys use very different definitions of what constitutes R&D activities. Secondly, at the KOF, the question about R&D activities is included within a general innovation survey, meaning that firms may be inclined to indicate that they engage in R&D (known as the spillover effect).

Figure C 1.9: Firms with R&D activities by sector and size



Example: In the food industry, 33% of firms with R&D activities have between 0 and 49 employees.
Source: FSO, Survey of R&D in the Swiss private sector in 2012

Figure C 1.10: Expenditure on R&D activities by sector and size



Example: In the food industry, 31% of expenditure on R&D activities is made by firms with between 0 and 49 employees
Source: FSO, Survey of R&D in the Swiss private sector in 2012

1.3 Why do firms undertake R&D activities

With product innovations, the primary goal is usually to preserve or increase market share, improve product quality and expand the product range. The size of company has little bearing on the motives for product innovations (Figure C 1.11). More growth-related goals (market share, expanding product range) are a little less relevant to small enterprises, presumably because many self-employed people want to run their business themselves and therefore – for fear of losing control and contending with mounting complexity – are only pursuing moderate growth at most. (Davidsson et al., 2010). The great importance of quality as a motive for innovation demonstrates that SMEs are usually seeking a differentiation or niche strategy and are not pursuing cost leadership.

Comparatively speaking, the development of environmentally-friendly products is seldom a goal of innovation activities at SMEs. The same can be said of reducing environmental impact (see below). We can only speculate on the reasons for the relatively minor importance of environmental concerns as an innovation goal at SMEs. Studies of SMEs in Europe reveal that a lack of financial resources may present an obstacle to such innovations. Moreover, SMEs are not keen to introduce environmental innovations if they feel they have little market power. (Triguero et al., 2014). Presumably, SMEs in Switzerland regard the returns on "green" innovation activities as uncertain and only worthwhile in the long term, prompting many of them to eschew such activities. Because they operate in niches, it may be that many firms also find it hard to introduce such innovations on the market.

For process innovations, increasing flexibility and reducing lead times are the priorities (Figure C 1.12). Due to their lean structures, SMEs are considered to be flexible and capable of responding to individual customer requirements (Fueglistaller et al., 2007). This probably explains why achieving greater flexibility is somewhat less important as a reason for process innovations at SMEs than at large enterprises. Nevertheless, it is still the most important goal at small enterprises, being cited by more than half of those that engage in process innovations. Cost-related goals are of comparatively minor significance at SMEs and at small enterprises in particular. This is because SMEs do not normally strive for cost leadership. The KOF survey did not inquire as to whether the two forms of innovation are mutually dependent, i.e. whether process innovations were introduced in order to enable product innovations.

Market and competitive environment – Findings of the new survey

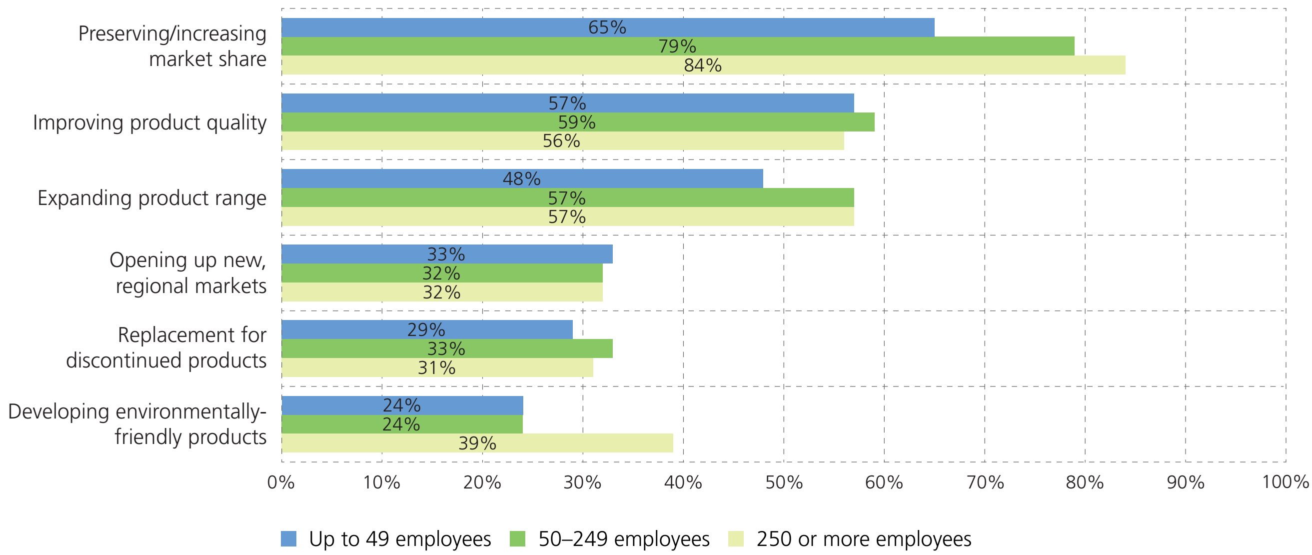
The market and competitive environment differs from one sector to another and can be seen as a major reason for the differing level and structure of innovation. Competitive pressure in a sector is multifaceted (competitors at home, competitors abroad, market entry barriers, technological progress etc.) In light of this, it is impossible to generalise as to whether or not a sector is exposed to intense competition. The differing competitive profiles can be illustrated by the four sector groups studied in our own survey: in the food industry, many products are commodities and, as such, can easily be replaced by competing products. Even innovative products can be copied by other firms, whether or not in a slightly modified form. While large enterprises endeavour to set themselves apart by building brands (branding), this is a much harder task for SMEs. Consequently, companies in the food sector perceive this as a major threat to their own market position. Competitive pressure normally stems from national providers, as foods are subject to a host of import restrictions in the shape of import duties or quotas. Process innovations are a prerequisite for low-cost production.

ICT providers are in a very different situation. In this sector, competitive pressure stems mainly from technological developments and short product life cycles, causing products to quickly become outdated. The sector benefits from high demand in Switzerland. This market environment demands product innovations above all else, and these are widespread at ICT providers (Figure C 1.3). The majority of these innovations are customised solutions that cannot really be described as scalable products. Competition from providers abroad is perceived as average in this sector, because services generally require close cooperation with the customer and, therefore, a base in Switzerland. Consequently, in the opinion of the companies surveyed, sales prices have fallen less sharply than in the other three sectors studied.

Competition from foreign providers is most keenly felt by firms from sectors in which there is largely free movement of foods (engineering, chemistry/pharmacy). These two sectors also describe the development of demand as difficult to predict. Presumably this is because these companies have a high export quota and so serve lots of different markets. Moreover, exchange rate fluctuations produce added uncertainty.[4]

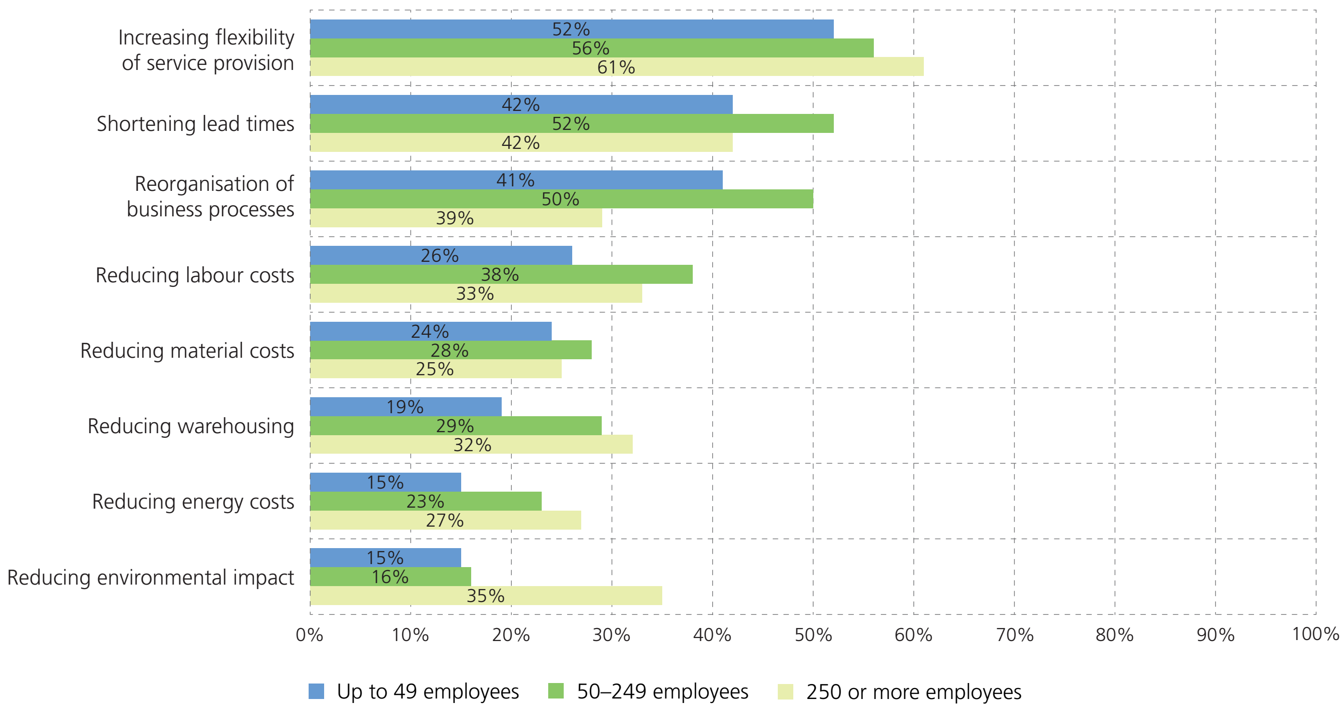
[4] The survey was carried out between November 2014 and the start of January 2015 and does not therefore factor in the impact of the abolition of the CHF/EUR floor in mid-January 2015.

Figure C 1.11: Innovation goals for product innovations, by size of firm



Source: KOF Innovation Survey 2011

Figure C 1.12: Innovation goals for process innovations, by size of firm



Source: KOF Innovation Survey 2011

1.4 Research and innovation mechanisms and collaborations

1.4.1 External knowledge sources and partners in the innovation process

The usual assumption is that a tight network of players and the use of a multitude of information sources have a positive impact on a firm's innovativeness (von Hippel, 1988). The use of external knowledge sources also features heavily in the open innovation approach that is a popular subject of debate right now (Gassmann et al., 2010). Therefore, we begin by investigating which external knowledge sources are of major importance to innovation at SMEs.

Figure C 1.13 illustrates the importance of knowledge sources for internal innovation activity.[5] The two main information sources for SMEs are customers and suppliers (in particular equipment suppliers) and, by extension, contacts along the value chain. However, the significance of these two information sources varies for different types of SME. Equipment suppliers are particularly relevant for companies in the construction industry and traditional industrial enterprises. These firms often take a rather passive attitude towards innovation activities and are reliant on the support of suppliers to enable them to implement innovation projects (de Jong & Marsili, 2006). In contrast, the majority of firms for which customers are an important source of knowledge are to be found in the high-tech and service sectors, i.e. sectors which frequently generate an unusually high volume of product innovations.

Universities and other research institutions are of relatively minor importance to SMEs overall. Only in the high-tech and modern services domains are they a little more widespread and significant.

Evidently, large enterprises draw more heavily than SMEs on external knowledge sources. Overall, however, the various information sources differ relatively little in terms of their importance to SMEs and large enterprises. There are marked differences with respect to customers, who are cited far more frequently as an important information source by large enterprises. This finding is surprising, given that close customer contact is regarded as a typical trait of SMEs (Fueglistaller et al., 2007). We can only make assumptions here as to the reasons why customers are far less important to SMEs as an external knowledge source. Presumably, much of the contact between SMEs and their customers is informal in nature, whereas large enterprises more commonly use customer surveys and other formal information sources. Equally, however, the difference may be due to the phrasing of the question in the KOF innovation survey: in the questionnaire, customers are listed under "Other firms" as an information source, meaning that companies that only serve private customers are omitted.

[5] The following knowledge sources are highly relevant to less than 5% of all firms so have not been listed in the illustration: Technology transfer offices (3.1%), firms with patents (2.6%).

R&D collaborations and the awarding of R&D contracts to external partners are another important external source of information for a company. Figure C 1.14 illustrates the extent to which innovative firms use these external knowledge sources. While SMEs frequently engage in R&D collaborations, the awarding of R&D contracts and R&D activities abroad is less widespread. For all three indicators, there is a correlation with firm size, which is consistent with other studies on knowledge and technology transfer (Arvanitis & Wörter, 2013). However, the difference between medium-sized and large enterprises is minimal where R&D collaborations are concerned. Presumably, small enterprises rarely enter into R&D collaborations because they require them to possess their own technical knowledge or their own R&D activities (Cohen & Levinthal, 1989), which is often not the case at these enterprises. By and large, however, the share of small and medium-sized enterprises that undertake R&D collaborations is surprisingly high, presumably because the term "R&D collaborations" was broadly interpreted by the respondents and they also took account of informal collaborations.

The small number of R&D contracts at small enterprises can presumably be attributed to their limited resources. R&D activities abroad by SMEs are very rare.

1.4.2 Collaborations

R&D collaborations

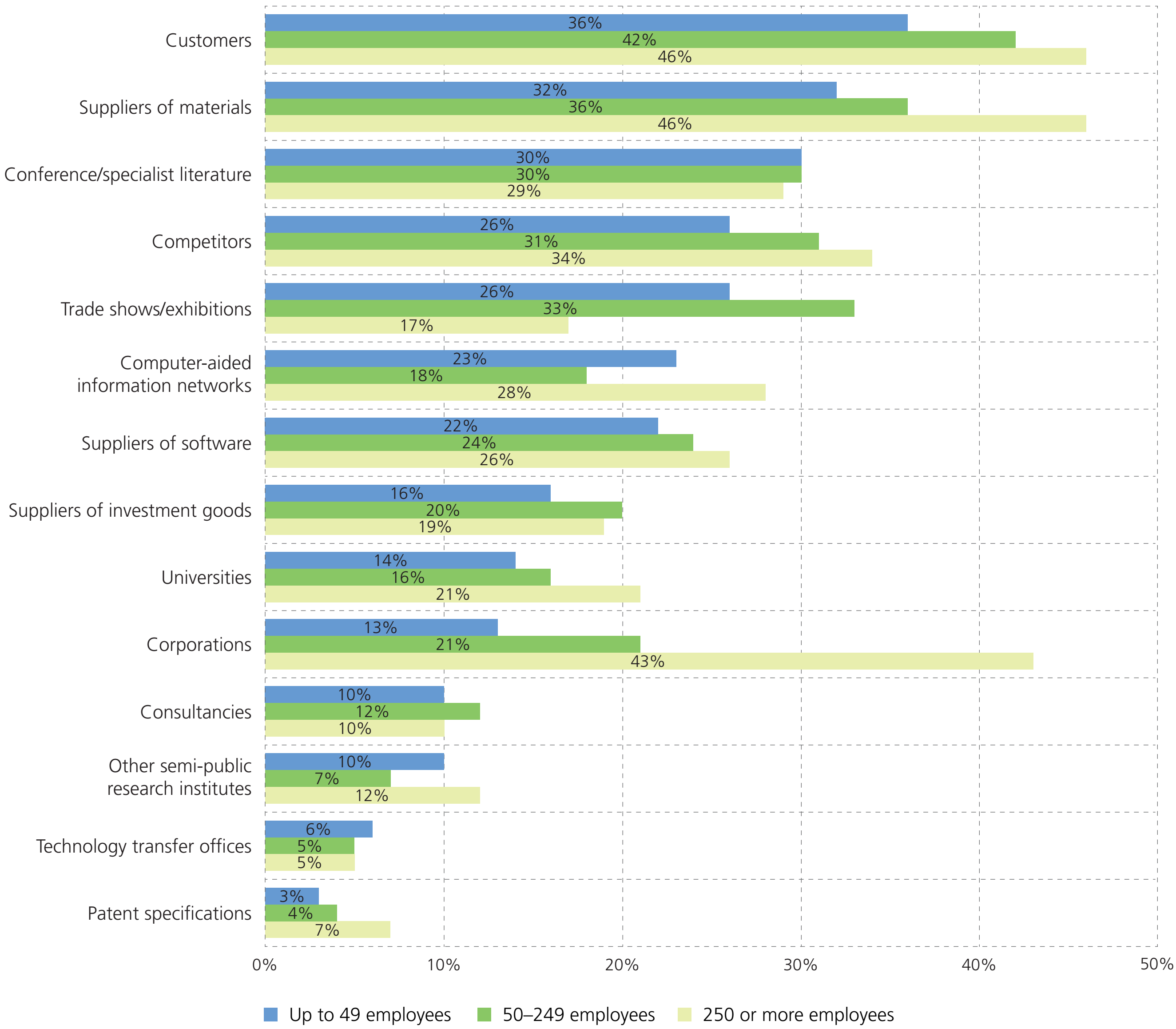
Interaction with other firms or research institutions is generally regarded as conducive or even essential to the innovativeness of SMEs. However, the importance of innovation networks differs depending on the sector and type of innovation. Moreover, a firm's internal resources also affect the decision whether to enter into such collaborations (Freel, 2003).

Representative statements about collaboration by SMEs can be made based on the KOF innovation survey, although that does not look at all forms of innovation collaborations, focusing only on R&D collaborations. A total of 32% of all small enterprises and 43% of all medium-sized enterprises are involved in an R&D collaboration (Figure C 1.14).

Figure C 1.15 shows the partners with whom firms are collaborating in such R&D collaborations. As with external knowledge sources in general, such collaborations are often with other companies, particularly suppliers and customers. Universities are significantly less relevant to SMEs than to large enterprises. The frequency of the cooperation partners mentioned demonstrates that, as a rule, firms collaborate with several partners at once.

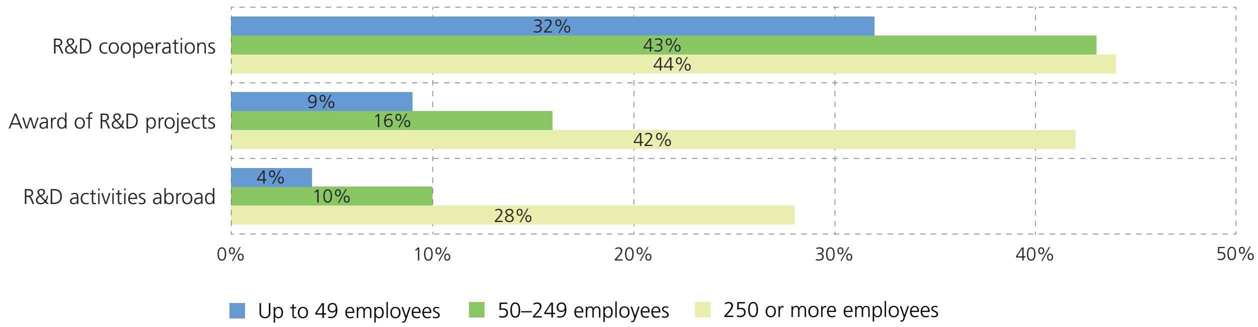
The motives for R&D collaborations are as follows: The main motives for SMEs are access to specialised technology and pooling complementary knowledge. Sharing costs is a more important factor for SMEs than large enterprises, due to the greater difficulties encountered by SMEs in financing innovation projects. Against this backdrop, it is surprising that this cost-related motive

Figure C 1.13: External knowledge sources by size of firm



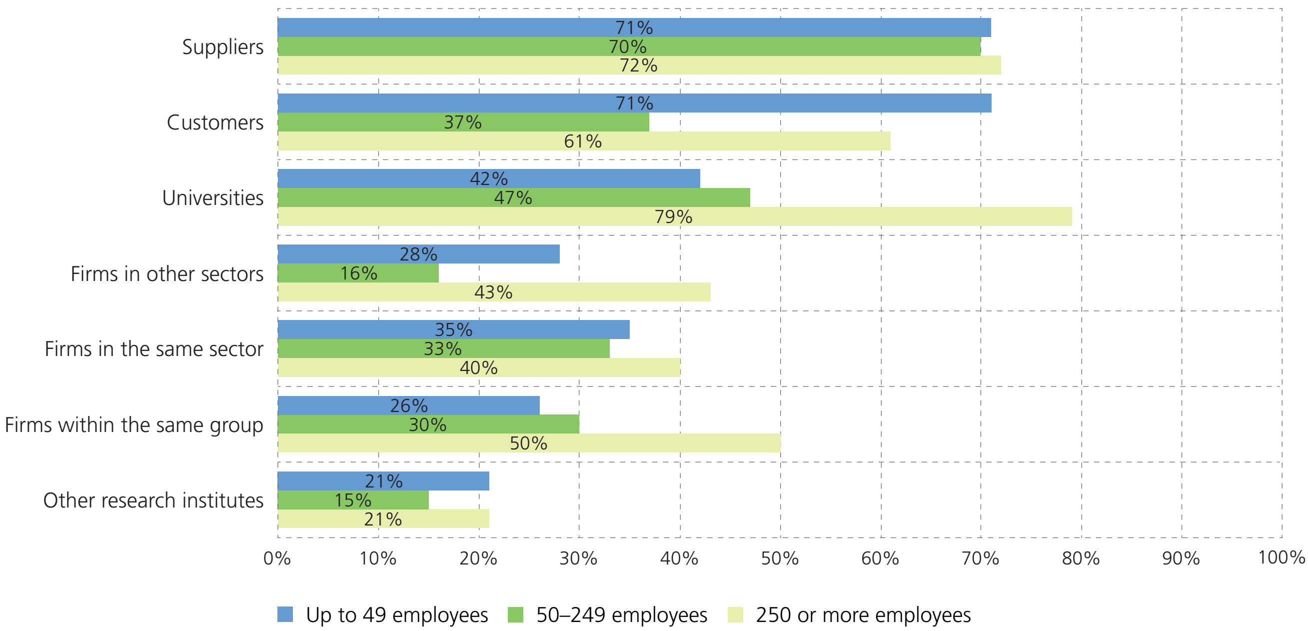
Source: KOF Innovation Survey 2013, calculations by the University of St. Gallen (KMU-HSG)

Figure C 1.14: External collaboration by size of firm



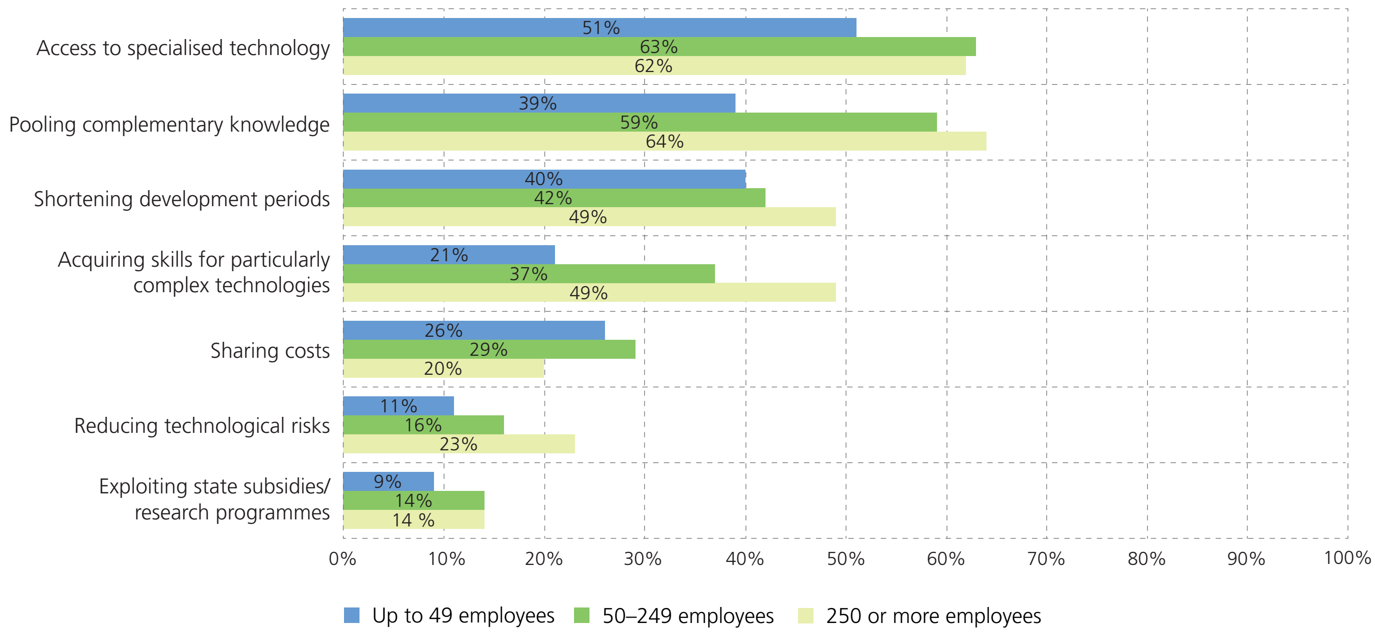
Source: KOF Innovation Survey 2013

Figure C 1.15: Partners in R&D collaborations by size of firm



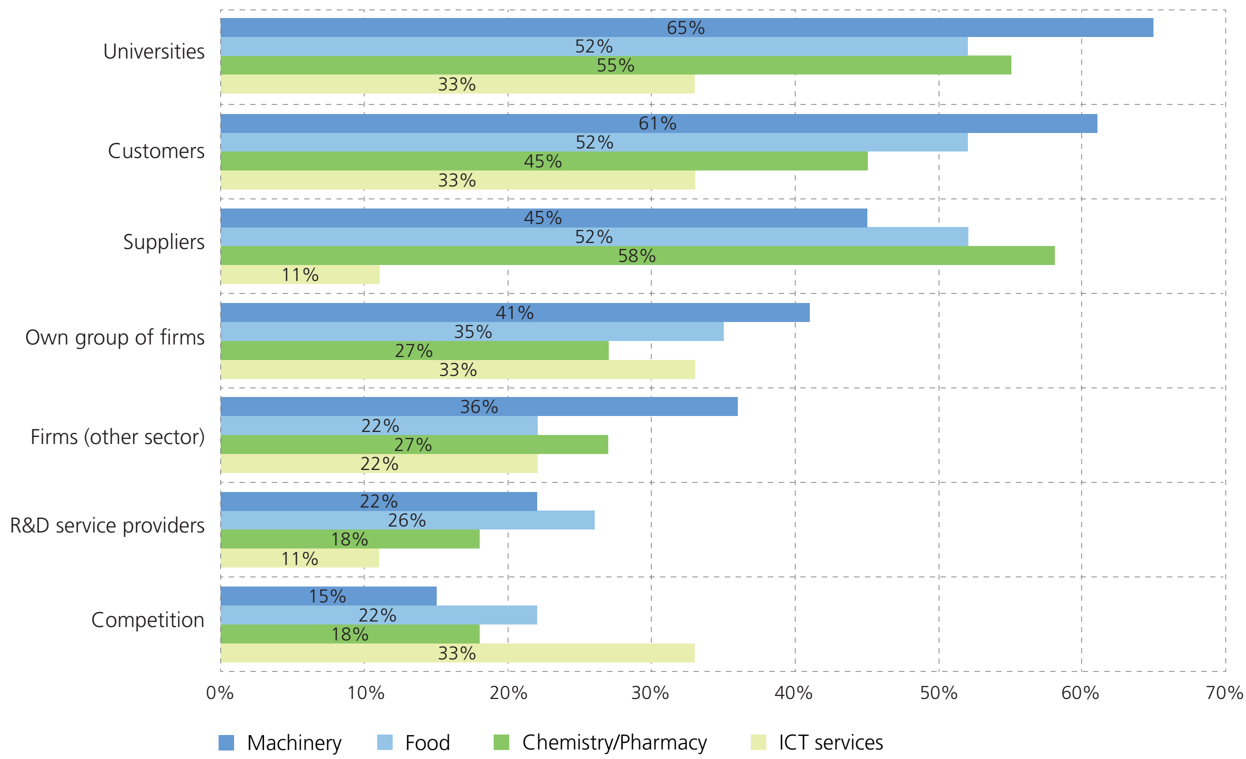
Source: KOF Innovation Survey 2013, calculation by the University of St. Gallen (KMU-HSG)

Figure C 1.16: Motives for R&D collaborations by size of firm



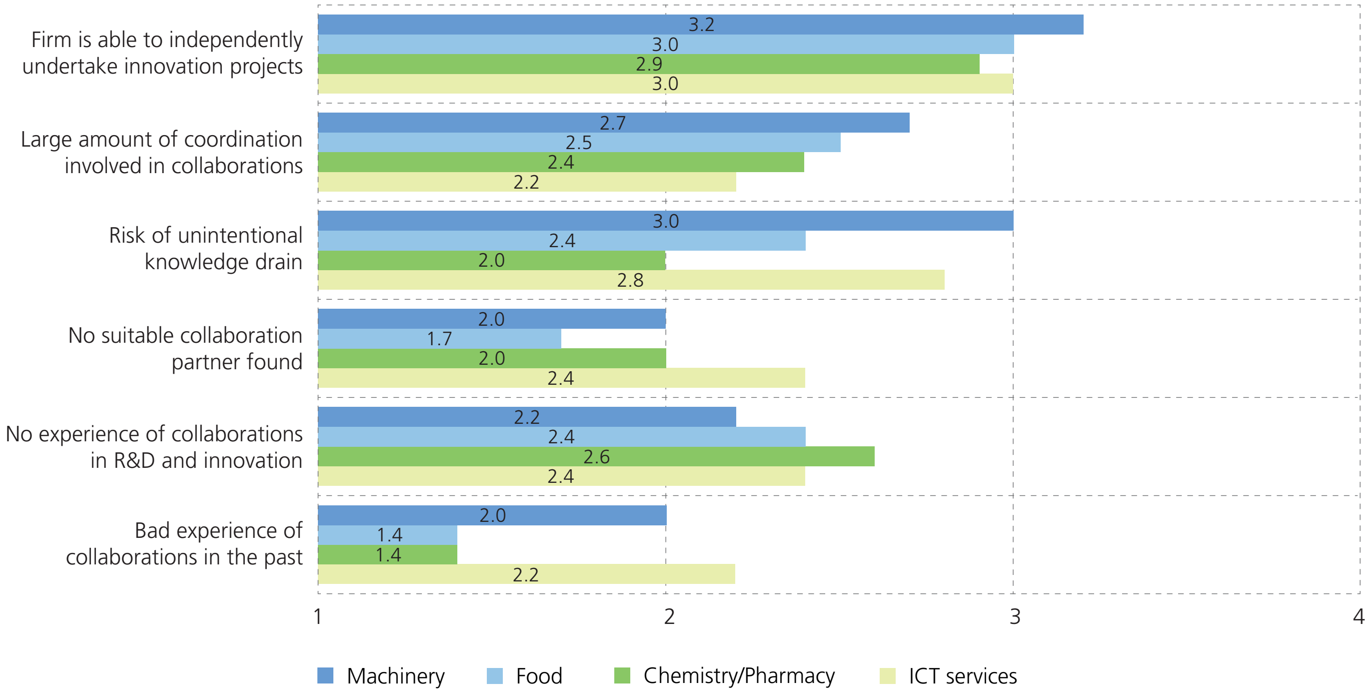
Percentage of firms with R&D collaborations
Source: KOF Innovation Survey 2011

Figure C 1.17: Frequency of cooperation partners in innovation collaborations by sector



The results are not representative for Switzerland as a whole
Source: Survey by the University of St. Gallen (KMU-HSG)

Figure C 1.18: Significance of the reasons for not entering into innovation collaborations by sector



Likert scale of 1: does not comply to 4: complies in full: The results are not representative for Switzerland as a whole.
Source: Survey by the University of St. Gallen (KMU-HSG)

was nonetheless cited as important by fewer than 30% of SMEs engaged in R&D collaborations.

Funding programmes enable firms to spread the risk of innovation projects, as some of the expenditure is assumed by other parties. Moreover, Federal Government Research (see Part A, sections 2.5 and 3.1.2) may require the formation of R&D collaborations. As a whole, however, state subsidies or subsidy programmes have little bearing on the decision whether or not to enter into R&D collaborations. The reasons for this are presumably twofold: Firstly, there are few such programmes in Switzerland (one example is the CTI project funding). Secondly, not all companies are aware of them (Hotz-Hart & Rohner, 2013).

Innovation collaborations – Findings of the new survey

As the KOF innovation survey only considers R&D collaborations, in the new survey we investigate innovation collaborations in general. Our survey reveals that 50 to 60% of innovative SMEs are involved in innovation collaborations. These are most widespread among ICT providers. Figure C 1.17 illustrates the partners with whom they collaborate. There are clear differences by sector. Although small and medium-sized ICT providers frequently collaborate, they have a comparatively sparse innovation network which is confined to their own group of companies, customers and competitors. Universities are used less frequently as cooperation partners than in the other sectors – due probably to the fast pace of technological change. An analysis of the size of cooperation partners, which is not illustrated here, also shows that ICT providers only collaborate with other SMEs and hardly ever with multinational enterprises. This finding was also identified as a weakness in the interviews with SME owners: ICT providers very seldom collaborate with large IT firms, as they rarely work on actual product innovations; rather, they mostly develop bespoke solutions. Firms in the other sectors investigated maintain a more broadly-based innovation network, which should have a more positive influence on the novelty of innovations (Nieto & Santamaría, 2007).

Why don't SMEs collaborate? - Findings of the new survey

The main motive across all sectors is that the firm itself can undertake innovation projects alone (Figure C 1.18). Companies may also balk at the coordination involved in collaborations, or lack any experience of such collaborations. One business owner from the mechanical engineering sector had this to say: "The fact is that, for reasons of capacity, we tend to say: 'We can do it ourselves'. Things always get rather complicated when various partners are involved."

Some SMEs in the mechanical engineering sector and ICT providers believe there is a risk of an unintentional knowledge drain. Entering into a collaboration always requires a certain amount of trust, as not all eventualities can be documented beforehand in a contract. Consequently the cooperation partners involved make themselves „vulnerable" to a degree, as they must disclose information and trust that the other party will not abuse that information. Trust-based collaboration is therefore more open to exploitation than other forms (Bergmann & Volery, 2009). In the sample, however, only a few mechanical engineering firms and ICT providers had had bad experiences with collaborations. On the whole, unintentional knowledge drain seems to be an underlying fear rather than a tangible threat. Switzerland's small size was cited as the reason for this: "You're always 'bumping into' one another. Sometimes A helps B, sometimes the reverse." It appears that it is possible to find suitable cooperation partners in most sectors.

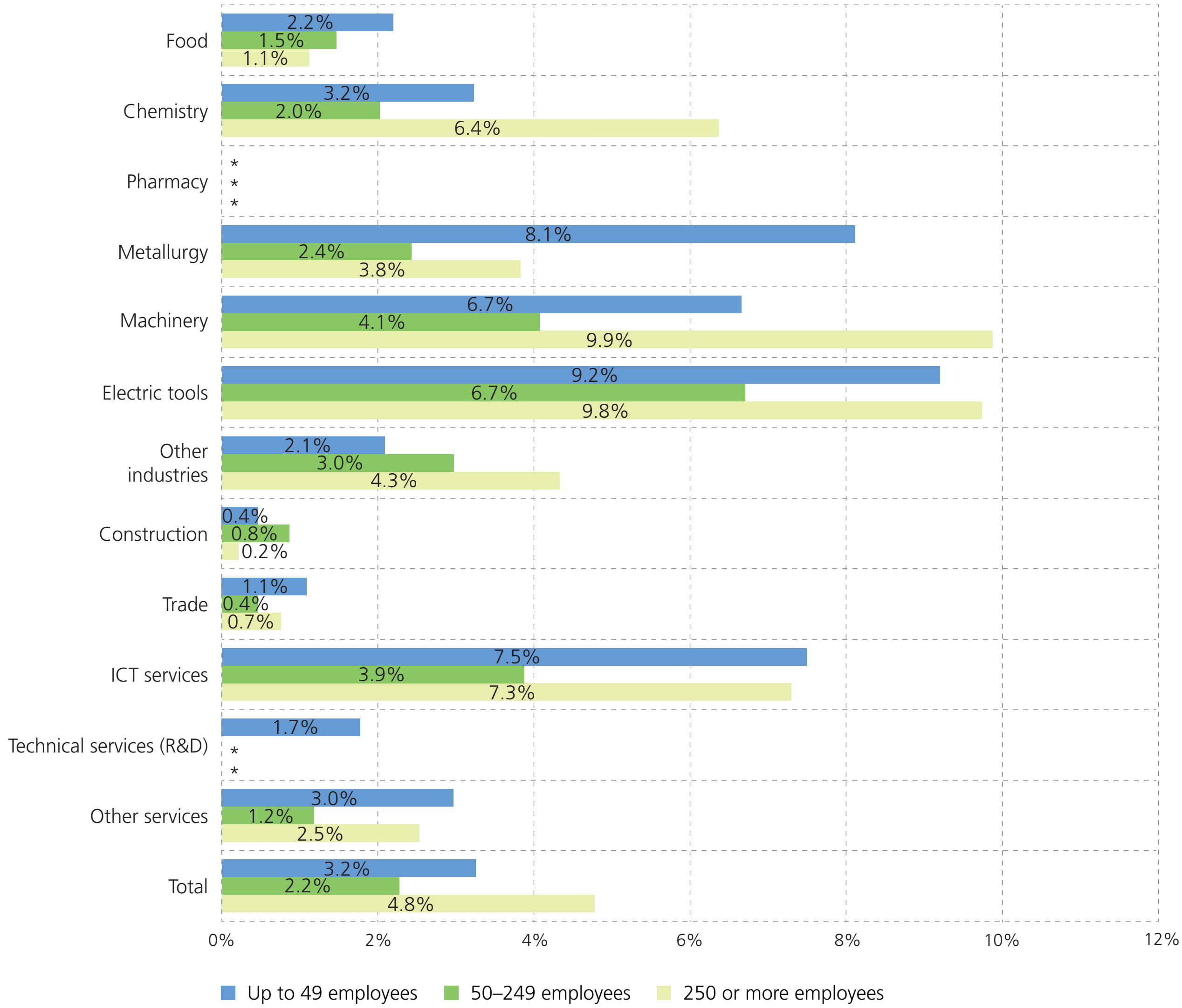
International comparison of innovation collaborations

Any international comparison of innovation collaborations involving SMEs is very limited, as the European Community Innovation Survey (CIS) and the Swiss KOF Innovation Survey ask slightly different questions on this subject. While the Swiss survey asks about collaboration in R&D activities, in the CIS the questions relate more generally to R&D innovation collaborations (Foray & Hollanders, 2015). The different phrasing of the questions probably explains Switzerland's below-average score on the Innovation Union Scoreboard for "Innovative SMEs collaborating with others" (European Commission, 2014, 2015).

Based on our own survey, we ascertained the proportion of SMEs involved in an innovation collaboration, but not in an R&D collaboration. This enables us to assess the bias created, as described above, by the differing questions. An analysis of our own survey reveals that innovation collaborations occur roughly 33% more frequently than R&D collaborations in the sectors investigated. This finding suggests that the corresponding value for "Innovative SMEs collaborating with others" for Switzerland on the Innovation Union Scoreboard should actually be around a third higher. This would place the value slightly above the average for the European countries investigated. These findings therefore suggest that innovation collaborations at Swiss SMEs are not a general weakness but rather that the postulated differences are simply the result of differing survey methods.

When interpreting the European average, it should also be borne in mind that innovation collaborations in many other European countries are encouraged by ad hoc, state-funded pro-

Figure C 1.19: Annual expenditure on innovation activities/sales by sector and size



* Due to the small number of cases, no value can be given
Source: KOF Innovation Survey 2011

grammes, which can also have a knock-on effect. Very few such subsidy programmes are available in Switzerland. One notable example is the CTI project funding, which directly promotes collaboration between research institutes and businesses (Hotz-Hart & Rohner, 2013). Accordingly, subsidy programmes are seldom a major motive in Switzerland for entering into R&D collaborations, as has already been demonstrated (Figure C 1.16).

1.5 Amount and financing of research and innovation expenditures

1.5.1 Expenditures on innovation

The amount of expenditure on innovation is a comprehensive input indicator for investments in innovation. This indicator illustrates the financial significance that firms ascribe to innovation. However, as such expenditures can be incurred in very different sectors, it is often difficult for the companies to indicate an exact amount. An interesting picture emerges with regard to expenditures on innovation relative to turnover. Firstly, the expenditure differs greatly by sector. This is indicative of the varying significance of innovation with regard to a firm's competitive position in the respective sectors. Secondly, in many sectors and overall, the structure of innovation expenditures is often u-shaped relative to turnover; i.e. small and large enterprises spend more, relatively speaking, than medium-sized enterprises. More detailed investigations for Germany show that innovation expenditures relative to turnover steadily decline the larger the firm and only return to a very high level at very large enterprises with over 1000 employees (Aschhoff et al., 2014), producing the general u-shaped trend. This correlation can be explained as follows: Some of the expenditures on systems and other research facilities consist of fixed costs and, as such, have a greater impact at small enterprises than at large enterprises. This explains the initially negative correlation between innovation expenditures and firm size. Very large enterprises often undertake extensive R&D activities and have their own, permanent, dedicated R&D departments. These are expensive to maintain, both in absolute terms and relative to turnover.

1.5.2 Nature of expenditures

The costs of innovation may be incurred in various areas. The KOF innovation survey makes a distinction between costs of research, development, construction/design and follow-up investments.[6] In contrast to the above, the costs are not estimated as an absolute amount, but on a scale of 5 (1 = no expenditures to 5 = very high expenditures).

At SMEs that have produced product or process innovations, high expenditure on development and construction/design is a relatively frequent occurrence, followed by subsequent, or follow-up investments. High research expenditures were only incurred by a very small number of all innovative SMEs.

What is striking about the figures here (Figure C 1.20) is that, in many cases, SMEs were able to produce their product or process innovations without incurring high costs for one of the categories surveyed. This suggests that many SMEs have introduced innovative solutions in a highly efficient manner, using few resources (Arvanitis et al., 2013). One possible reason for this finding is that SMEs regard even minor improvements to products, requiring little expenditure, as product innovations, whereas larger firms take a more systematic approach to developing new products and devote more financial resources to developing products with greater novelty value. Duran et al. (2015) reveal that family-owned companies invest less in innovation activities and yet have a higher innovation output. They argue that the innovation process is more efficient at family-owned companies as they are more concerned with economy and their open, trust-based culture promotes the exchange of ideas. These findings – comparatively low expenditures on innovation (Figure C 1.19) even though innovative products account for a big share of turnover (Figure C 1.5) – confirm this thesis for SMEs in general. Nonetheless, when interpreting these figures, it should be borne in mind that value added per person employed is significantly greater at large enterprises that at SMEs. The postulated innovation efficiency of SMEs is thus not associated with higher value added in the SME sector.

1.5.3 Access to financing opportunities

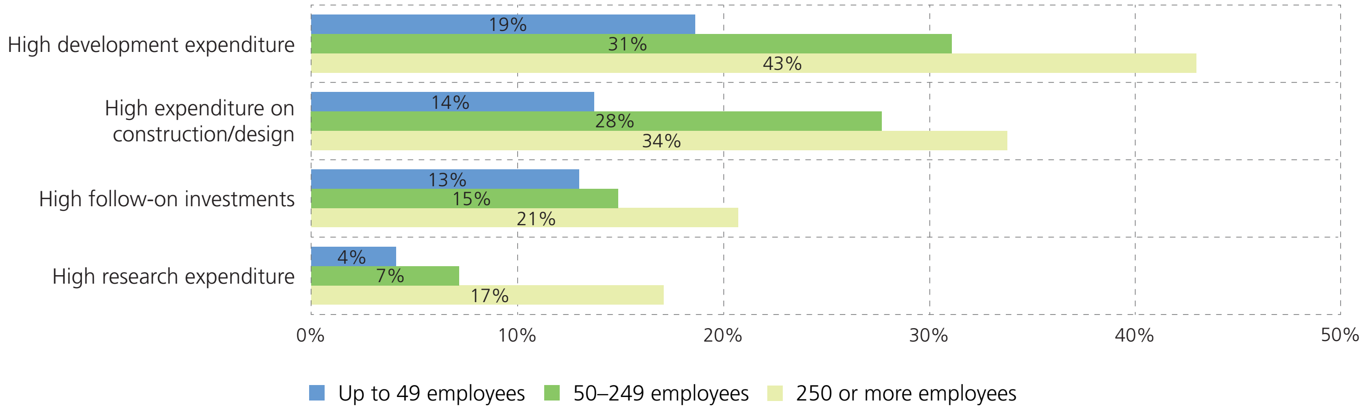
SMEs are able to meet their external capital requirements either by raising additional equity investments or through borrowing. Borrowing-wise, SMEs are mainly reliant on bank loans, because they do not have the critical size necessary to independently raise outside funding on the capital market. Unlike large enterprises, however, SMEs and start-ups struggle to satisfy the banks' information requirements in many respects (e.g. quality of financial statements, experience of the management). Thus collateral features more prominently in the lending process for these types of enterprise. Firms that lack collateral and have low equity may therefore be severely restricted in their borrowing capability, even if they have a financially viable project to present. Banks prefer to lend to companies with a relatively low default risk, as they do not have to back them with as much of their own equity. Therefore, particularly in the case of start-ups and firms in so-called high-risk sectors (e.g. catering), there is a certain reluctance to lend. This is confirmed by a SECO study on access to financing for SMEs in Switzerland (MIS Trend, 2013).

When analysing hurdles to raising credit, it should be borne in mind that, in quantitative terms, it is comparatively rare for an SME to fail to obtain a loan in Switzerland. In the SECO survey, only around a third of SMEs indicated that they have a bank loan or credit facility. By far the majority of the SMEs, particularly those from the service sector, have no need of a loan. Just 12% of the SMEs without bank financing do not use any credit because it was refused them; a disproportionate number of those are in the catering sector. Even among SMEs whose financing requirements

Financing opportunities: Findings of the new survey
Financing problems were also cited as an obstacle to innovation in our own survey, mostly by small and medium-sized enterprises – the majority of those in the service sector. Although the business owners feel the situation has improved, they still believe there are failings. As one business owner from the ICT segment said: "I know lots of smaller enterprises that have good projects worthy of support, but they don't get any financial support." According to the business owners, whether an innovation or a new product will prove itself on the market is impossible to say until financial resources have been invested, so resources are always vital in order to be innovative. Subsidies as part of CTI projects do not help, as the funds go not to the businesses, but to universities and other institutes.

[6] Costs of information technology (devices + software) are also ascertained. However, these are usually minor, so we will not be discussing them in any further detail here.

Figure C 1.20: Share of firms (product innovators only) with high corresponding expenditure, by size



"High expenditure": indication of 4 or 5 on a Likert scale of 1: none to 5: very many
Source: KOF Innovation Survey 2011

have increased over the last twelve months, the majority obtained financing. The request was only turned down outright in 6% of cases (MIS Trend, 2013).

So, despite problems in individual areas, it is wrong to assume there is a general SME credit crunch in Switzerland. While the financing situation of SMEs in many OECD countries has deteriorated in the wake of the financial crisis, Switzerland – along with a handful of other countries – is a positive exception to this. Lending to SMEs rose steadily between 2007 and 2012, albeit at a slower pace than in previous years (OECD, 2014b).

In the equity sphere, investments by business angels, venture capital and private equity firms are significant, albeit only for a small percentage of all SMEs. Opinions differ as to whether Switzerland has a sufficiently high level of equity investments for innovative firms. In a study for Avenir Suisse, Sieber (2009) does not believe there is a real lack of venture capital in Switzerland, although critical funding shortfalls can occur in the early start-up stage of technology-oriented firms. In SECO's opinion, the market for equity investments in Switzerland is functioning, but efforts need to be made to further improve the conditions for such investments (SECO, 2012a).

1.5.4 Optimum research and innovation expenditures

An analysis of expenditures on R&D activities raises the question of what the optimum level for such expenditure is. Normally, the theoretical assumption is that a firm's optimum R&D expenditure depends on the behaviour and decisions of market participants. However, a market failure or somewhat irrational decision-making behaviour can engender a level of research and innovation expenditure that is not optimum from a business or economic perspective. Inadequate investment in research and innovation may be due to the innovators' failure to take full account of the added benefit for the customer. This is the case if, for instance, firms are unable to adequately protect their innovations and competitors wholly or partially copy innovations. Conversely, excessive investment in research and innovation may arise if, for instance, companies are financing similar research programmes in parallel. It is normally assumed that firms invest too little in research and innovation (Jones & Williams, 2000; Wang & Huang, 2007). Against this backdrop, the governments of a number of countries are making efforts to increase the extent of research and innovation activities (OECD, 2010; Ortega-Argiles et al., 2009). However, the optimum level of research and innovation expenditures cannot be scientifically ascertained.

General environment: Findings of the new survey

The higher education environment, the existence of other innovative firms and the comparatively cooperative manner in which market participants interact were regarded as conducive to innovation by SMEs in Switzerland. The openness of the population to innovation, high spending power and cultural diversity were also identified as sources of potential. As proof of the great potential for innovation, the business owners surveyed cited the fact that lots of large enterprises first test new products on the Swiss market before launching them in other countries. Proximity to successful large enterprises can be another source of opportunities for innovations, one example being software solutions for the financial industry.

In the food industry, the following conditions were considered fairly critical to the innovativeness of SMEs: High prices in Switzerland are a hindrance to food exports, causing many Swiss producers to confine themselves to the domestic market. Consequently, fixed costs – such as costs for the certification of products – place a far greater burden on SMEs than on large enterprises. Moreover, the two major distributors Migros and Coop have a dominant position in food retail. Food producers thus have only a very small number of potential distribution channels for innovative products. Some producers believe there are more opportunities to position niche products in countries that are bigger than Switzerland. At the same time, however, they pointed out that the Swiss market is comparatively cooperative whereas in Germany, for example, commercial practices are tougher and the focus is far more on price. Some administrative arrangements that place a burden on SMEs in the food sector, such as the salt monopoly, were criticised. The focus group also felt that the "Swissness requirement"[7] hampers innovativeness at SMEs: "If a company goes to the effort of innovating and has incurred costs, it's a massive constraint if, at the end of the day, you're not allowed to put the Swiss cross on the product."

In the focus group for ICT providers, high labour costs and inadequate financing opportunities were seen as detrimental to innovativeness at SMEs. The group argued that, in Switzerland, the costs of the personnel required to develop and programme innovations are prohibitively high. Therefore, many large enterprises now have software solutions programmed abroad, at branches of their own company. Moreover, small ICT providers often lack the financial resources to develop their own innovative products.

[7] This statutory requirement is intended to strengthen the "Swiss" designation of origin and sets out precise rules for the requirements that a product or service must fulfil in order to be designated as "Swiss".

In engineering, the high labour costs were also perceived as a challenge for SMEs, a situation that has only worsened since the lifting of the CHF/EUR floor in January 2015. One business owner commented: "In Spain, you can get two engineers for the cost of just one here. Which also means that, in Spain, you can call on more manpower when you need the capacity." The high costs, it is argued, force companies to produce innovative products, increasing the risk of bad investments and claims. Furthermore, it is hard for firms to find qualified personnel with a technical training background.

1.6 The general environment for and obstacles to innovation

1.6.1 General environment

The general environment for business in Switzerland can be described as good to very good. Switzerland has a stable political environment, a well-developed physical infrastructure, an efficient administration and low taxes (WEF, 2014; World Bank, 2014). In comparative studies of the international situation, a multitude of factors are cited as important to a firm's innovativeness (Allman et al., 2011; Cornell University et al., 2013; OECD, 2014a), making it difficult to rate the importance of individual factors.

While a stable political environment and low taxes are undoubtedly important to the innovativeness of SMEs, the relative importance of these factors is almost impossible to assess, as firms in Switzerland take these for granted. The fact that Switzerland ranks in first place on the Innovation Union Scoreboard is evidence that, generally speaking, the conditions for innovation in Switzerland are very good. The percentage of innovative SMEs in Switzerland is also high by international standards (European Commission, 2014; Foray & Hollanders, 2015).

Yet this generally positive assessment reveals nothing about the situation in individual sectors or with regard to individual conditions. Because of this, the subject of general environment was also covered by the focus groups/group discussions held in selected sectors. When interpreting the following statements, it should be borne in mind that these are based on the assessments of a small number of companies and, as such, cannot be considered representative for all firms in Switzerland. Rather, the statements reflect a mood and are indicative of a general environment that is perceived as advantageous or somewhat problematic.

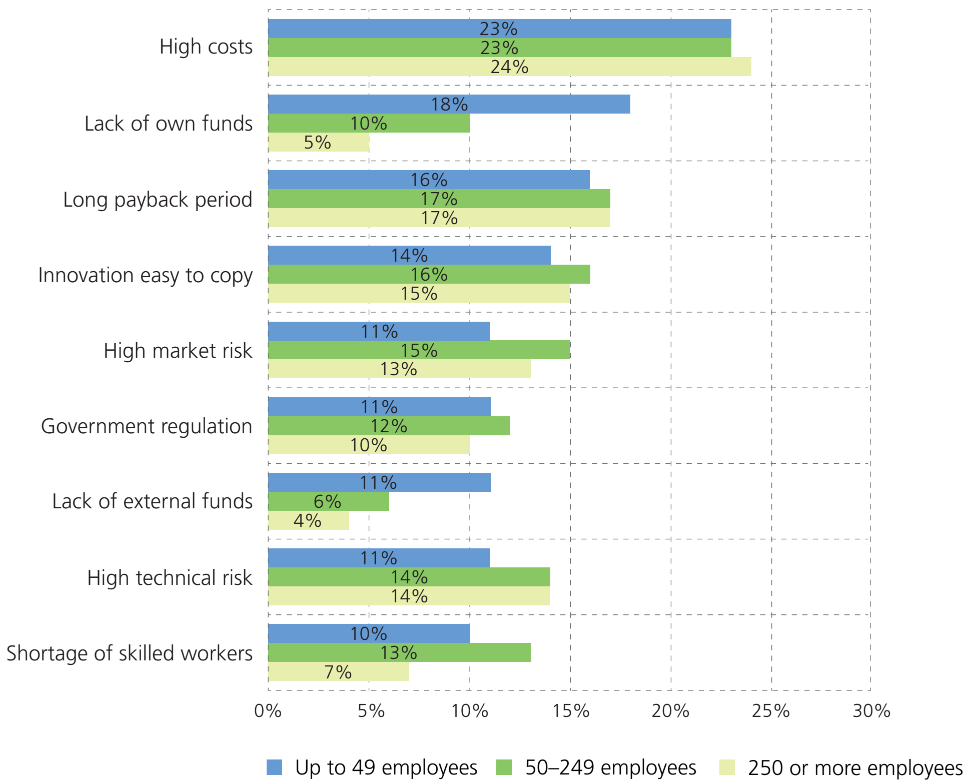
1.6.2 Obstacles

Obstacles to innovation are obstacles that cause firms to refrain from or abort innovation projects, or considerably delay them. Figure C 1.21 shows the extent to which various aspects present an impediment to their innovation projects for companies in Switzerland.[8] The question was aimed at all firms, regardless of whether or not they have been able to undertake an innovation project in the last three years. It is clear that cost-related factors present a particular obstacle. The costs of undertaking innovation projects are felt by SMEs to be too high or the payback periods too long. A lack of their own funds and external funds is far more likely to present an obstacle to innovation for SMEs than for large enterprises. These two indicators have a clear, negative correlation to firm size. This is partly due to the difficulties SMEs sometimes experience in obtaining financing, as discussed above. A lack of own funds is perceived as an even greater obstacle than a lack of external funds, suggesting that owner-managed businesses prefer to self-finance and do not seek to obtain any external financing (Mishra & McConaughy, 1999).

Aside from a lack of their own funds, factors internal to the business are seldom perceived as an obstacle. Fewer than 10% of all SMEs consider organisational problems or a lack of information about the state of the art to present obstacles to innovation. This result is surprising, as a lack of skills within the business is frequently cited as an obstacle by SMEs in other countries (such as the UK) (Freel, 2003, 2005). This finding suggests that – in the perception of businesses at least – employees are highly qualified, which may be due to Switzerland's very well-developed education system.

[8] The illustration in Figure C 1.21 only includes those obstacles perceived as significant by a total of 10% of the firms. The following obstacles are perceived as significant by fewer than 10% (in descending order): high taxes (9%), shortage of R&D personnel (8%), lack of market information (7%), lack of IT staff (5%), acceptance problems (4%), organisational problems (4%), lack of technical information (3%).

Figure C 1.21: Obstacles to innovation by size



Source: Own calculation on the basis of the KOF Innovation Survey 2013

Obstacles to innovation: Findings of the new survey

Obstacles to innovation were also covered in our own survey in four selected sectors and were discussed by the focus groups. The picture revealed is similar to that outlined above, again with significant differences between the sectors. The high costs and long payback period of innovations are a particular concern in capital-intensive sectors such as the food, chemistry and pharmacy industries. ICT providers identify high salary costs in Switzerland as a problem, making it hardly worthwhile developing new products. Firms often counter this by outsourcing development activities abroad. Moreover, a lack of own funds or external funds presents an obstacle for ICT providers. For small ICT providers in particular, funding shortfalls – coupled with the high salary costs of programmers – are frequently viewed as an obstacle to innovation: "In summary I would say that the high level of wages, lack of financial resources and large number of fragmented companies hinder innovations in the ICT sector."

In the perception of the firms surveyed, government regulations can only be regarded as a real obstacle to innovation in the chemistry/pharmacy sector; the REACH Chemical Regulation and the licensing requirements were cited in particular. The costs of applying for patents are also a major factor in this sector. Export restrictions and tariff barriers are examples of administrative obstacles in mechanical engineering and in the food industry.

1.7 Summary and conclusion

The key findings of this study can be summarised as follows: By international standards, SMEs in Switzerland can be regarded as more innovative than average; marketing and organisational innovations are the most widespread, followed by product and process innovations. The major sectoral differences can be explained by differing competitive environments and technological capabilities.

If we look only at the share of firms that have introduced a product, process or other form of innovation, SMEs are less frequently innovative than large enterprises. This does not apply, however, when turnover from innovative products is investigated. In this regard, SMEs are on a par with large enterprises, or even in some cases more innovative. Although Swiss SMEs invest less money relative to turnover in innovation, in proportion to turnover they generate bigger returns on innovative products than large enterprises. These findings indicate that SMEs use their resources highly efficiently for innovation. The majority of expenditure on innovation at SMEs is incurred for activities close to the market, such as product development as well as construction and design. High research expenditures are more the exception at SMEs. While the share of innovative SMEs has been falling in recent years, conversely the share of turnover from innovative products has actually risen slightly overall, suggesting that innovation is increasingly concentrated at fewer SMEs.

The two main knowledge sources for SMEs in the innovation process are customers and suppliers. Universities and other research facilities are only relevant to a comparatively small number of SMEs. While SMEs frequently engage in R&D collaborations, the awarding of R&D contracts and R&D activities abroad is less widespread.

The high costs and long payback period, coupled with insufficient own funds, present an obstacle to innovation at SMEs. High salary costs are a key factor here. Furthermore, in most cases innovation necessitates certain acquisitions or the use of machinery; some of these are fixed costs, making them a more important consideration for small enterprises, relatively speaking, than for large enterprises. Small enterprises in particular find it harder than large enterprises to finance innovation. There are, however, signs that SMEs deliberately choose not to obtain money from external lenders or investors, preferring instead to remain independent.


NEC

Disney Research Zurich is the symbol of a long and fruitful collaboration between The Walt Disney Company and ETH Zurich. At the lab in Zurich, IT researchers conduct basic research on behalf of Hollywood. These scientists develop complex tools and algorithms that will be used throughout The Walt Disney Company. Since being established in 2008, a large number of publications have appeared in specialist scientific journals, and numerous patent applications have been filed. Photo: Disney Research Zurich

PART C: STUDY 2

Research and innovation activities of multinationals in Switzerland

The following text is an abridged version of a study conducted by Prof. Oliver Gassmann, Florian Homann and Prof. Maximilian Palmié (University of St. Gallen). This summary has been approved by the various groups that have supported the elaboration process. The full version of the study was published in the SERI publication series (www.sbfi.admin.ch).

Contents

2 Research and innovation activities of multinationals in Switzerland

2.1 Introduction

2.1.1 General context

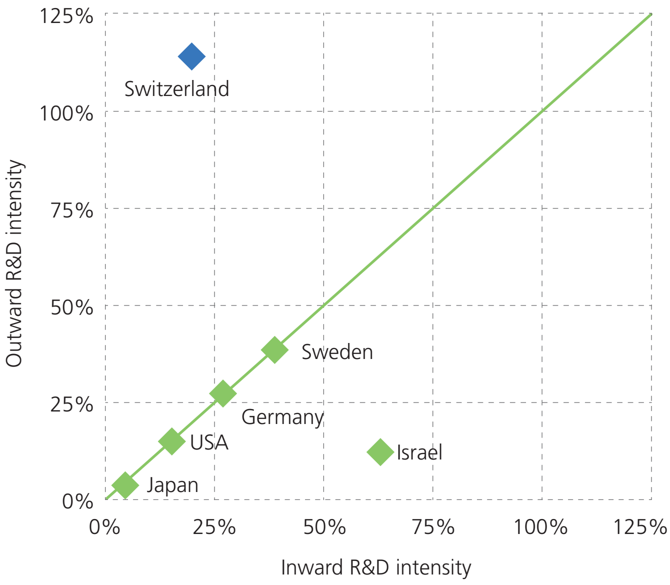
In the last few decades, there has been a growing tendency at many firms to internationalise whole swathes of their value added activity. Along with other aspects of their value chain (such as production), this trend is now also extending to their research and innovation activities. In OECD countries, the share of private sector expenditures on research and development (R&D)[1] that can be attributed to the local affiliates of foreign companies rose from an average of around 11% to over 16% between 1994 and 2004 (Guimón, 2011). This trend is even more pronounced in Europe. A study of fifteen states of the European Union, which together represent 87% of the EU's population and 91% of its GDP (Eurostat, 2014), revealed an increase from just under 24% to over 38% for the aforementioned parameter between 1994 and 2004 (Guimón, 2011). This indicates that firms generate a substantial portion of their value added from international activities in the research and innovation sphere (Dunning & Lundan, 2009).

As well as being attractive from a business perspective, the internationalisation of research and innovation activities also benefits the countries in which foreign companies establish their research and innovation activities. It creates high quality jobs, generates knowledge for the local economy and increases the capacity of a national economy to absorb new knowledge generated elsewhere (von Zedtwitz & Gassmann, 2002). Research and innovation activities of foreign companies impact in many different ways on the various actors in the host country's national innovation system. The establishment of research and innovation activities by multinational enterprises has engendered competition between countries and it seems that activities in research and innovation are currently the main driver of future direct investments in Europe (Ernst & Young, 2014). Switzerland is also involved in this competition to attract investment.

2.1.2 Current situation in Switzerland and goal of the study

Large enterprises, many of which are multinationals, are vitally important to Swiss research and innovation. In 2012, the private sector in Switzerland spent a total of CHF 12.8 billion on R&D activities (total BERD[2]; FSO, 2014). CHF 10.5 billion or 82% of those expenditures originated from large enterprises (economiesuisse & FSO, 2014). In the same year, affiliates of Swiss companies spent CHF 15 billion on R&D activities abroad (outward BERD), whilst investments by foreign affiliates in R&D activities in Switzerland totalled just CHF 2.6 billion (inward BERD).[3] As Figure C 2.1 shows, by international standards Switzerland occupies a unique position in this respect.

Figure C 2.1: Inward R&D intensity (inward BERD / total BERD) vs. outward R&D intensity (outward BERD / total BERD)



Source: OECD and FSO, SERI illustration (in keeping with Dachs et al., 2012)

In order to benefit as an economy from the internationalisation of research and innovation activities by firms, it is important to offer a general environment that is conducive to those activities. This is partly in order to retain existing research and innovation activities in Switzerland and encourage new ones, and partly to attract more research and innovation activities from abroad (Guimón, 2011; Meyer-Krahmer & Reger, 1999).

[1] In keeping with Part A of the present report, in this study the term "research and innovation" encompasses both the definition of research and development (R&D) as per the Frascati Manual (OECD, 2015) and the definition of innovation as per the Oslo Manual (OECD & Eurostat, 2005). As many official statistics relate only to R&D, where no research and innovation data are available, R&D is used. This is especially true of information on expenditures and personnel.

[2] The term "BERD" refers to R&D expenditure by the private sector ("business enterprise expenditure on research and development"). The values for BERD are not confined to large multinationals, but cover the expenditure of all companies.

[3] Due to the data situation, the definition used here for "outward BERD" refers exclusively to R&D expenditure of Swiss controlled affiliates abroad, and not to R&D expenditure of Swiss companies abroad in general. Likewise, the definition of "inward BERD" relates exclusively to R&D expenditure of foreign controlled affiliates in Switzerland.

The aim of this study is to investigate how research and innovation activities of multinationals benefit the Swiss research and innovation landscape and to explore why multinational enterprises undertake research and innovation activities in Switzerland. It also investigates the reasons for the appeal of various other research and innovation locations at national level and discusses possible improvements to the general environment for research and innovation activities by multinational enterprises in Switzerland. This analysis was based on existing literature and a qualitative and a quantitative investigation (see Chapter 2.6).

In this study, the term multinationals refers to companies with affiliates in at least two different countries. The focus is in large enterprises with 500 or more employees. The term "Swiss multinationals" refers to multinationals with their head office in Switzerland.

2.2 How research and innovation activities of multinationals benefit Switzerland

2.2.1 Multinationals in the national research and innovation system

Multinational enterprises play a pivotal role for national innovation systems, as they often have connections with various actors: other firms in the form of collaborations or customer/supplier relationships, and universities and research institutes (Narula & Guimón, 2009). This is the main way in which multinationals facilitate knowledge diffusion and, therefore, the generation and exploitation of knowledge in the innovation system.

Multinationals are thus a key driver of innovation which, in turn, drives an economy's productivity and growth (Alkemade et al., 2015). Although the flexibility and specialisation of small and medium-sized enterprises (SMEs) have a very positive effect on their innovativeness, many lack the capacity to undertake innovation processes entirely independently (Lee et. al., 2010). As their resources are limited, SMEs are less able to innovate in a radical or transformative way; instead, they typically generate incremental innovations (Bos-Brouwers, 2010). In contrast to SMEs, however, the management of large enterprises has a more long-term strategic outlook, so they are better able to generate radical innovations (Bos-Brouwers, 2010). Moreover, multinational enterprises are very important partners for SMEs. On average,

Figure C 2.2: Top 15 Swiss multinationals by R&D expenditure

Firms	Sector	R&D expenditure worldwide in 2013 (in CHF million)	Rank worldwide (by R&D expenditure)	R&D intensity in 2013 (in %)	Share of R&D expenditure abroad (in %)
Novartis	Pharmacy	8806.9	5	17.1	63
Roche	Pharmacy	8687.5	6	18.6	75
Nestlé	Food	1683.6	75	1.8	61
ABB	Energy and automation technology	1367.4	88	3.7	95*
Syngenta	Agro-chemistry	1224.9	106	9.4	n.a.
Liebherr-International	Machinery, domestic appliances	533.7	224	4.8	n.a.
TE Connectivity	Electrical engineering	512.8	233	4.3	n.a.
Actelion	Pharmacy	404.7	284	22.7	n.a.
Givaudan	Chemistry	392.4	289	9.0	n.a.
Garmin	Navigation	324.9	338	13.9	n.a.
Weatherford International	Oil and gas industry	235.9	428	1.7	n.a.
Clariant	Chemistry	198.7	478	3.3	n.a.
Swatch	Watches	193.7	492	2.3	n.a.
Kudelski	Electronics	181.3	519	21.6	n.a.
Sika	Chemistry	165.9	566	3.2	76*

*Estimate; n.a.: not available
Source: Hernández et al.(2014); Nestlé (2015); Novartis (2015); Roche (2010); von Zedtwitz (2014)

30.3% of the turnover of SMEs is generated from customer relationships with listed Swiss joint-stock companies. These are important partners in purchasing and procurement, marketing and distribution and R&D. The relationships between SMEs and multinationals have an indirect and positive influence on the innovation system and the international activities of SMEs (Beier et al., 2013).

The impact on a national economy of the arrival of foreign multinationals can be either direct or indirect.

Direct effects comprise impact on an economy's balance of payments, on competition between companies, on the job market, on technology transfer and on institutional transfer. The net effect on the host country can be both positive and negative.

Indirect effects involve relationships between multinational enterprises and local firms, and external effects. As regards relationships between multinational enterprises and local companies, the effects may be monetary or non-monetary in nature (joint ventures or alliances with local firms or customer/supplier relationships). Particularly in the case of equity-based connections such as joint ventures, such effects are very similar to the direct effects. External effects on local, non-affiliated companies are created by the unintentional transfer of knowledge from the multinational (Dunning & Lundan, 2008). Essentially, direct and indirect effects affect similar areas (balance of payments, competition, job market, technology transfer). These areas form the structure for the following discussion of how research and innovation activities by multinational enterprises benefit Switzerland.

2.2.2 Impact of multinationals' research and innovation activities on the balance of payments

The impact on an economy's balance of payments of multinationals' activities depends on a range of factors affecting the economy and is mostly beyond the control of an individual firm (Dunning & Lundan, 2008). In Switzerland, multinational enterprises are directly responsible for up to 36% of gross domestic product, up to 22% of that total being attributable to Swiss multinationals and up to 14% to foreign multinationals (Figure C 2.3; Naville et al., 2012). The 20 most research and innovation-intensive Swiss multinational enterprises alone generate roughly 4.7% of Switzerland's GDP (CHF 26,000 million; BAKBASEL, 2013). Moreover, in Switzerland, multinational enterprises are directly responsible for up to 29% of jobs, up to 18% of that total being attributable to

Figure C 2.3: Estimate of the economic importance of multinationals to Switzerland, 2013

Share in gross value added as % of GDP	16–36%
Share in total workforce	11–29%
Share in corporate taxes (direct taxes)	35–42%

Source: Federal Statistical Office FSO (2008, 2015); Hauser et al (2009); Naville et al. (2012) in: Walser & Bischofberger (2013)

Figure C 2.4: Share of high-tech exports in total exports of manufactured goods

	2003	2013
Switzerland	25%	27%
USA	30%	18%
Singapore	57%	47%
Germany	17%	16%
France	20%	26%
United Kingdom	26%	8%

Source: World Bank

Swiss multinationals and up to 11% to foreign multinationals (Figure C 2.3; Naville et al., 2012). The 20 most research and innovation-intensive Swiss multinational enterprises employ around 80,300 people in total (full-time equivalents, BAKBASEL, 2013).

Swiss firms are largely responsible for R&D expenditures. In 2012, the share of R&D expenditure of foreign controlled affiliates in Switzerland (inward BERD) in relation to total expenditures on R&D in Switzerland (total BERD) was just 20%, which is on the low side compared with other countries (Figure C 2.1).

As regards the share of high-tech exports in exports of manufactured goods, the figure for Switzerland is average but stable (Figure C 2.4).

2.2.3 Impact of multinationals' research and innovation activities on competition

Increased competition as a result of the activities of foreign multinational enterprises can have either a positive or negative influence on local businesses.

- The influence may be positive if the multinational enterprise creates incentives for local companies to improve their own products or processes, particularly if, in addition to the competition, local firms are able to benefit from technology or knowledge transfer.
- A negative influence can arise if local companies are unable to make the necessary investments or cannot profit from knowledge or technology transfer and are exposed to competition from the multinational (Dunning & Lundan, 2008).

Swiss SMEs often collaborate with multinational enterprises in research and innovation activities: 27% of the SMEs surveyed as part of Study 1 (Part C) indicate that they collaborate with multinationals, and slightly more frequently with foreign than Swiss multinationals. The interviews with SMEs reveal that encounters with multinational enterprises can be highly beneficial for SMEs: multinationals that deliberately invest in high wage countries often place the focus on promising areas, presenting SMEs with an opportunity to ride on their coat-tails. Collaborations allow SMEs, particularly suppliers of highly specialised components, to reach niche markets by integrating their activities into multinationals' value chains and thus generate economies of scale by increasing their turnover. Many Swiss SMEs have become hidden champions[4] as a result of collaborating with multinationals and have attained a leading position in a particular niche on the global market (Bigler, 2014; Etemad et. al., 2001).

2.2.4 Impact of multinationals' research and innovation activities on initial education and continuing education and training

By their own estimation, Swiss multinational enterprises are more heavily involved in most areas of initial education and continuing education and training than foreign multinationals, such as offering apprenticeships, collaborations with universities of applied sciences, universities and ETH (Federal Institutes of Technology) and in terms of improving the R&D infrastructure. When surveying Swiss and foreign multinational enterprises, the responses of the Swiss multinationals in these areas have significantly higher average values. Swiss multinationals report a slightly higher level of involvement (marginally higher than average values) in regional industry and research associations. As regards continuing education and training for employees, however, the firms' own assessments suggest a slightly higher level of commitment among foreign multinationals (marginally higher than average values among foreign multinationals, Figure C 2.5).

The findings paint a more sharply defined picture than previous studies (Mühlemann, 2013) and the in-depth interviews conducted for this study, which did not suggest any differences between Swiss and foreign multinationals. However, it was apparent in the interviews that the knowledge intensity of the activities carried out has a greater bearing on the provision of apprenticeships than the company's national origin. Where there is a strong focus on research and innovation activities, which was more frequently the case among foreign multinationals in the interviews than among Swiss multinationals, employees who are graduates of a university represent a larger portion of the workforce, meaning a concomitantly smaller number of apprentices at the firm concerned.

SMEs believe that research and innovation activities by multinationals yield little or merely average value added (Figure C 2.6). Multinationals' education and continuing professional development activities, their collaborations with universities and their regional commitment are beneficial to SMEs. Roughly a third of SMEs do not identify any value added from the commitment of multinationals.

In terms of both quality and quantity, multinational enterprises are responsible for the majority of collaborations with universities. Research-oriented activities of firms at universities in particular are dominated by multinationals. For many years, ETH Zurich and EPFL have been acting as partners who are responsible for the vast majority of private sector third-party funding in research. In the past, numerous multinational research units have also been established at the University of St. Gallen, such as the SAP Lab, Audi Lab, Hilti Lab and Bosch Lab.

[4] These are global market leaders who are barely known outside a sector but have built immensely strong competitive positions.

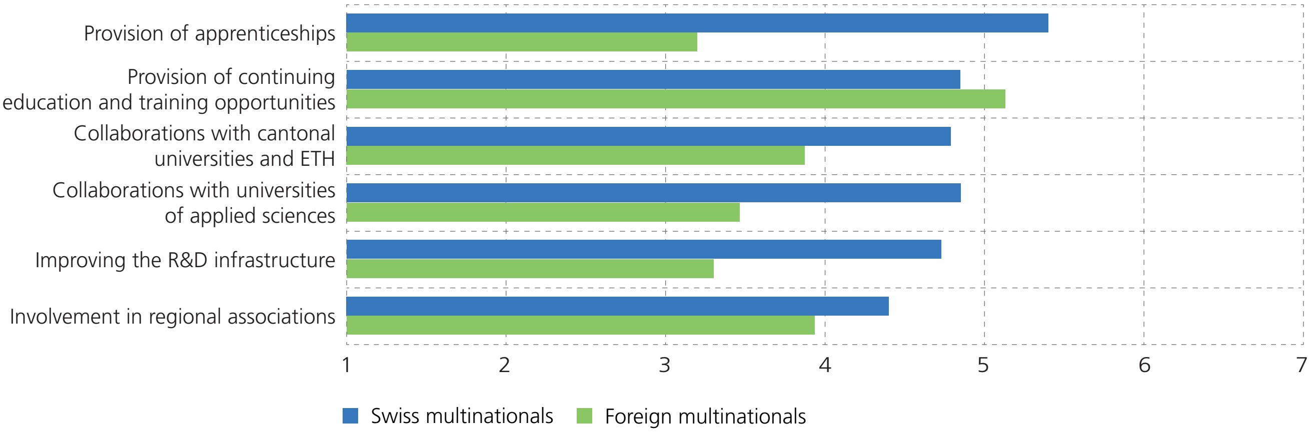
Training new talents at a Swiss multinational: the example of Bühler

Internationally active Swiss family company Bühler AG employees around a quarter of its more than 10,000 staff in Switzerland. Numbering 560 as at the end of 2013, apprentices make up a significant portion of the workforce. So far, in its more than 100-year history Bühler has trained in excess of 7,500 apprentices. Bühler's training programme has already won several awards, in recent years chiefly in recognition of its innovative range of international placements for apprentices: since 2008, apprentices in Switzerland have had the option of completing a placement of several months abroad, at international locations. For this programme, in 2010 Bühler received an award from the Stiftung Enterprise and the Swiss Federal Institute for Vocational Education and Training (SFIVET). In January 2012, it received the award for Idea of the Month from IDEE-SUISSE and at the same time was nominated for the Creativity Award 2011/2012. So that apprentices still have access to training materials during their time abroad, Bühler developed this concept in partnership with the Wil-Uzwil Vocational and Further Education Centre, as part of the ClassUnlimited project. Today, video is used for vocational teaching, creating a virtual classroom on two large screens at each location abroad. In 2014, Bühler was awarded the Leonardo European Corporate Learning Award for this concept (sources: interviews, media, website).

Successful collaborations between multinationals and universities: the example of the Bosch Internet of Things and Services Lab at the University of St. Gallen

The Bosch IoT Lab, a long-term collaboration with the University of St. Gallen established in 2012, is a laboratory for business innovations involving the Internet of Things, in which eight doctoral students and one scientific and one operational head conduct research with the aim of identifying and implementing early on business opportunities in the realm of the Internet of Things. Research at the Bosch IoT Lab is conducted horizontally on the subject of business models and technologies for the Internet of Things and vertically in the form of practical application projects. One key feature of the Bosch IoT Lab is the publication of research findings. So far, the work has yielded 32 publications at international conferences or in specialist journals. As well as the scientific aspect, the application projects pursue the clear aim of commercialisation, either within the Bosch Group or externally as a start-up. Just how successful the latter can be is demonstrated by the start-up Comfy, which in 2014 won both the AXA Innovation Award and the Be.Project Award from Bearing Point and was also among the finalists of Venture Kick and the 2015 Pioneer Prize (sources: interviews, document analysis, media, websites).

Figure C 2.5: Commitment to education, continuing education and training and collaborations with universities as well as regional commitment (self-assessment by multinationals)

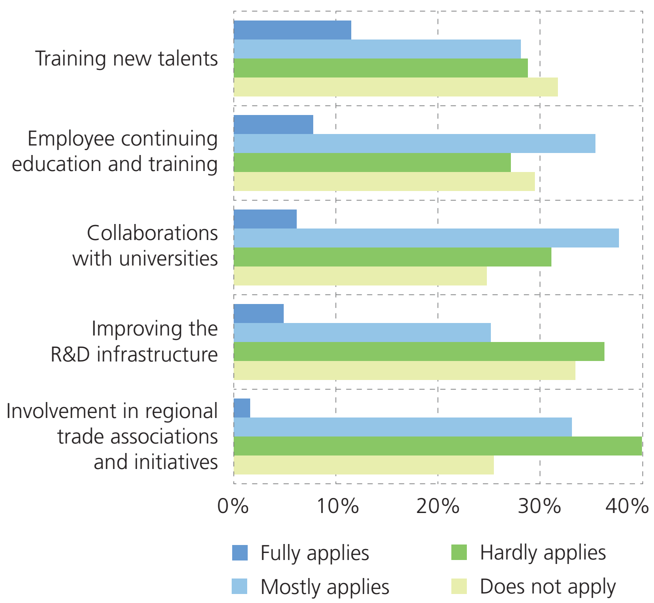


Likert scale from 1: far fewer than other firms through 4: the same as other firms to 7: far more than other firms
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=46)

The advantage of such research units, which are typically supported by multinational enterprises with ample resources and a strong research bias, lies in their long-term nature and their research orientation. In contrast to conventional contract research and development that is typical of SMEs, these labs favour research in relevant areas with plenty of academic rigour and a strong research orientation. This is also reflected in the publication activities of the professorships involved.

There has been an increase in the number of firms collaborating with universities in recent years: between 2008 and 2010, 70% of companies collaborated with institutions from the ETH Domain (2002–2004: 57%), 43% with cantonal universities (2002–2004: 38%) and 69% with universities of applied sciences (2002–2004: 56%). The percentage of large enterprises that have collaborated with universities is higher than the percentage of SMEs (Arvanitis et al., 2013). On average, 8% of universities' total budget stem from third-party funds from private research mandates or related services (FSO, 2013).

Figure C 2.6: Value added of multinationals' research and innovation activities for SMEs (self-assessment by SMEs)



Source: Survey of Swiss SMEs (n=131); survey for Study 1 (Part C): "Research and innovation activities of small and medium-sized enterprises in Switzerland"

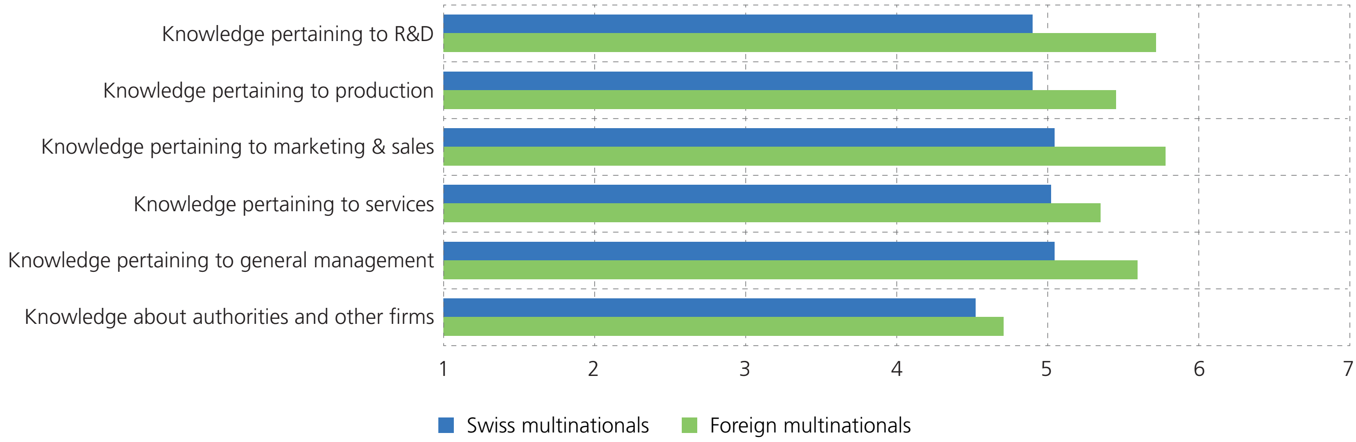
Universities benefit greatly from cooperating with firms, particularly multinational enterprises. The collaborations have a positive impact on social relevance and on the quality of teaching and research, as the interviews with university representatives show. There is also a reciprocal reputation effect which, for the universities – besides the common research interest and joint research funding – is a key outcome of the collaboration. In terms of training, collaborations enable practical and research-led teaching, which impacts positively on students' education.

2.2.5 Impact of multinationals' research and innovation activities on technology transfer

Both Swiss and foreign multinational enterprises contribute to Swiss research and innovation by sharing knowledge. Figure C 2.7 shows for various forms of knowledge consistently high values for the extent to which multinationals share their knowledge with other firms.

The responses of foreign multinationals show slightly higher average values than the responses of Swiss multinationals. Consequently, by their own assessment, foreign multinationals engage to a greater extent in knowledge transfer than their Swiss counterparts. The interviews with university representatives reveal that they profit from technology and knowledge transfer by multinational enterprises, as is also illustrated by the following case study on IBM Research – Zurich.

Figure C 2.7: Extent to which multinationals share knowledge with other corporate entities



Likert scale from 1: not at all to 7: to a very great extent
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=47)

Technology and knowledge transfer by multinationals: the example of IBM Research - Zurich

US company IBM has a long history in Switzerland: IBM has been operating a research centre in Switzerland since 1956, since 1963 on its own campus in Rüschlikon where, today, between 350–450 employees from over 45 nations are employed. As the European arm of IBM Research, as well as conducting cutting-edge research for information technology, IBM Research – Zurich (hereafter IBM) is tasked with fostering close collaborative relationships with academic and industrial partners and playing an active role in the Swiss and European research and innovation system.

In Switzerland, IBM maintains strong partnerships with the scientific community, particularly in the ETH Domain. With four professors and numerous post-doctoral and doctoral students, ETH Zurich is permanently represented on the IBM Campus in Rüschlikon. Scientists and engineers from IBM and ETH conduct their own and joint projects at the Binnig and Rohrer Nanotechnology Center (BRNC) there. The partnership with ETH Zurich has existed since IBM began its research activities outside the USA in 1956. With its numerous talents, ETH Zurich was one of the main reasons why IBM decided on Zurich as a location. Since the beginning, IBM and ETH Zurich have been working together in IT, the engineering sciences and physics. The BRNC, which was opened in 2011, forms the core of a ten-year strategic partnership. Through this collaboration, ETH Zurich has been able to successfully implement an innovative model for cooperation and for funding research. Scientific findings made by the collaborations have been published in renowned specialist journals; the issues surrounding intellectual property and publication rights are covered in a framework contract. Research findings obtained and funded by both partners are jointly published and patented and projects undertaken individually are published individually.

However, IBM's collaborations are not confined to ETH Zurich. In total, it has over 90 collaborations with partners at home and abroad, around a dozen of which are with various Swiss organisations on government-funded projects. Furthermore, IBM engages in various collaborations with Swiss SMEs, the positive impact of which on the Swiss research and innovation landscape was confirmed in the interviews with the SMEs involved. As well as collaborating with Swiss universities and SMEs, IBM also cooperates with European universities and SMEs on projects that are part of the European research framework. Currently (as at June 2015) IBM is collaborating on 68 of the EU-funded FP7 projects and supports a further 209 EU FP7 projects in a variety of ways. In total, therefore, the research centre collaborates with 1,900 partners in Switzerland and in Europe. IBM plays a leading role in these collaborations in terms of involving Swiss SMEs in EU projects.

Spin-offs from IBM Research also contribute to the regional and national research and innovation landscape: in 1997, the IBM Laser Enterprise division, a section of the research centre, was taken over by JDS Uniphase. This takeover had a significant influence on the region, as confirmed by the interviews with SME representatives. Following the takeover, JDS Uniphase opened a location in Zurich, both for manufacturing and to develop laser technology; at its peak in 2000, this site employed around 400 people. Today, this location belongs to II-VI Laser Enterprise GmbH with registered office in Zurich, which is a wholly-owned affiliate of II-IV Incorporated.

In total, IBM Research - Zurich has employed hundreds of doctoral and post-doctoral students since it was founded, most of whom remain at IBM for two years and are supported and further educated by the scientists. These highly-qualified specialists are in strong demand in the Swiss business and

scientific community and as such contribute to the growth of the local IT sector, either by forming start-ups, through teaching and research activities at ETH, universities and universities of applied sciences or in leading positions at existing companies.
To sum up, through its cutting-edge research, collaborations with universities and other research institutes, the promotion of its own technology-based spin-offs and start-ups by universities and by cooperating with SMEs, IBM hugely benefits the Swiss research and innovation scene. It is an example of a multinational enterprise that exerts a major influence on research and innovation in Switzerland, where it undertakes research and innovation activities along the entire value chain, from basic research and applications through to manufacturing and services. Ultimately, this creates cluster effects, which in turn directly or indirectly influence the establishment of research and innovation centres by the likes of Microsoft and Google (sources: interviews, document analysis, media, websites).

2.3 Why multinationals undertake research and innovation in Switzerland

2.3.1 Criteria for choosing a research and innovation location

The internationalisation of industrial research and innovation is a complex process. To understand the political implications, it is essential to consider the various motives and reasons when choosing a location (Guimón, 2011). From an economic perspective, there are two major factors that justify a decision to locate research and innovation activities abroad (Håkanson & Nobel, 1993): sales-related motives and input-related motives. Sales-related motives include the intention to adapt products or processes to local requirements and ideas. Research and innovation cooperation with lead users, or trend-leading users or customers in key markets thus results in the internationalisation of research and innovation. Input-related motives might include the desire to take advantage of the local scientific infrastructure, such as an attractive job market for engineers or preferential access to local universities (Håkanson & Nobel, 1993).

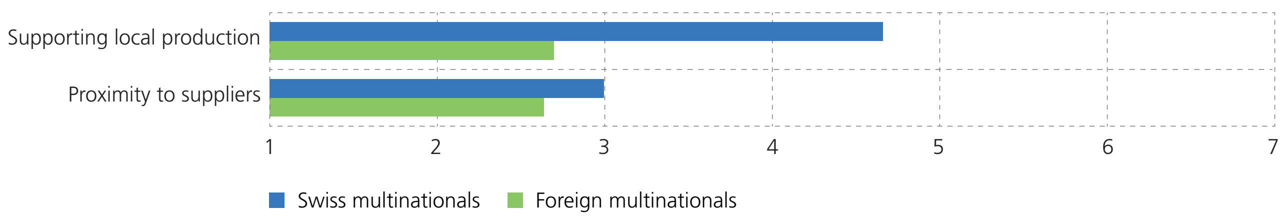
Håkanson und Nobel (1993) also observe that the sales-related motives can be divided into three different categories: Firstly, supporting local production, secondly proximity to markets and customers and thirdly political factors (such as trade barriers or tax benefits). Specific motives when choosing a location for research and innovation activities may typically fall into one of these three categories or (as regards the input-related motives) observing and exploiting local research and innovation potential. The sections below illustrate the role played by these four categories of motive in decisions by multinationals to establish research and innovation activities in Switzerland.

2.3.2 Supporting local production

As a criterion when deciding to establish research and innovation activities in Switzerland, supporting local production is of moderate importance to multinational enterprises; Swiss multinationals attach the greatest importance to supporting local production, as the responses by multinationals to the various points reveal (Figure C 2.8).

These findings are corroborated by the comments made by company representatives in the interviews: particularly for Swiss multinationals that rely heavily on expertise in order to produce their products, supporting local production is a key criterion when relocating their research and innovation activities. Proximity to the supplier, meanwhile, is less important as a factor these days, as was confirmed in the in-depth interviews.

Figure C 2.8: Importance of the motives in the category "Supporting local production"



Likert scale from 1: not at all to 7: to a very great extent
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=45)

2.3.3 Proximity to markets and customers

Proximity to the market and customers is cited as an important reason for research and innovation activities in Switzerland by foreign multinationals to a far greater extent than it is by Swiss multinationals, as is apparent from the average values for the responses of Swiss and foreign multinationals (Figure C 2.9). This may be due to the significant difference observed between European (average 4.2) and non-European multinationals (average 5.0) on the question of access to the European market

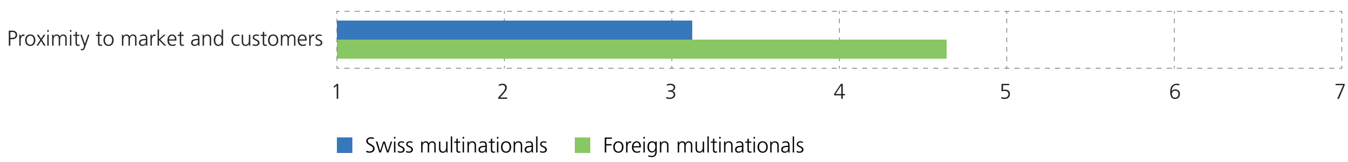
The interviews reveal that the importance of the market motive is very sector-specific. While proximity to the market and customers is comparatively important in, for instance, the energy sector in relation to the Swiss market and in the IT sector in relation to the European market, it plays a lesser role in the globally-oriented pharmaceutical and chemical sectors. Nonetheless there are also products in the chemical and pharmaceutical sectors for specific, e.g. Asian markets, which are often developed locally. The national licensing and registration of a medicine is another important factor.

2.3.4 Political factors

Before the political factors are discussed as drivers of the internationalisation of research and innovation, it should be mentioned that the survey carried out as part of this study confirms the findings of Håkanson & Nobel (1993), namely that these motives are the least important. Conspicuously, however, there are big differences in this category between the individual motives, as is apparent from the marked differences in the average values for the responses (Figure C 2.10).

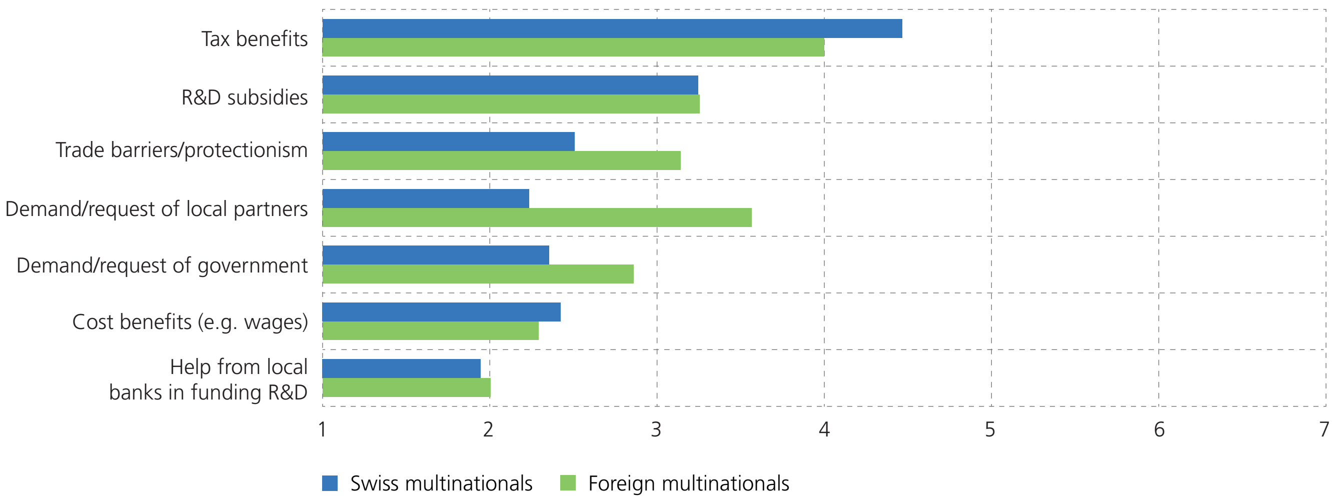
While tax benefits are the third most important of all the motives included in the survey, the other six motives in the "political factors" category are among the least important. This is corroborated by the findings of the interviews, in which the tax situation in Switzerland was cited by a few Swiss and foreign multinationals as a reason for locating research and innovation activities there, whilst the other six reasons were not cited as one of the main reasons in any of the interviews. Figure C 2.10 also shows that, with the exception of tax and cost benefits, the political factors are rated as more important on average by foreign multinationals than by their Swiss counterparts.

Figure C 2.9: Importance of the motives in the category "Proximity to market and customers"



Likert scale from 1: not at all to 7: to a very great extent
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=45)

Figure C 2.10: Importance of the motives in the category "Political factors"

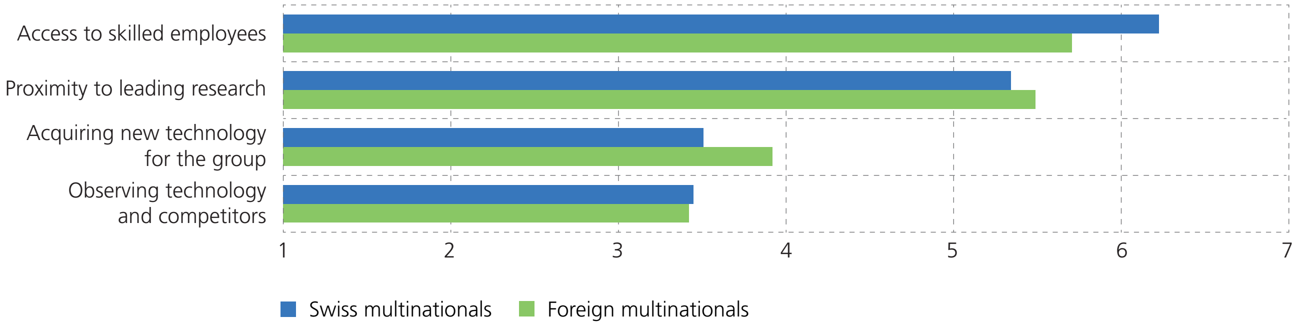


Likert scale from 1: not at all to 7: to a very great extent
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=45)

2.3.5 Observing and exploiting local research and innovation potential

Input-related motives, which fall under the category "Observing and exploiting local research and innovation potential", are a very important category of motives for choosing Switzerland as a location for research and innovation activities. The two chief motives in this category - access to skilled employees and proximity to leading research - achieve the highest average scores of all the motives surveyed, placing them top of the list of reasons for choosing Switzerland as a research and innovation location (Figure C 2.11). Acquiring new technologies and observing technological progress and competitors are also important reasons for Swiss and foreign multinationals alike, as shown by the average values for the responses given.

Figure C 2.11: Importance of motives in the category "Observing and exploiting local research and innovation potential"



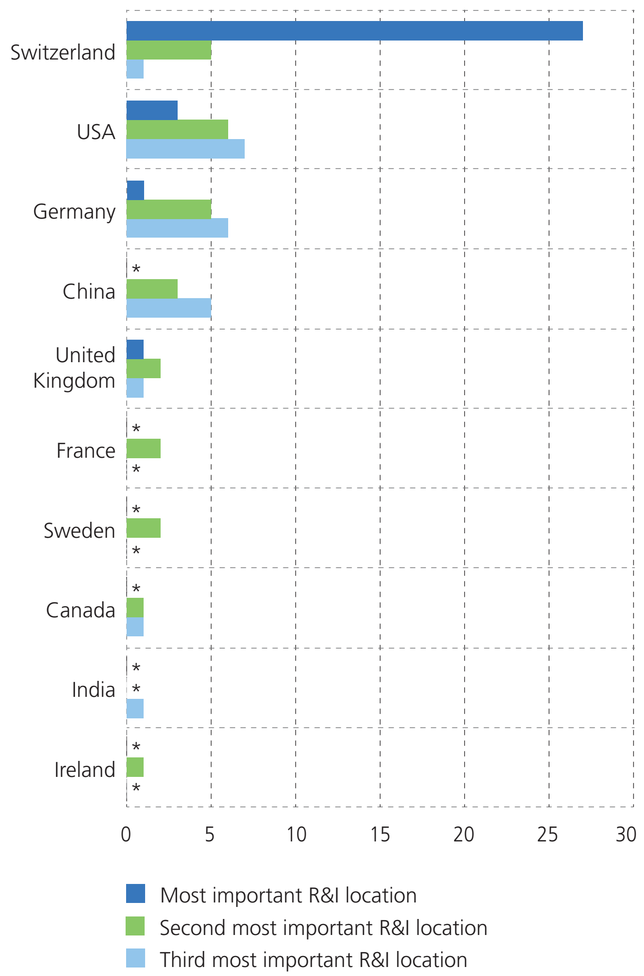
Likert scale from 1: not at all to 7: to a very great extent
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=45)

Figure C 2.12: Top 20 Swiss firms by patent applications in Switzerland 2006–2011

Rank	Firm	Canton	Patent applications (% of all patent families in Switzerland)	Sector
1	Roche	BS	13.9	Pharmacy
2	Novartis	BS	11.1	Pharmacy
3	ABB	ZH	9.0	Energy and automation technology
4	Syngenta	BS	3.6	Agro-chemistry
5	Nestlé	VD	3.3	Food
6	Clariant	BL	3.2	Chemistry
7	Tetra Laval International	VD	3.1	Packaging
8	OC Oerlikon	ZH	2.4	Plant engineering
9	Endress & Hauser	BL	2.2	Measurement technology
10	Swatch	BE	2.0	Watches
11	Sonova	ZH	1.6	Hearing devices
12	Synthes	SO	1.5	Medtech
13	Schindler	NW	1.4	Machinery
14	Sika	ZG	0.9	Chemistry
15	Rieter	ZH	0.9	Machinery
16	Sulzer	ZH	0.8	Machinery
17	Givaudan	GE	0.8	Chemistry
18	Mettler-Toledo	ZH	0.7	Electronic devices
19	SIG	SH	0.6	Machinery
20	Bühler	SG	0.4	Machinery
	Total Top 20		63.4	

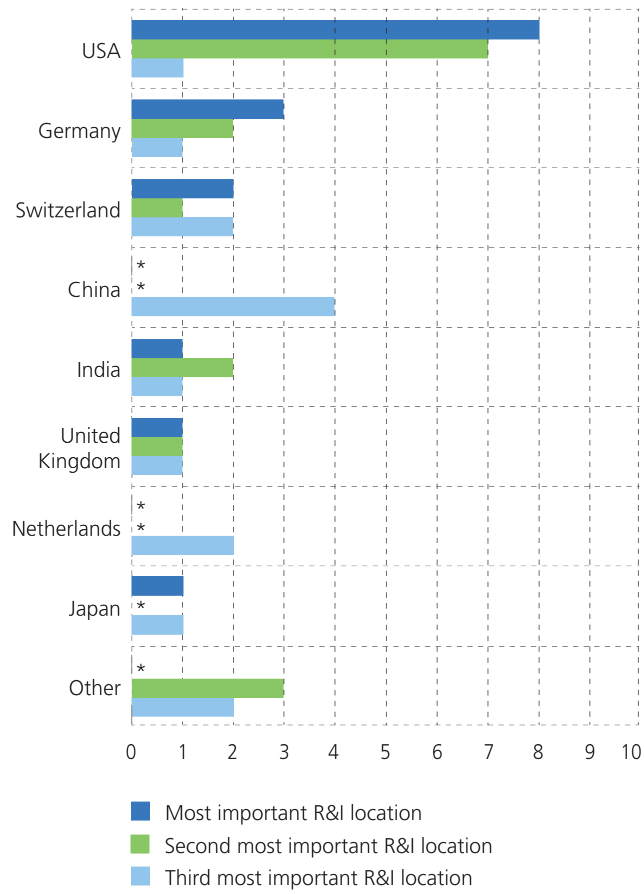
Source: BAKBASEL (2013); Müller (2012)

Figure C 2.13: Most important research and innovation locations for Swiss multinationals



*not available
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=32)

Figure C 2.14: Most important research and innovation locations for foreign multinationals



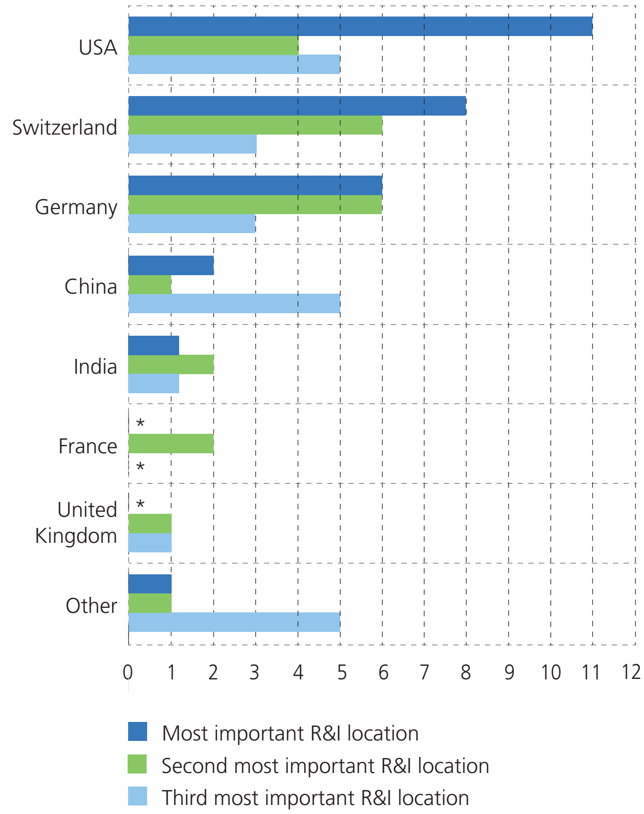
*not available
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=16)

The interviews reveal that Swiss universities, particularly ETH Zurich and EPFL, are fundamental factors with respect to "Access to skilled employees" and "Proximity to leading research". The generally good level of education in Switzerland also promises easy access to specialists (see also Chapter 2.4) and various interviewees mentioned the high standard of living in Switzerland, which attracts top scientists to Swiss locations.

2.3.6 Research and innovation-intensive sectors in Switzerland

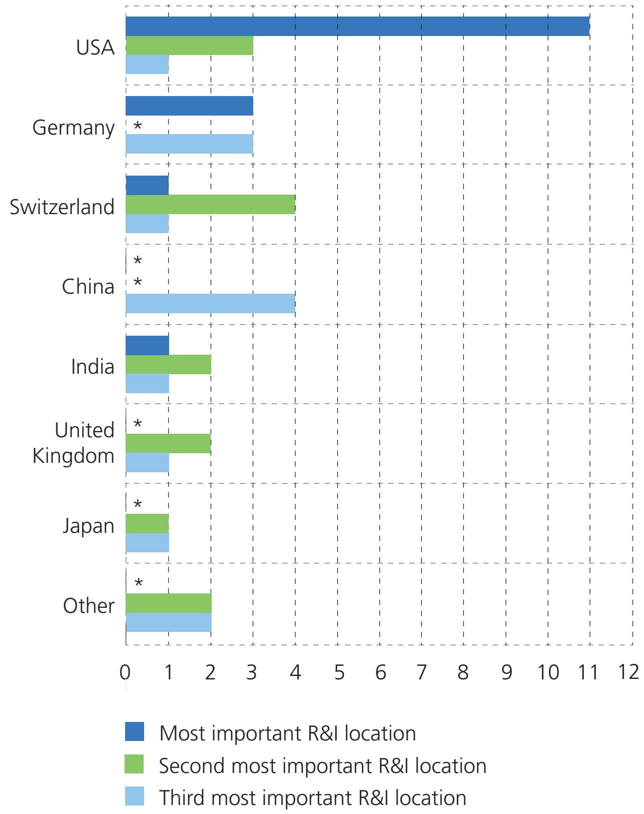
The importance of individual sectors to the Swiss research and innovation landscape is apparent from the sectors of major Swiss multinationals which make a substantial contribution to Switzerland's research and innovation scene (between 2006–2011, the Top 20 companies alone based on patent applications, all of them Swiss multinationals, were jointly responsible for 63.4% of patent applications in Switzerland (Figure C 2.12). The prominent position of the two pharmaceutical companies Roche and Novartis underlines the importance of pharmaceutical research and innovation in Switzerland. Syngenta, Clariant, Sika and Givaudan are the four companies representing the chemistry sector in the Top 20. The interviews with chemistry and pharmacy companies reveal how important these sectors are to Switzerland's appeal as a location for research and innovation: as the chemistry and pharmacy industries develop many innovations for the global market, multinational enterprises have less pronounced ties to individual markets when choosing a location for research and innovation activities. What matters most to them is the availability of an environment conducive to research and innovation. Consequently, Switzerland is in direct, international competition as a location for research and innovation in these sectors, most notably with the USA (see Section 2.3.7).

Figure C 2.15: Most important research and innovation locations for their own industry according to Swiss multinationals



*not available
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=30)

Figure C 2.16: Most important research and innovation locations for their own industry according to foreign multinationals



*not available
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=16)

2.3.7 Importance and appeal of various locations for research and innovation activities

Figures C 2.13 and C 2.14 show the frequency with which various locations are cited in the survey by multinational enterprises when ranking the most important, second most important and third most important locations for their companies.

For Swiss multinationals, Switzerland is far and away the top location for research and innovation, which can be explained by firms' domestic focus when selecting locations for their research and innovation activities (Belderbos et al., 2013). Other important locations are the USA, Germany and China. The findings also reveal that the USA and Germany are the second most important locations for Swiss multinationals, with China ranking third. Other Western European countries (Figure C 2.13) are also important for Swiss multinationals.

The survey reveals that Switzerland is deemed far less important as a research and innovation location by foreign multinationals than by their Swiss counterparts. For those that do undertake research and innovation activities in Switzerland, the USA is far and away the most important location, followed by Germany and Switzerland. Locations in emerging countries such as China and India are also considered important by foreign multinationals (Figure C 2.14).

Figures C 2.15 and C 2.16 show the frequency with which various locations are cited in the survey by Swiss and foreign multinationals when ranking their most important, second most important and third most important locations for their respective industry.

According to the findings, Switzerland is considered to be an attractive location for research and innovation by Swiss multinationals and their foreign counterparts. However, both Swiss and foreign multinationals rate the USA as the most attractive location for research and innovation, followed by Switzerland, Germany and China. Foreign multinationals in particular describe the USA as an especially attractive location for research and innovation (Figures C 2.15 and C 2.16).

The reasons why Google chose Zurich as a location
The US Internet group has its biggest development centre outside the USA in Zurich. Established in 2004, by 2015 more than 1,500 people worked for Google in Zurich. Moreover, Google has big growth plans: by 2020, it plans to increase its office space by 50,000 square metres.
Various factors influenced Google's choice of location: the innovation-friendly climate in Switzerland, the proximity to research and the scientific community, good access to qualified IT specialists in the Zurich area, the multilingual environment, favourable tax conditions, Zurich's central geographical location in Europe, the high standard of living and good level of paid enjoyed by specialists in Zurich, as well as the easy procedures for visa applications for European specialists who are unable to work in the USA. In June 2015, Google Switzerland boss Patrick Warnking cited the close collaboration with ETH Zurich and EPFL as particularly important factors. This was confirmed by earlier interviews conducted by the authors at Google's headquarters in Mountain View: excellence in research and science were key considerations when choosing Zurich as a location (sources: interviews, document analysis, media, websites).

As regards the actual choice of location, however, in recent years there have also been some "danger" signs with respect to Switzerland's appeal as a location: a number of Swiss multinationals have relocated the management of their research and innovation and some of their centres of excellence abroad. The head office of the Novartis Institutes for Biomedical Research, for example, is now in Massachusetts, in closer proximity to one of the world's biggest talent pools for scientists and leading academic institutions (Novartis, 2002), ABB has relocated its Center of Excellence for robotics to Shanghai so that it can better support China's fast-growing production industry (ABB, 2006) and Schindler is continually expanding its research and innovation locations in India and China, to enable it to supply its products on the local markets on even more competitive terms (Schindler, 2012). Initially, this was described as complementarity (additional research and innovation locations were thought to be a source of new growth that would not compete with domestic research and innovation). In the long run, however, it is proving to be more of a substitution effect. Swiss research and innovation in the traditional technologies is being scaled back in favour of the new locations; research and innovation is following the qualitative and quantitative resources and, above all, the key markets.

2.4 Implications for Switzerland

Although Switzerland still occupies a leading position on the international innovation stage, the country's comparative advantages are waning. Contrary to popular opinion that Switzerland's innovativeness is driven chiefly by SMEs, it is evident that it is the symbiotic system of multinationals with the other actors in the Swiss economy and universities that make Switzerland one of the world's leading innovation nations. The appeal of research and innovation to foreign multinationals is a strong indicator of an economy's innovativeness, as capital and talents are becoming increasingly mobile (Florida, 2005) and potential sites must compete by offering the best environment for research and innovation.

This section describes how multinational enterprises assess the appeal and scope for improvement of the general environment for research and innovation in Switzerland. In keeping with Guimón (2011), the discussion is structured as follows: (1) Availability of qualified personnel; (2) Quality of universities, research institutes and technology parks; (3) Tax and financial incentives for industrial research and innovation; (4) Promotion of collaborations between actors in the national innovation system; (5) Presence of pilot markets for key technologies; (6) Intellectual property rights.

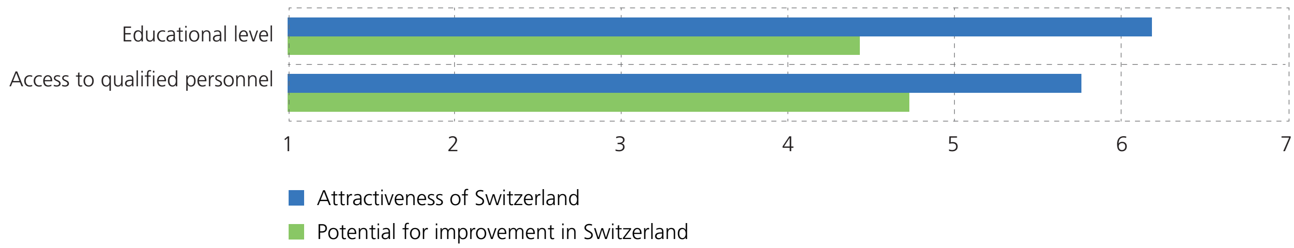
(1) Availability of qualified personnel

To increase the availability of qualified personnel, political influence can be exerted firstly by improving the education system (Hotz-Hart & Rohner, 2014) and secondly by attracting foreign specialists (Lewin et al., 2009).

With respect to educational level, Switzerland is deemed very attractive by multinational enterprises, as shown by the average scores for the responses obtained (Figure C 2.17). This was also corroborated in the interviews, in which the tiered educational system with its very high basic level turned out to be one of the main reasons for Switzerland's appeal in terms of education. As revealed by the average scores in the responses, multinational enterprises attach moderate importance to improving the educational level. The interviews with multinationals and SMEs revealed that, from the firms' perspective, there is scope for improvement in terms of increasing the prominence of the natural sciences in education.

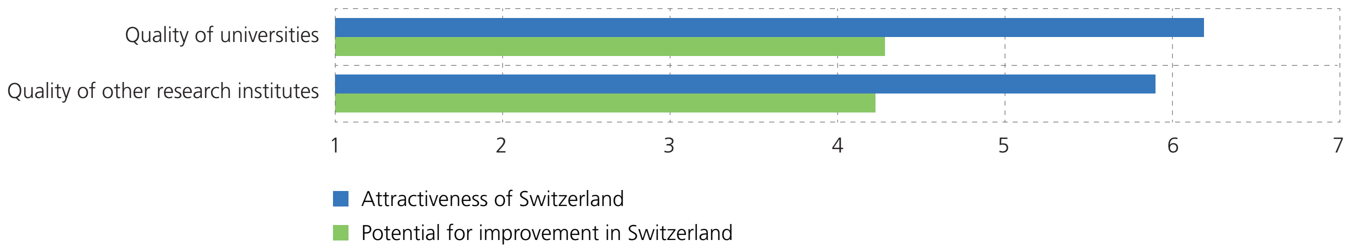
The average responses given reveal that access to qualified personnel is another key factor in Switzerland's appeal; however, this aspect is nonetheless deemed to have scope for improvement (Figure C 2.17). The interviews reveal that access to international specialists and top executives is particularly important for companies, as is Switzerland's long-term appeal to these people. Following the acceptance of the popular "Stop mass immigration" initiative" in February 2014, companies fear that access to specialists may deteriorate, compounding the already widespread phenomenon of a skills shortage (Kägi et al., 2014). It is therefore very important for Switzerland to ensure access to foreign specialists going forward and to increase investment in education in Switzer-

Figure C 2.17: Attractiveness and improvement potential of Switzerland in regard to the availability of qualified personnel



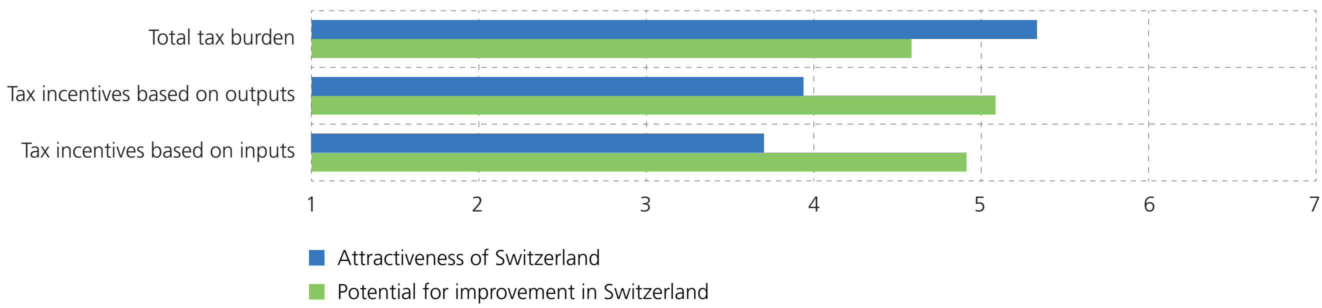
Likert scale from 1: very unattractive to 7: very attractive or from 1: improvement is unimportant to 7: improvement is very important
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=48)

Figure C 2.18: Attractiveness and improvement potential of Switzerland in regard to the quality of universities and other research institutes



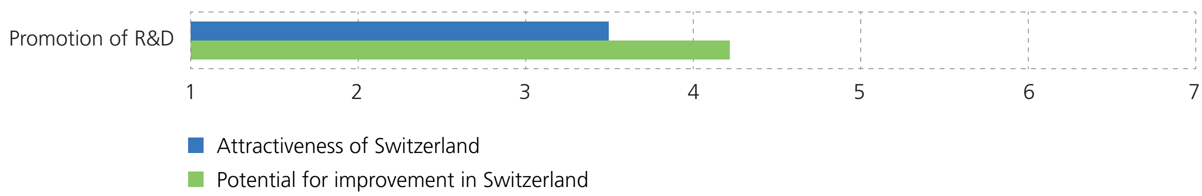
Likert scale from 1: very unattractive to 7: very attractive or from 1: improvement is unimportant to 7: improvement is very important
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=48)

Figure C 2.19: Attractiveness and improvement potential of Switzerland in regard to tax and financial incentives



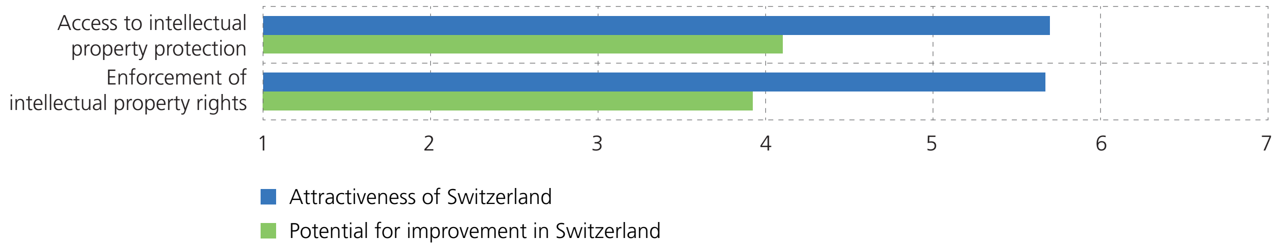
Likert scale from 1: very unattractive to 7: very attractive or from 1: improvement is unimportant to 7: improvement is very important
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=48)

Figure C 2.20: Attractiveness and improvement potential of Switzerland in regard to the promotion of R&D



Likert scale from 1: very unattractive to 7: very attractive or from 1: improvement is unimportant to 7: improvement is very important
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=48)

Figure C 2.21 Attractiveness and improvement potential of Switzerland in regard to intellectual property rights



Likert scale from 1: very unattractive to 7: very attractive or from 1: improvement is unimportant to 7: improvement is very important
Source: Survey by the University of St. Gallen (ITEM-HSG) (n=48)

land. The competition for the best talents in the world will be won if Switzerland continues to attract and retain research and innovation from abroad. Would Google have come to Zurich had the popular "Stop mass immigration" initiative already been adopted when it made that decision? Research and innovation thrives on openness, particularly when – as is the case at multinationals – that research and innovation is mobile.

(2) Quality of universities and research institutes

The quality of universities, research institutes and other scientific infrastructure can be influenced by public-sector promotion of research and innovation and by more efficient management of public research institutes (Dunning & Lundan, 2009; Guimón, 2011). Overall, both the quality of the universities and the quality of research institutes was rated as very good by multinationals, as is evident from the high average scores for the responses to the question about Switzerland's appeal in regard to these criteria (Figure C 2.18). These findings were confirmed in the interviews, during which the high quality of ETH Zurich and EPFL in particular were cited as location factors that are especially important for research and innovation (see Section 2.3.5). The potential for improvement in regard to the quality of universities and other research institutes was assessed as moderate, as revealed by the average scores given by the multinationals (Figure C 2.18). The growing autonomy of the universities, one example being the increased autonomy of the University of St. Gallen in 2015, is also seen as a good sign.

(3) Tax and financial incentives for research and innovation

Overall, multinational enterprises take a favourable view of the total tax burden in Switzerland. However, the country fares much worse for tax incentives based on inputs, one example being the multiple deductibility of research and innovation expenditures from profits tax (Linder, 2014), and outputs such as licence boxes (KPMG et al., 2011). Multinationals rate the potential to improve these aspects as medium to high (Figure C 2.19). However, it should be borne in mind here that Switzerland's tax environment is currently in the throes of major upheaval, with the introduction of the corporate tax reform (CTR III).

Compared with other countries, Switzerland has significantly fewer direct grants and tax schemes than other countries. In 27 of the 34 OECD countries and a number of non-OECD countries, expenditures on research and innovation are currently eligible for direct tax breaks (OECD, 2013). Although tax incentives are not a key criterion when choosing a research and innovation location, they could strength the innovation system (Lokshin & Mohnen, 2013). The heavy cost burden would be lessened by lower taxes, which are likely to be particularly attractive to multinational holding companies. Once a multinational has relocated a holding company to Switzerland, it becomes easier for it to also establish its research and innovation activities there.

(4) Promotion of collaborations between actors in the national innovation system

Targeted promotion of collaborations between various actors is a means of strengthening the national innovation system; the availability of and involvement in collaborations between industry and the scientific community may discourage innovative firms from seeking additional knowledge sources abroad (Schmiele, 2012).

In the survey conducted as part of this study, multinational enterprises rate the promotion of R&D as the least attractive of all the points surveyed (Figure C 2.20). The companies interviewed also feel government support, either from SNSF and the CTI or from the EU, plays an important role when choosing Switzerland as a location.

(5) Presence of pilot markets for key technologies

Pilot markets are an increasingly important consideration when choosing a location for research and innovation activities (von Zedtwitz & Gassmann, 2002). Although governments are able to use public procurement procedures to create incentives for this (Guimón, 2011), these strategies are chiefly employed by catch-up economies (e.g. South Korea). The risk of competition-distorting subsidies is high. Moreover, the size of the economy and the respective domestic market have a bearing on the feasibility of such strategies.

(6) Intellectual property rights

Strong intellectual property rights and good enforceability of the protection they afford are cited in the literature as important factors to consider when choosing a location for research and innovation activities, which can be politically influenced (Guimón, 2011). Switzerland is well-placed in this respect, with both access to protection and the enforcement of intellectual property rights being rated as good (Figure C 2.21). The interviews reveal that none of the firms questioned feel that Switzerland's lack of novelty and inventive step checks for patents puts it at a disadvantage compared with other countries.

According to Guimón (2011), in order to promote foreign direct investment in research and innovation, politicians should improve the visibility of the described advantages for investing companies and offer support to facilitate foreign investment in local research and innovation activities. Furthermore, politicians could contribute to the renewal or expansion of existing research and innovation activities by offering follow-up services. Some examples of such services would be support for the establishment of research and innovation collaborations, support with the recruitment of new talents and specialists or assistance with applying for state subsidy programmes (Guimón, 2011; UNCTAD, 2007).

2.5 Summary and conclusion

The internationalisation of value-adding activities is a widespread trend among multinational enterprises which, nowadays, is no longer confined to distribution and production activities but also extends to research and innovation. As well as being attractive from a business perspective, this internationalisation of research and innovation activities also benefits the countries in which multinationals establish their research and innovation. In order to profit from the internationalisation of research and innovation, it is very important for national economies to offer a research and innovation location that will attract multinational enterprises. Multinational companies play a key role in Switzerland in the national research and innovation system and in networking the parties with respect to the diffusion, generation and exploitation of knowledge. Switzerland benefits from the research and innovation activities of multinationals in various ways, including the significant contribution of multinationals to its value added, the greater competitiveness of local companies, the creation of well-paid jobs in Switzerland, the high-quality training offered for new talents, the consolidation of the higher education domain through collaborations in research and teaching and the network of Swiss actors in the research and innovation system at home and abroad. Multinationals thus act as a catalyst in Switzerland's complex research and innovation system.

Observing and exploiting local research and innovation potential are by far the most potent reasons for multinationals to undertake research and innovation activities in Switzerland and are greatly influenced by, firstly, the very good access to highly-qualified specialists and, secondly, proximity to leading research, particularly with ETH Zurich and EPFL or within their environment. Proximity to the market and customers and support for local production are of medium importance overall, whilst political factors are of relatively minor importance overall. However, it is evident that tax advantages (one of the motives for this category) are a major incentive for multinationals when choosing a particular country for their research and innovation activities.

Access to qualified specialists remains one of the biggest challenges faced by multinational enterprises. Following the adoption of the popular "Stop mass immigration" initiative in February 2014, multinationals believe access to foreign specialists and top executives is jeopardised and fear that they may no longer be able to satisfy their research and innovation personnel requirements in the future. It is therefore particularly important for multinationals that the initiative is implemented in a way that does not restrict access to vital specialists.

In summary, it can be said that, although the general environment for research and innovation activities by multinational enterprises in Switzerland remains good, with increasingly tough international competition, international openness and robust promotion of research and innovation are very important.

2.6 Methods

To obtain a full picture of the various actors in the Swiss research and innovation system, a mixed method approach was used for the study, consisting of a qualitative and a quantitative investigation.

The qualitative investigation was based on semi-structured expert interviews. Companies and institutions from various sectors that are heavily involved in R&D were selected; a total of 20 interviews were conducted with (a) six large multinational enterprises from Switzerland; (b) four foreign large multinational enterprises engaged in research and innovation in Switzerland; (c) seven Swiss universities (universities, ETH, universities of applied sciences); and (d) three locally/regionally active Swiss SMEs.

To ensure the representative nature of these interviews, firms heavily involved in research were deliberately chosen. The six Swiss multinationals interviewed are among the top 20 Swiss companies based on patent applications in the period 2006–2011; collectively, these six companies were responsible for more than 40% of patent applications in Switzerland over that period (Figure C 2.12; Müller, 2012). The four foreign multinationals interviewed engage in substantial research and innovation activities in Switzerland and are all among the top 100 companies in the world based on R&D expenditures (Hernández et al., 2014) as well as the top 100 patent applicants at the European Patent Office (2014; EPO, 2015) or the USPTO (2012; IFI CLAIMS® Patent Services, 2013). The seven Swiss universities were selected based on their relevance to the Swiss research and innovation system, while also ensuring their geographical spread. When selecting the SMEs, the focus was placed on R&D-intensive firms.

The results of the quantitative survey conducted in parallel were used for the statistical analysis of the qualitative findings obtained for individual elements. Two groups of companies were formed for the quantitative investigation: The first group, comprising 108 large multinational enterprises, was personally contacted and 36 (33%) completed the survey. Of those 36 companies, ten are among the top 20 patent applicants in Switzerland (Figure C 2.12; Müller, 2012) and another five are among the top 100 patent applicants at the EPO (EPO, 2015). All the companies are among the top 2,500 companies in the world based on R&D expenditures (Hernández et al., 2014) or are of comparable stature, if they do not publish precise figures on their R&D expenditures and therefore do not appear on the aforementioned list. The second group, comprising 255 companies with activities in Switzerland, was contacted anonymously. Of this group, 18 companies (7%) completed the survey. 13 of these companies could be identified, employ at least 50 people in research and innovation in Switzerland and are among the top 2,500 companies in the world based on R&D expenditures (Hernández et al., 2014) or are of comparable relevance, if they do not publish precise figures on their R&D expenditures. In light of this, the comparatively small sample size is not a negative factor, as the sample represents companies that are responsible for a substantial share of research and innovation in Switzerland. The questions that form the basis for the online survey are listed in the appendix to the full version of this study. The responses on the questionnaires were elicited as absolute values, percentage values or a selection from a Likert scale (1–7). In the presentation of the results, the number of usable responses from the sample is indicated each time as n.

The online survey was not sent to SMEs. For these, reference was made to the survey results of Study 1 "Research and innovation activities of small and medium-sized enterprises in Switzerland" (Part C). A number of questions were added by the authors of this study. As there are not enough universities in Switzerland to permit quantitative investigations, these are only taken into account in the qualitative interviews. The relevant industry associations were largely responsible for making the necessary contacts and sending out the survey.

The European Space Agency (ESA), of which Switzerland is a founder member, is – as part of its Rosetta mission – investigating the history of our solar system by examining a comet, one of the most ancient forms of celestial bodies that is closest to the origin. The question the mission is attempting to answer is whether comets brought pre-biotic molecules and water to Earth and if they could therefore have played a role in giving birth to life. This mission is one of the most interesting and most demanding in European space research. Swiss researchers and industry representatives have made major contributions to Rosetta. Photo: ESA

PART C: STUDY 3

Supply and demand in public innovation promotion

Review and survey of firms nominated for innovation prizes

The following text is an abridged version of a study conducted by Prof. Frédéric Varone (University of Geneva), Prof. Andreas Balthasar (Interface, University of Lucerne), Milena Iselin and Chantal Strotz (Interface). This summary has been approved by the various groups that have supported the elaboration process. The full version of the study was published in the SERI publication series (www.sbfi.admin.ch).

Contents

3 Supply and demand in public innovation promotion

Review and survey of companies nominated for innovation prizes

3.1 Background and objective

The public promotion of research and innovation is, in the main, the responsibility of the Confederation (Part A), but the cantons and regions have also launched activities to promote innovative firms as part of their business and economic development programmes (Hess & Klöpper, 2011). Most of the cantons have laws governing economic development that provide for activities for promoting innovation. Some, like the Canton of Bern, are currently developing their own laws for the promotion of innovation, which should afford them the opportunity to support new companies, regional networks or cluster organisations and to sustain specific measures to promote innovation. Other promotional activities have been developed in recent years to respond to regional economic situations and particular interests. Moreover, municipalities are often responsible for settling innovative firms within their bounds and for establishing technology and innovation parks. As a result of this variety of accountabilities, the promotion of innovation takes place today at all political levels in federalist Switzerland. This complexity raises questions in particular about coordination and coherence as well as the duplication of activities by public authorities. It is therefore unsurprising that in its territorial review of Switzerland in 2011, the OECD made critical remarks about the number of mostly uncoordinated providers of innovation promotion and the lack of clear demarcation between them (OECD, 2011a).

This study will take up this problem. In the first section, we will try to document the providers of services for promoting innovation. In the process, innovation promotion is understood in a very broad sense, and includes all economic development measures that serve to support companies in their innovation processes (Klodt, 2010). We pursue the following key questions:

- Who are the cantonal, regional and national providers of activities to promote innovation?
- Are there cantonal or regional differences in the provision of innovation promotion?
- Can a connection be found between the number of innovation promotion providers in a canton and key economic policy figures, such as the number of new companies established or the economic strength of a canton?

The second section of the study is devoted to the demand for the public promotion of innovation, with a focus on the needs of especially innovative firms. For this purpose, companies nominated for one of the important Swiss innovation prizes were surveyed, and the following key questions were considered:

- Which firms apply for innovation prizes?
- To what degree do these innovative firms in Switzerland take advantage of cantonal, regional, national and international innovation promotion?
- How do these innovative firms assess public providers of promotional instruments?

The supply of and demand for the public promotion of innovation is then analysed. On this basis, and based also on the discussion at an expert workshop in April 2015 with specialists from the cantonal, regional and national levels of Swiss innovation policy, the results are presented in a final section and gaps in the research are uncovered.

3.2 Supply: Providers of innovation promotion in the cantons, regions and Confederation

In the past, numerous studies have dealt with Swiss innovation policy. These studies refer frequently to the variety of cantonal, regional and national activities to promote innovation (Hotz-Hart & Kissling-Näf, 2013; Leresche, 2014; OECD, 2011b). A non-exhaustive list of providers of innovation promotion in the cantons, regions and Confederation was produced as a foundation for the survey carried out as part of this study, and that list will be presented in summarised form below.[1]

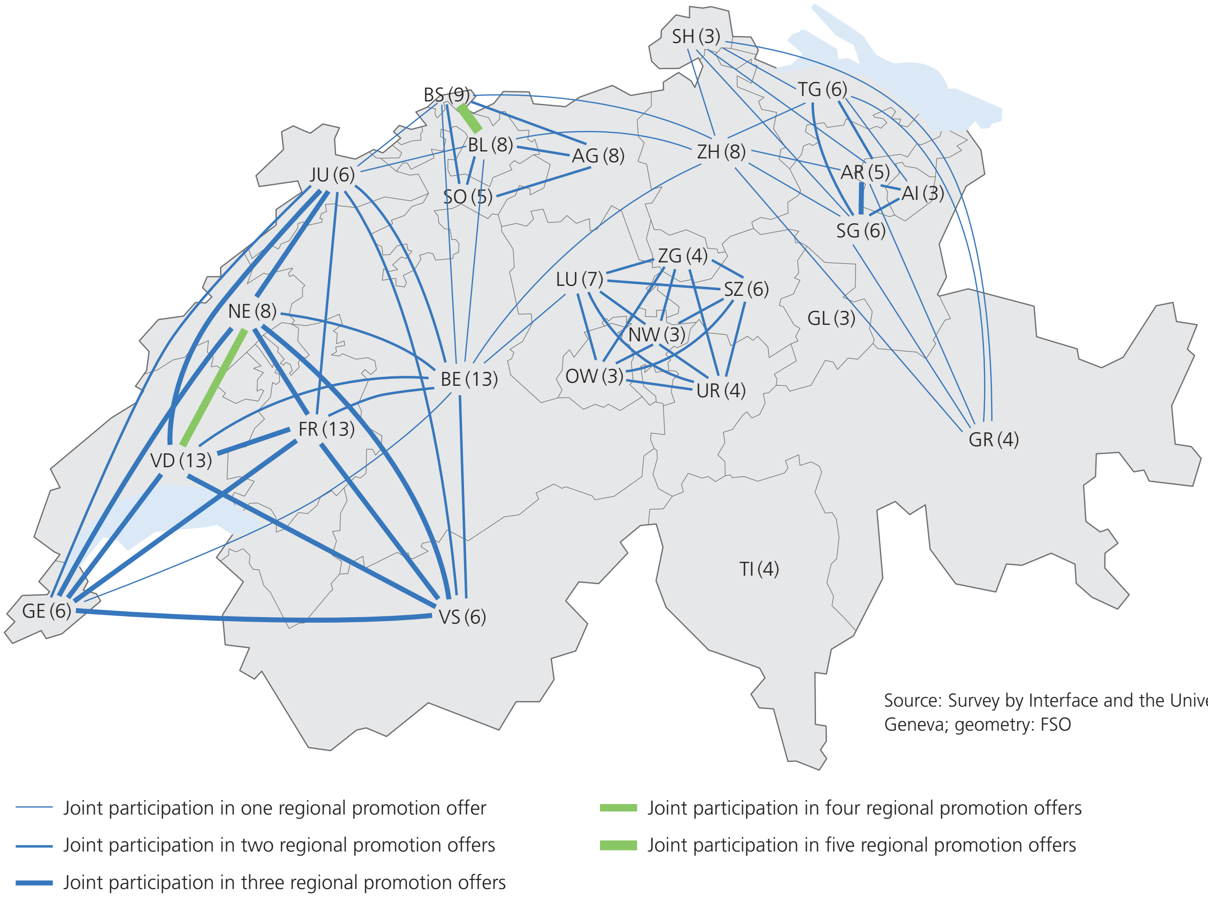
3.2.1 Overview of providers of public innovation promotion

A total of 93 cantonal, 14 regional and 19 national providers of services to promote innovation were identified. There are substantial cantonal and regional differences between the providers as well as in intercantonal cooperation in innovation promotion. Figure C 3.1 illustrates the number of providers in each canton and shows how the cantons cooperate with one another within the scope of regional promotional activities.[2] The individual number of providers in a canton comes from the number of cantonal providers we identified as well as from the number of participations in regional promotional activities. The number of intercantonal promotional activities represents the connections between the cantons: the stronger the connections, the more frequently do two cantons participate in joint promotional activities.

[1] A more extensive list of providers is contained in the long version of this study. Moreover, the Swiss Science and Innovation Council (SSIC) published an inventory of Swiss innovation policy in December 2015 after this study was concluded (Good, 2015).

[2] Figure C 3.1 shows 12 of the total of 14 regional providers, allocated to individual cantons. These are the providers who were assessed as part of the survey of companies nominated for innovation prizes. The following three providers of regional innovation promotion were also added: InnoVarc, Swiss Design Transfer and platinn (Innovation Platform of Western Switzerland). However, they were not assessed by the firms that responded to the survey.

Figure C 3.1: Innovation promotion in the cantons and regions



Source: Survey by Interface and the University of Geneva; geometry: FSO

Methodical approach and limitations

The survey of the providers of public innovation promotion took place via Internet research during November and December 2014. Several sources were consulted: the official websites of the cantons, the "regiosuisse" network unit for regional development, the Confederation's SME portal, the website of the Association of Swiss Technology Parks and Business Incubators and the "Ansiedlung Schweiz" website.[3] Using these sources, the snowball principle was applied to find further providers. Finally, the list was submitted to the project support group and amended with additional information supplied by the group.

It is clear that a list of providers of innovation promotion put together as described here cannot make any claim to completeness. For example, cluster organisations and the relationships between providers within a canton were not considered. This affects large cantons in particular, which have providers of public innovation promotion in the various regions that cooperate with one another. When interpreting the results, it should also be noted that the pool of data (number of providers) does not allow for statements about the intensity or quality of innovation promotion in an individual canton. In spite of these provisos, we find the review exhaustive enough to permit some conclusions about the supply of public activities to promote innovation.

[3] See http://www.regiosuisse.ch/; http://www.kmu.admin.ch/; http://www.swissparks.ch/; http://www.ansiedlung-schweiz.ch/standortpromotion/wirtschaftsfoerderung-der-kantone/

The figure makes it clear that the western Swiss cantons in particular have many providers. Moreover, analyses of the regional cooperations enabled the identification of four regional focal points: "Western Switzerland", "Central Switzerland", Northwestern Switzerland" and "Eastern Switzerland". If the number of providers in a canton (under consideration of the size of the working population) is correlated to important economic indicators,[4] the connections are interesting: cantons that are not very competitive and show a low rate of new business creation[5] have disproportionately high numbers of providers in comparison with the other cantons.

3.2.2 Types of innovation promotion instruments

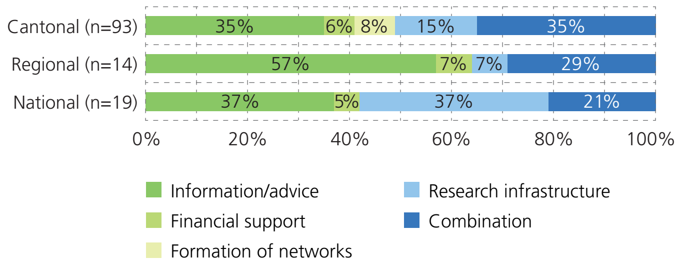
Providers of public innovation promotion can supply a variety of instruments for promotion. The study assigns each provider to one of five types corresponding to the instruments it offers: information and consulting, the formation of networks, research infrastructure, financial support or a combination of several instruments. The categorisation of cantonal, regional and national providers to the five types is shown in Figure C 3.2.

Within the scope of promotional activities at the cantonal and regional levels, the cantons invest above all in information and consulting (Type 1) and in a combination of promotional activities (Type 5). The Confederation concentrates on financial support in particular (Type 4) in addition to providing information and consulting. Investments in the formation of networks (Type 2) and the research infrastructure (Type 3) are comparatively low at the national, cantonal and regional levels. However, close scrutiny of the offers makes it clear that research infrastructures and the formation of networks each appear frequently in combination with information and consulting. Financial support is often combined with information and consulting, and research infrastructures are often combined with financial support and information and consulting.

3.2.3 Comments on the available financial resources of the cantons and Confederation

The Confederation's expenditure on innovation promotion is widely known, but there is no reliable, publicly available information on the corresponding expenditure by the cantons. Attempts to find information on the cantons' available financial resources were unsuccessful: the approach of identifying this expenditure via the cantonal budgets failed as a result of the insufficient transparency and comparability of the information. Against this backdrop and on the basis of the data, it is not possible to provide reliable information about the financial resources invested by the Confederation, the cantons and the municipalities in innovation promotion.

Figure C 3.2: Types of instruments in cantons, regions and the Confederation



Source: Survey by Interface and the University of Geneva

We can assume that in certain cantons transparent information on expenditure for innovation promotion definitely exists, but this information is not always publicly available. A further problem is that there is no recognised framework for defining which spending is earmarked for innovation promotion. Without such a framework, the data have no basis for comparability, even if the figures were known.

3.3 Demand: The role of public innovation promotion for innovative firms

In this study, the list of those who seek such services focuses especially on innovative firms, defined as those that were nominated for an innovation prize.

The representative character of the sample of nominated companies can be examined using a comparison with data from the KOF innovation survey (Arvanitis et al., 2013). This comparison shows that the individual cantons (firm domicile), sectors,[6] age groups[7] and firms sizes[8] are well represented by the responding companies.

3.3.1 Contact with providers of public innovation promotion

The survey inquired whether companies had contact with providers of public innovation promotion, and if so, with whom. This question differentiated between providers at the international, national, and cantonal/regional levels. All of the providers identified as part of the supply analysis were listed individually.

On the whole, 53 (65%) of the 82 respondents stated that they had contact with providers of public innovation promotion. 29 firms (35%) had no contact whatsoever. Starting with the

[4] The UBS Cantonal Competitiveness Indicator was used as an indicator of competitiveness (Hafner et al., 2014), but 2012 statistics on newly founded businesses (by canton) from the Swiss Federal Statistical Office were also used as an indicator of the number of new companies established.

[5] Low level of competitiveness: (r = –0.362). Low rate of new business creation: (r = –0.561).

[6] Categories: high-tech industries, low-tech industries, construction, modern services, traditional services.

[7] Categories: 0–5 years, 6–10 years, 11–20 years, 21–50 years, 51–90 years, 91 years and more.

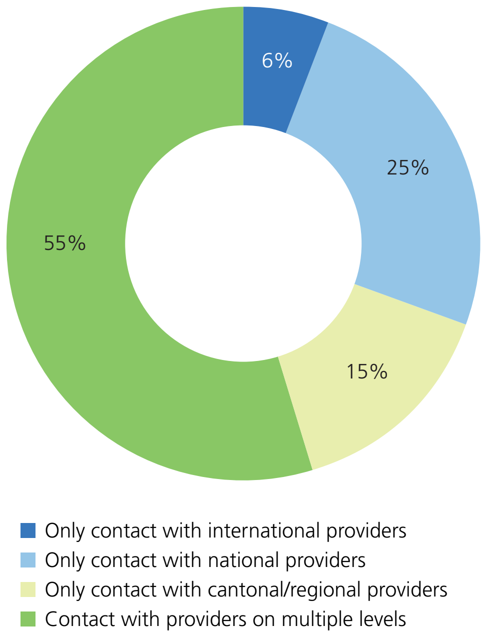
[8] Categories: fewer than 10 employees, 10 to 49 employees, 50 to 249 employees, 250 and more employees.

Methodical approach and limitations

Demand for public innovation promotion on the part of especially innovative firms was surveyed using a questionnaire sent to companies nominated between 2010 and 2014 for the Swiss Economic Forum's Swiss Economic Award or Swiss Technology Award, the Swiss Venture Club's Prix SVC, or IDEE Suisse's Swiss Innovation Prize. Spot comparisons with the results of other innovation surveys enabled additional insights (Arvanitis & Wörter, 2013; Arvanitis et al., 2013; Waser & Hanisch, 2014; Part C: Study 1). A total of 317 firms were contacted in January and February 2015. The utilisable return rate was 26% (which corresponds to 82 firms).

The study's limitations lie in the fairly modest number of firms that took part in the survey. In addition, when interpreting the results it must be borne in mind that firm needs can vary widely, and that this has an effect on estimates of the benefits of promotional activities, among other things.

Figure C 3.3: Contact with providers of public innovation promotion (n = 53)



Source: Survey by Interface and the University of Geneva

53 firms that had contact, we will illustrate the level at which these contacts took place. Figure C 3.3 shows the contacts by level of public promotion. It is apparent that 29 of the respondents (55%) had contacts with providers of public innovation promotion on multiple levels. Three-quarters had contact with providers on two levels, and one-quarter had contact with providers on three levels. Contacts with national and cantonal/regional providers were most frequently combined. Only 3 companies (6%) had contact exclusively with international providers, 13 (25%) had contact exclusively with national providers, and 8 (15%) had contact exclusively with cantonal/regional providers.

It is interesting to take the analysis further and find out more about the providers mentioned in the various categories:

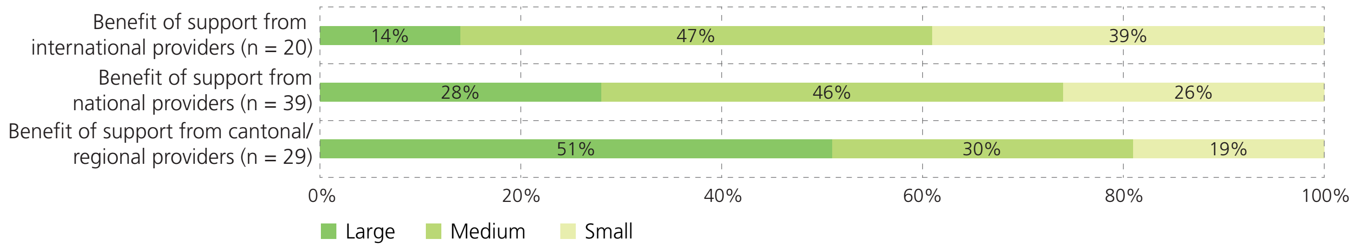
- At the international level, a total of 20 companies (38%) stated that they had had contact with providers of innovation promotion services; of these firms, 19 (95%) had contact with EU Research Framework Programmes and 6 (30%) with EUREKA/Eurostars. The other providers at the international level were contacted less frequently.[9]
- Across all contacts, a majority of the respondents – 39 (74%) – had contact with national providers of innovation promotion services. The respondents most frequently mentioned the Commission for Technology and Innovation CTI (34 companies or 87%), followed by the Swiss Federal Institute of Intellectual Property (IPI) (14 or 36%) and the transfer office of the ETH Zurich (10 or 26%). Other providers at the national level were contacted less frequently.[10]
- Of the respondents, 29 firms (55%) stated that they had had contact with cantonal/regional providers; these contacts were distributed among providers from 15 cantons. 24 companies (83%) only had contact with providers from one canton, and in individual cases, there were contacts with providers from two, three or even five cantons. The greatest number of contacts took place with providers in the Cantons of Bern (7 firms), Zurich and Valais (5 firms each) as well as Geneva and Vaud (4 firms each). The most frequent contact was with platinn, the joint innovation promotion initiative of the western Swiss cantons (7 firms) and its cantonal antenna CimArk (5 firms); the Bern Economic Development Agency (6 firms); and the Economic Development Office of the Canton of Geneva, the Ark Foundation, and GENILEM (4 firms each).

The analysis allows to conclude that firms in western Switzerland have more frequent contact with many and varying providers of public innovation promotion than do firms in German-speaking Switzerland.

[9] Other international providers named in the survey were COST, Active and Assisted Living (AAL), Young Enterprise Switzerland and Enterprise Europe Network (EEN).

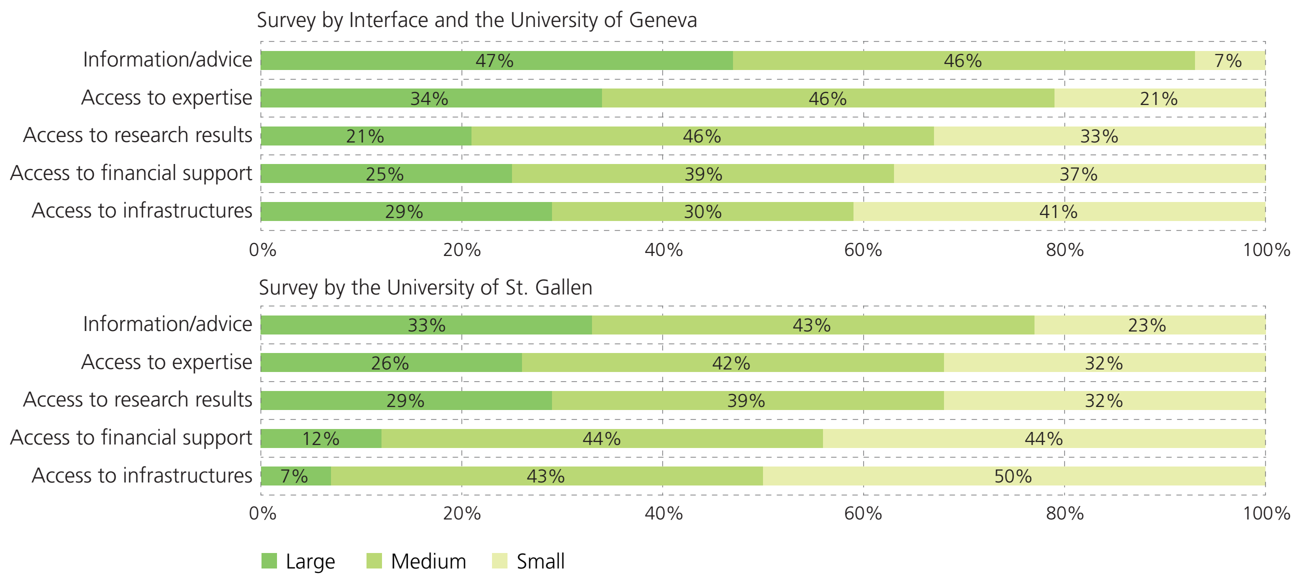
[10] Other national providers named by the respondents include the Technology Transfer Office TTO of the EPFL, the Swiss National Science Foundation (SNSF), the SFOE pilot, demonstration and flagship programme and FOEN environmental technology promotion.

Figure C 3.4: Overall benefit of the support of international, national and cantonal/regional providers of innovation promotion



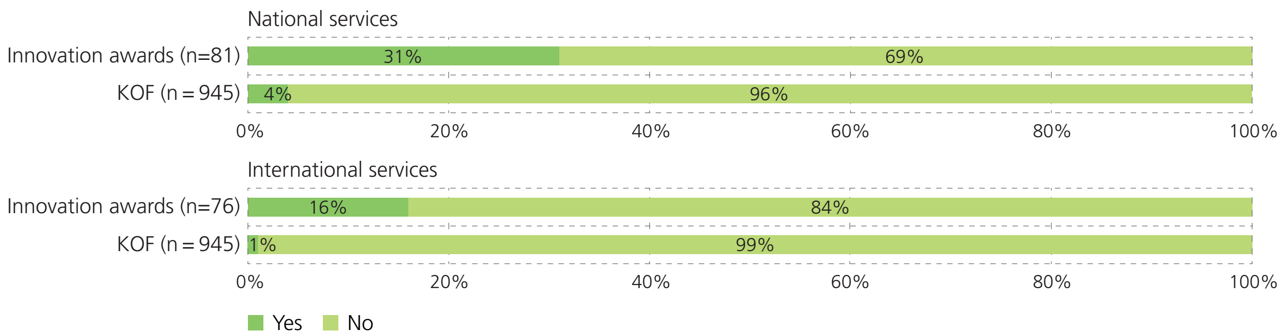
Source: Survey by Interface and the University of Geneva

Figure C 3.5: Overall benefit of the different support services[11]



Source: Survey by Interface and the University of Geneva; survey by the University of St. Gallen (Part C: Study 1)

Figure C 3.6: Use of public promotion 2010–2014



Source: Survey by Interface and the University of Geneva; survey by KOF (Arvanitis et al., 2013)

[11] The firms who responded in the survey and who participated in promotion offers at the three levels – cantonal/regional, national and international – indicated their appreciation of the usefulness of individual support provided. In order to determine overall usefulness these appreciations were first aggregated. The average for the three levels was then calculated for each type of service.

3.3.2 Type and benefits of contact

The survey participants were requested to name the support services they received through their contact with international, national and cantonal/regional providers of innovation promotion and the benefits they derived from these services.[12]

Figure C 3.4 presents the perceived overall benefit of the support of international, national and cantonal/regional providers. It shows that respondents particularly value their contact with cantonal and regional providers: 51% stated that these providers were of great benefit to them. Contact with national and international providers was estimated to be less beneficial.

These results must be viewed with caution, as companies have widely varying needs and expectations of the benefits of innovation promotion. It is likely to be true of the majority that cantonal and regional providers are particularly important. But if a firm has specific needs, it requires a specific provider of innovation promotion services.

In addition to considering the overall benefit at all three levels, we can consider the overall benefit with respect to the different support services. Data from the survey of firms nominated for an innovation prize can be compared with a survey conducted by the University of St. Gallen as part of Study 1 (Part C). An estimate of the overall benefit of the different support services can be seen in Figure C 3.5.[13]

The figure illustrates that the respondents generally estimated the benefit of the "soft" services to be high: 47% assessed the benefit they derive from information and consulting contacts as high, and another 46% rated it as medium. Information and consulting is clearly the service whose benefit is considered the most valuable. This conclusion was also reached by the University of St. Gallen survey conducted as part of Study 1 (Part C). In second place are services in connection with access to expertise, including human resources for projects and dissertations: their benefit was assessed by 34% of the respondents as high. Those surveyed by the University of St. Gallen responded more reservedly. The surveys also made it clear that companies were most reserved in their assessment of the benefit of services that provide access to financial support and infrastructures.

3.3.3 Use of public sector funding

Participants in the survey of innovation prize nominees were also asked whether they had taken advantage of public sector funding at the national and international levels for their innovation projects during the period 2010 to 2014. Since this question was posed the same way in the KOF innovation survey, a comparison is possible (Arvanitis et al., 2013). Answers from the survey of companies nominated for innovation prizes and the innovative firms surveyed by the KOF are shown in Figure C 3.6.

A total of 31% of the respondents took advantage of funding through national services (such as CTI). Funding through international services (such as the EU programmes) was used by 16%. These shares were significantly lower in the KOF innovation survey. This comparison makes it clear that companies nominated for an innovation prize in particular take more frequent advantage of public sector funding than other innovative firms. This is possibly because nominees for innovation prizes represent a group of especially innovative firms that can profit more frequently from public sector funding.[14]

3.4 Attitudes toward public innovation promotion

The survey also offers insights into the attitudes of the surveyed innovation prize nominees toward public innovation promotion: they were asked for their agreement or disagreement with a series of statements about public innovation promotion. Figure C 3.7 shows the results. In addition, the survey differentiated between those who had taken advantage of public funding and those who had not.

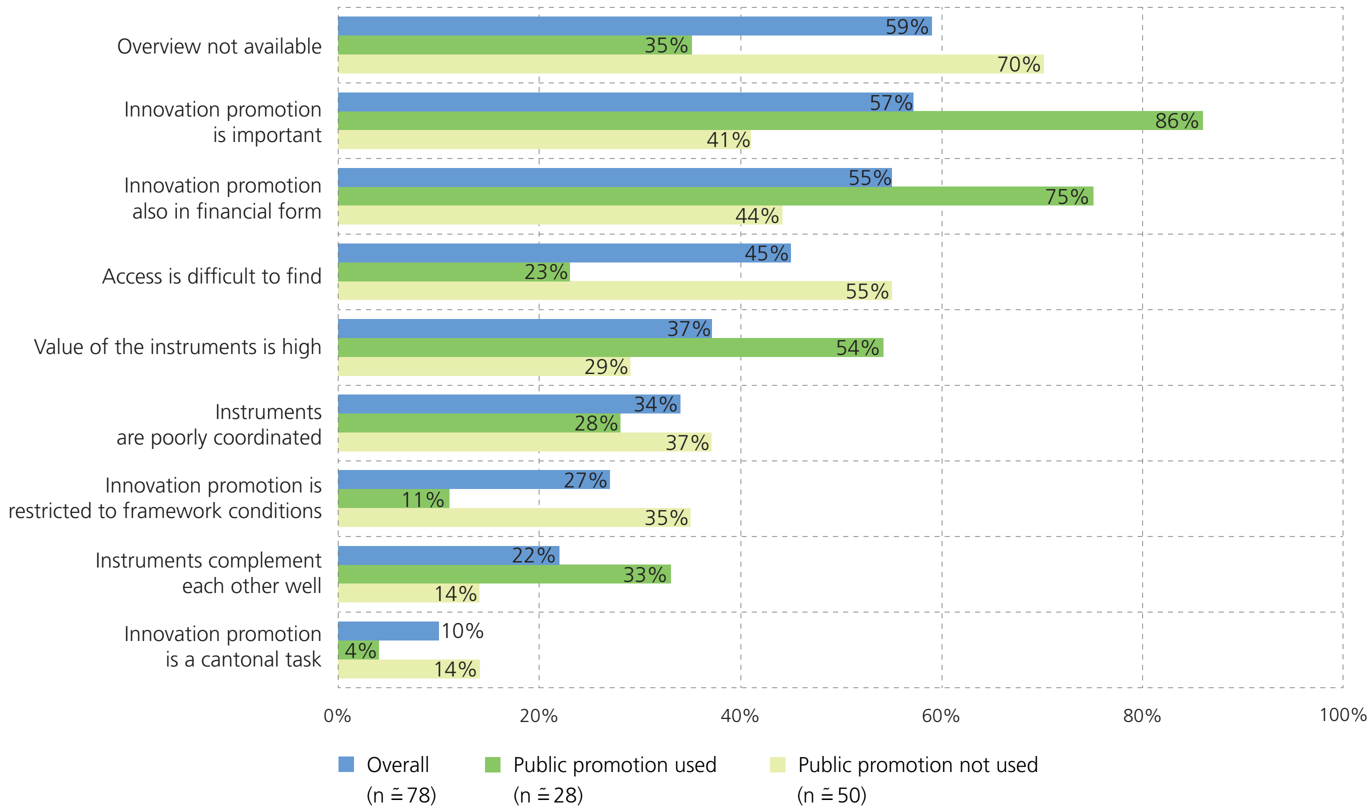
In the main, four insights can be derived from the figure:
- A majority of the respondents places great value on the importance of public innovation promotion: 57% of firms believe it to be important that public innovation promotion exists. Respondents who have taken advantage of public funding see its importance as twice as great as companies that have not made use of such funding
- In general, the survey participants rate the benefit of public providers as rather low: only 37% of companies saw the benefits as high. However, if the results are considered from the perspective of whether a respondent received public funding or not, a different picture emerges: more than half the (54%) respondents who have taken advantage of public promotion assessed the benefits as great.
- A little over half (59%) of firms voiced the criticism that there is no overview of the public innovation promotion of the Confederation, cantons and regions. 45% complained that it is difficult to find access to the right providers. The nominated companies who made no use of promotion each voiced greater dissatisfaction than those who took advantage of it: 70% of companies said there was no overview, and 55% stated that it is difficult to find access to the right providers.

[12] The services they were asked to assess were information/consulting, access to expertise, access to research results, access to financial support and access to infrastructures.

[13] Of the 1129 SMEs approached, 154 responded to the survey.

[14] The survey also contained questions that differentiate firms according to size and linguistic region, but owing to the low rate of response, these aspects will not be dealt with here.

Figure C 3.7: Attitude of respondents toward public innovation promotion (share of firms that agreed with the statement)



Information in parentheses (n) can vary slightly owing to questions left unanswered by individual firms.
Source: Survey by Interface and the University of Geneva

- Only 22% of the respondents agreed with the statement that the promotion offered by the Confederation offer complements that offered by the cantons and regions. Firms that made no use of promotion at all are even more critical: only 14% of firms agreed with this statement.

3.5 Conclusion

Public promotion of innovation takes place in federalist Switzerland today at all political levels. This raises questions about coordination and coherence as well as the duplication of activities by public authorities. This study has taken up this problem.

The variety of accountabilities in federalist Switzerland means that both the Confederation and the cantons are active in matters of innovation policy. It is therefore unsurprising that in its territorial review of Switzerland in 2011, the OECD made critical remarks about the number of mostly uncoordinated providers of innovation promotion. Both providers of services for innovation promotion and companies nominated for innovation prizes (as – potential – users of these offers) share the OECD's assessment that there is duplication in Swiss innovation policy. An exhaustive overview of all providers of public innovation promotion and their offers was not available at the time this study was produced. In addition, there is no reliable list of the resources expended by the cantons on innovation promotion.

What is remarkable, however, is this study's conclusion that most providers of public innovation promotion do not regard this circumstance as problematic; rather, they see it as variety that encourages competition. In their view, there is no particular need for action to promote the transparency or clarity of innovation policy offers. Another point emphasised by the providers is that the promotion offers at the different levels – cantonal/regional, national and international – are perceived as complementary and highly functional.

However, the responding firms assess this situation somewhat differently: public innovation promotion is seen by a majority of respondents as important, but many companies lack an overview of providers and their services. In particular, firms that have never made use of support believe that such an overview is lacking. They also believe that it is difficult to find access to the right providers and that the offers of the Confederation and those of the cantons/regions do not complement each other optimally.

This study does not enable a conclusive answer to the question of whether it is necessary to improve the overview of providers of public innovation promotion; the empirical bases are too narrow to permit this. However, both the high number of providers recorded and the results of the survey both indicate a certain need for action with regard to an overview and the coordination of public innovation promotion in Switzerland.

The providers' assessments are based on the opinions expressed at a workshop involving representatives of key institutions. Around 320 firms were surveyed that had been nominated for a major Swiss innovation prize between 2010 and 2014. A systematic survey of all providers of innovation promotion would be required to reliably clarify the question of a need for action, and in contrast to this study, private providers would need to be included since they take on important tasks with individual topics (such as venture capital). In the process, the cooperation strategies and activities, networking among the players and the complementarity of the offers for the benefit of business would have to be documented individually. Companies' different expectations must also be considered. In addition to industries, firm size and linguistic region, the "lifecycle phases" of companies should be included. Only this kind of analysis would permit a reliable conclusion about how well the coordination of activities and cooperation among the providers really works, and whether there is an effective need for action.

PART C: STUDY 4

Universities of applied sciences in the Swiss research and innovation system

The following text is an abridged version of a study conducted by Prof. Benedetto Lepori (Università della Svizzera italiana) and Christoph Müller (socio5.ch). This summary has been approved by the various groups that have supported the elaboration process. The full version of the study was published in the SERI publication series (www.sbfi.admin.ch).

Contents

4 Universities of applied sciences in the Swiss research and innovation system

4.1 Introduction

The universities of applied sciences (UAS) were introduced at the end of the 1990s, in a far-reaching reform of Switzerland's education system. The establishment of UAS as the second form of university, alongside the existing universities and the federal institutes of technology, heralded the upgrading of tertiary vocational and professional education and training. This marked the arrival of a binary higher education system in Switzerland, similar to that found in many other European countries (Kyvik & Lepori, 2010; Lepori et al., 2013).[1]

With respect to the development of the Swiss research and innovation system,[2] the aims of the reform were essentially twofold (Federal Council, 1994): Firstly, to improve the education of qualified experts at tertiary level, based on the belief that secondary vocational and professional education was not meeting the needs of the increasingly science-oriented economy. Viewed in this light, the upgrading of the UAS was a continuation of the vocational baccalaureates introduced back in 1994. Secondly, the UAS were intended to support the research and innovation activities of small and medium-sized enterprises (SMEs). The UAS reform was thus also a concept for promoting economic innovation in the regions outside the larger cities.

The UAS rapidly expanded their activities, becoming an important partner in the Swiss research and innovation system. This is apparent from the growth in the number of students, the volume of applied research and development (aR&D) entrusted to them and, by extension, the resources they require. Today, the UAS account for more than half of Bachelor's students and around 10% of total aR&D expenditures in the higher education sector.[3] As is shown in Chapter 4.4, the aims of the reform have been largely achieved: the UAS help maintain a pool of qualified human capital, the transfer of research findings and regional development.

One of the cornerstones of the reform was to establish the UAS as "equal but different to universities", with a different mandate geared towards vocational and professional education and applied research. In fulfilment of this mandate, the UAS are intended to supplement the universities. Chapter 4.3 investigates the extent to which this was the case and the extent to which Swiss UAS have been able to escape the "academic drift" trend observed in the majority of European countries.

The development of the UAS is the result of political decisions and a dedicated policy by the federal government and the cantons to promote the development of higher education institutions with a specific profile.

This study was written at a time of far-reaching changes in the management of higher education in Switzerland (introduction of the HEdA in 2015). As is shown below and in section 4.3.4, these changes affect the UAS in a very particular way.

When the UAS were introduced, the management structures at federal level were very distinct from those for universities. The Universities of Applied Sciences Act (UASA) provided for relatively direct intervention by the state in the decisions and activities of the UAS and, as such, had a significant influence on their development, such as the accreditation requirement for the individual courses. Ultimately, the separate management structures resulted in markedly different profiles for the UAS compared with universities.

The enactment of the Higher Education Act (HEdA) in 2015 marks a turning point in the structure and management of higher education in Switzerland. Nowadays, the universities and UAS are part of a uniform system of higher education (albeit one with varying regulations). The HEdA stresses the importance and value of institutional autonomy and dictates that the state shall have only indirect control over the education provided at universities.

This new context does, however, give rise to some uncertainty regarding the future development of the UAS, their position in the Swiss research and innovation system and their relationships with universities. Chapter 4.5 discusses some of the major challenges that need to be addressed at the political level.

The creation of the UAS: an independent segment with its own rules

When the UAS were introduced with the Universities of Applied Sciences Act (UASA), in 1995, the principle was that they would be very distinct from the universities, with separate management and financing systems. The UAS were given an independent profile with a specific mandate and were to be managed as a separate system. Consequently, the UAS sector was designed from the outset to operate in parallel to the university segment. Similarly to

[1] For simplicity's sake, the term universities is used throughout to describe the cantonal universities and the federal institutes of technology. This is consistent with the customary usage of the term universities as a generic term for higher education institutions that have the right to award doctorates. The scope of application defined in the Higher Education Act (HEdA) includes cantonal universities, federal institutes of technology, universities of applied sciences and universities of teacher education. This study looks only at UAS. Teacher training is only included in the statistical data if it is provided at UAS (which is not the case in every canton). In addition to university education (Tertiary A), Switzerland's tertiary education system includes higher vocational and professional education (Tertiary B), which comprises courses at Colleges of Professional Education and Training (PET colleges) as well as the Federal PET Diplomas and the Advanced Federal PET diplomas (SCCRE, 2014). In the ISCED classification, this is equivalent to levels 5 to 8. Graduating from upper secondary level is a prerequisite for tertiary education.

[2] The definition of research and innovation and the research and innovation system is explained in the introduction to this report.

[3] Unless indicated otherwise, the statistical data were obtained from the Federal Statistical Office (FSO); www.bfs.admin.ch (December 2015).

other European countries, from the 1970s onwards Switzerland leaned towards a functional differentiation in higher education, with the creation of two separate segments which enjoy the same reputation but are required to fulfil different tasks. This distinction between UAS and universities is expressed in the principle of "equal, but different". This model differs markedly from the vertical differentiation model, in which tasks are allocated according to status. Under that model, prestigious universities devote themselves primarily to research while the less prestigious ones are dedicated chiefly to teaching (Bleiklie, 2003).

This distinction was consistently implemented at the political level. Thus the "applied research" mandate meant that the UAS should not strive purely for the acquisition of knowledge but should seek solutions to practical problems and create economic innovations. Furthermore, R&D at UAS was to take place in cooperation with private-sector partners and social institutions. The requirement to provide a professional education determined the structure of the courses, the teaching methods (with a high proportion of interactive education) and the stipulation that the majority of lecturers should have professional experience or a professional activity outside the UAS.

The mandate of the UAS has changed little over the last 20 years. Their professional orientation is generally seen as a strength of UAS courses. The scope of their educational mandate was broadened with the introduction of Master's programmes. In the sphere of R&D, efforts have been made to more precisely describe the research mandate of the UAS. Today, it is recognised that, rather than being entirely separate areas, basic and applied research are two extremes of a continuum, with possible intermediate and hybrid forms. Drawing on the concept of use-inspired basic research (Stokes, 1997) the research mandate in areas in which the latest knowledge does not offer solutions to practical problems was widened to basic research. This is particularly true of newly emerging fields of research and areas that lack a parallel research tradition at universities in Switzerland (KFH, 2005, 2013).

With the UASA, the 1995 UAS reform implemented a new management structure in parallel to the management of universities, with separate committees and regulations. At federal level, the Federal Office for Professional Education and Technology (OPET), which was part of the Federal Department of Economic Affairs (FDEA), was responsible for the UAS, whereas the Federal Department of Home Affairs (FDHA) was responsible for universities. The Swiss Conference of Cantonal Ministers of Education (EDK) was in charge of intercantonal coordination; the Rectors' Conference of the Swiss Universities of Applied Sciences (KFH) was established as a counterpart to the Rectors' Conference of the Swiss Universities (CRUS). As a specific financing body for UAS research, the promotion agency CTI was allocated additional funds to promote the development of R&D capacity (Mayer et al., 2006).

Being responsible for vocational and professional education, the federal government was able to establish binding regulations for all UAS, resulting in greater uniformity in the UAS segment than at the universities. Since 2004 there has been a joint planning process involving the federal government and the cantons, referred to as a Masterplan, which sets the strategic objectives for the development of the UAS, and this process will continue until the end of 2016. The Masterplan also enabled the development of the UAS to be coordinated with the available financial resources at federal and cantonal level. Finally, all UAS courses also had to be accredited by the federal government. This ensured that the state had direct control over the composition and scope of the educational programme, as well as proof that that it met an actual need. Since the HEdA came into effect, only institutional accreditation has been necessary, and UAS planning will now take place as part of the general university planning process (from 2017 onwards).

This policy was conducive to the emergence of a clear profile for UAS (Chapter 4.3) and influenced their contribution to the Swiss research and innovation system (Chapter 4.4). Moreover, it enabled the growth of the UAS segment to be properly managed. However, this policy has come under fire for granting the UAS too little autonomy and creating barriers to cooperation between universities and UAS.

4.2 The development of universities of applied sciences

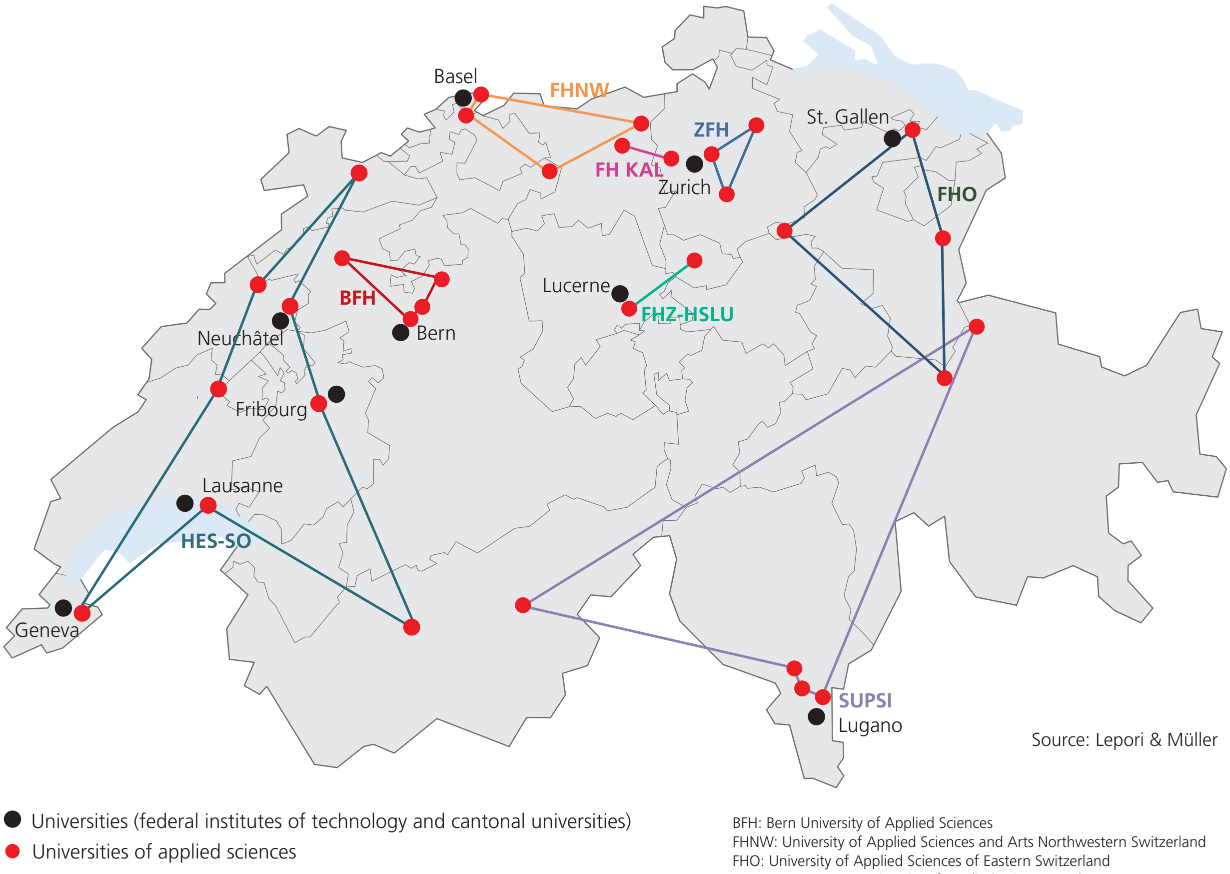
In the late 1990s, seven public UAS were founded, according to geographical criteria. To this end, Switzerland was divided into UAS regions (Figure C 4.1). The UAS emerged largely from the amalgamation or upgrading of predecessor establishments, such as the higher vocational colleges, some of which already undertook applied research activities.

Although the individual UAS were run by individual cantons, cantonal conventions or private operators, they were essentially subject to federal rules, reflecting the federal government's responsibility for vocational and professional education (Federal Constitution, Art. 63). The federal rules on the UAS' mandate, organisation and management were very different to the rules applicable to universities. The UAS were given four mandates by the federal government: vocational and professional education at tertiary level, continuing education and training, aR&D and services.

The rapid surge of the UAS (Figure C 4.2) was driven in part by the integration of additional fields of education. The UAS have evolved from institutions focusing on engineering, economics and services into multi-sector educational institutions. Today, the educational programmes offered by UAS cover the majority of areas of vocational and professional education, aside from the artisanal and commercial vocations, which are mainly taught following on from vocational education and training and in higher vocational education. Teacher training can also be an exception, as there are independent universities of teacher education in some cantons.

Three UAS (Berner Fachhochschule BFH, Scuola universitario professionale della Svizzera italiana SUPSI, Zürcher Fachhochschule

Figure C 4.1: Universities in Switzerland



BFH: Bern University of Applied Sciences
FHNW: University of Applied Sciences and Arts Northwestern Switzerland
FHO: University of Applied Sciences of Eastern Switzerland
FHZ-HSLU: Lucerne University of Applied Sciences and Arts
HES-SO: University of Applied Sciences of Western Switzerland
SUPSI: University of Applied Sciences of Southern Switzerland
ZFH: Zurich University of Applied Sciences and Arts

Figure C 4.2: Basic data on UAS in Switzerland

	2000	2004	2008	2012	2014
Total staff (full-time equivalents, FTE)	5062	7425	9355	13032	14106
Students at diploma and Bachelor's level	21944	35650	38320	52795	55564
Students at Master's level	0	0	2082	6726	7509
Total expenditure in CHF million		1243	1860	2328	2545
Expenditure for aR&D in CHF million	90	181	352	514	611
Personnel for aR&D (in FTE)	470	1077	1754	2667	3049
Share of expenditure for aR&D		15%	19%	22%	24%
Share of personnel for aR&D (in FTE)	9%	15%	19%	20%	22%

Source: FSO

ZFH) each cover just one canton and four UAS cover several cantons and are based on intercantonal agreements. They also have different governance and organisational forms: some UAS are more centrally coordinated while others are more along the lines of holding structures, with greater autonomy for the individual campuses (Kiener et al., 2012). Geographically, the UAS are more widely dispersed than universities and are also present in medium-sized cities with a long industrial tradition, such as Brugg, Winterthur and Yverdon. The intention is that, thanks to their geographical proximity, the UAS will contribute to regional development. The federal council also accredited the private UAS Kalaidos (2005) and Roches-Gruyère (2008 to 2018). However, these are not investigated further in this report.

Following on from the inclusion in the Federal Constitution of the new university article (63a), since 1 January 2015 the universities of applied sciences – along with the conventional universities – have been subject to the new Higher Education Act (HEdA).

4.2.1 Initial education and continuing education and training

According to the UASA, the primary mandate of UAS is to prepare students for a vocational or professional activity. Over a period of three academic years, UAS programmes must lead to a professional Bachelor's qualification which gives direct access to the job market. As such, the UAS meet growing demand from students and the job market for tertiary education. UAS programmes can be offered as full-time courses (lasting three years at Bachelor level) or part-time courses (longer study period of four years), in order to accommodate demand from students who are already in work. Continuing education and training is another statutory mandate of the UAS (lifelong learning).

Often, UAS programmes are the result of the restructuring of existing educational programmes offered in higher vocational and professional education. In areas that were integrated later on – such as art, health and teacher training – some of the UAS study programmes were the result of programmes that had been transferred from secondary to tertiary level. The "tertiarisation" of vocational and professional education – a trend that is common to all European countries (Witte et al., 2008) – met the need for more advanced skills, but may also be a reflection of the fact that a number of professions are striving for a higher status. The biggest impact of the UAS on the Swiss job market is the wider access to higher education and the increase in academic degrees at tertiary level (see Chapter 4.4).

Generally speaking, admission to a UAS requires a vocational baccalaureate. This is either acquired part-time during vocational education and training or full-time following on from vocational education and training. An additional year of work experience in a subject-specific area is a formal requirement for admission with an academic baccalaureate for subjects for which candidates normally have a vocational baccalaureate.

In the wake of the Bologna Declaration, from 2005 onwards diplomas at UAS were gradually replaced by Bachelor's degrees (180 ECTS). This reform ensured international recognition for the qualifications and facilitated access to Master's programmes at universities. Currently, however, UAS Bachelor's graduates must obtain up to 60 additional ECTS in order to be admitted to a university Master's programme in the same subject area.

Since 2008, UAS have selectively been offering their own Master's programmes (usually 90 ECTS) which, among other things, teach research-related skills. In order to be accredited, they must be closely related to applied research.

4.2.2 Applied research and development

The R&D mandate of the UAS as defined by the 1995 UAS reform was a major innovation. Some engineering colleges (particularly in Brugg, Winterthur, Yverdon and Ticino) already had a research tradition, working closely with industry. Up till then, the majority of other institutions and disciplines – including those subsequently integrated into the UAS – engaged in little research.

In recent years, there has been a marked increase in aR&D activities at UAS, and aR&D has expanded beyond engineering disciplines to encompass all disciplines. Between 2000 and 2014, total expenditures on aR&D rose from less than CHF 100 million a year (Lepori & Attar, 2006) to more than CHF 600 million (Figure C 4.3). Over the same period, the share of aR&D in total expenditures of UAS increased from less than 10% to 24%. The share of UAS in total expenditures on aR&D across the whole university sector climbed from around 3.6% in 2000 to roughly 10%.

As shown by Figure C 4.3, the objective of R&D activities being undertaken in all disciplines has been thoroughly achieved. That said, the scope and intensity of those activities vary considerably between the disciplines. In 2014, for instance, three quarters of aR&D expenditures were incurred in the four disciplines architecture, technology, chemistry and economics. With aR&D expenditures of almost CHF 250 million and over 40% of its personnel devoted to aR&D, the technology and IT disciplines now feature heavily on the Swiss research scene. In disciplines such as social work, health or the arts, by contrast, aR&D activities are still largely a nascent phenomenon.

4.2.3 Financing: conflict between teaching and research

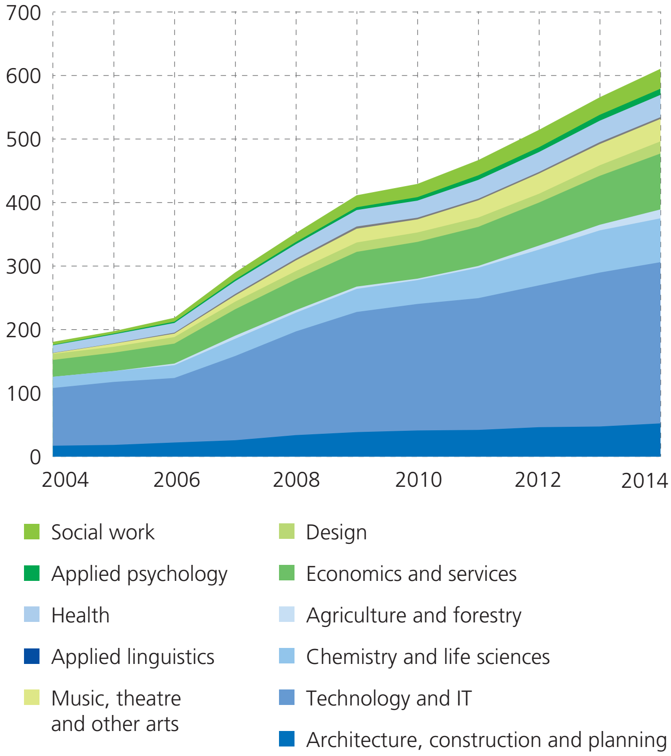
The development of the UAS and the strong growth in student numbers went hand in hand with a marked increase in public financing. This increase reflects the broadening of UAS activities under the 1995 Act. As can be seen from Figure C 4.4., the composition of financing sources has changed little since 2006.

Two thirds of the income of UAS are directly proportional to the number of students: based on the standard costs specified in the Masterplan (for each discipline), the UAS receive a fixed amount for each enrolled student. This financing system is designed partly to reflect the demand for education but at the same time to encourage the UAS to broaden their range of study programmes and compete for students.

aR&D and services should also be geared towards demand from external customers – particularly private enterprises – and as such be funded mainly by third-party funds. Conversely, universities receive substantial amounts from their local or regional authorities for basic research. Assistance for aR&D at UAS provided by the federal government as the responsible authority is correspondingly low; at some UAS, the cantons reward the acquisition of external funds with additional bonuses. As Figure C 4.5 reveals, the UAS relied mainly on third-party funds to finance their aR&D activities (42% of aR&D revenues in 2014; compared with 34% for universities), particularly contracts with the private sector.

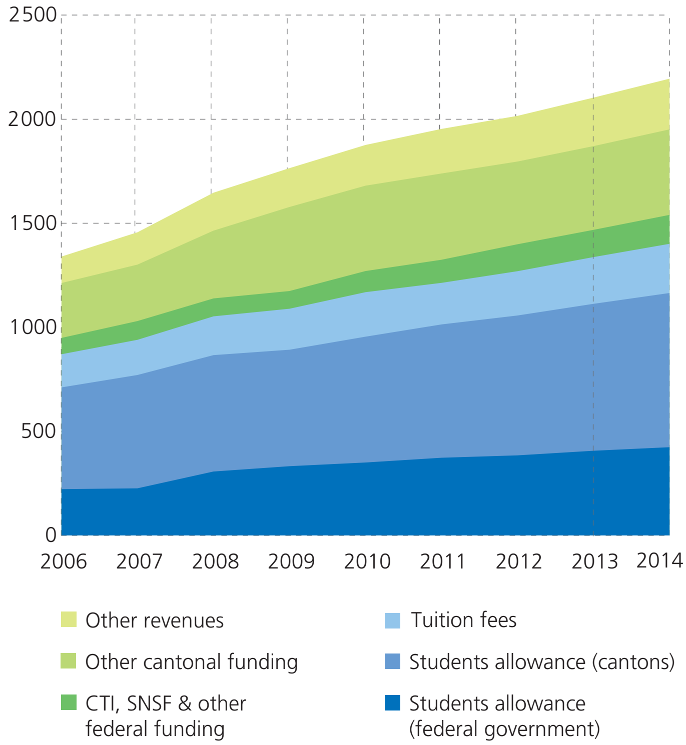
In parallel to the increase in third-party funds acquired for aR&D, however, local and regional authority funding was also increased. This illustrates the complementary nature these two

Figure C 4.3: aR&D expenditure of UAS by field of education – excluding UTE and teacher training, in CHF million



Source: FSO, Lepori & Müller illustration

Figure C 4.4: Funding sources of the UAS, in CHF million



Source: FSO, Lepori & Müller illustration

Research outside the university sector: European experiences

In the 1960s and 1970s, institutions similar to the Swiss UAS were established in the UK and in Germany (polytechnics in the UK, universities of applied sciences in Germany), but they did not have a research mandate. The focus was on their educational remit. The introduction of the binary system was intended to ease the pressure of growing student numbers at universities.

From the 1990s onwards, almost all UAS in Europe were given the right to engage in research. However, the status of and government support for their research mandate vary greatly from one country to another. As outlined by the OECD in 1998, the political aim of excluding research from certain institutions was seldom maintained in the long term.

A comparative study from 2010 divided the countries into three groups (Kyvik & Lepori, 2010): Countries where research is the core mission of UAS and is a major activity (including Finland, Norway and Switzerland), countries where UAS research is at the experimental stage (Czech Republic, Netherlands) and countries that are somewhere in-between these stages (Germany, Ireland).

There are various reasons for the expansion of research at UAS. Firstly, in many countries research is a prerequisite for earning the status of a fully-fledged university. The granting of a research mandate is seen as an enhancement of status. Secondly, research is deemed necessary to secure and improve the quality of practical education at tertiary level, because this is closely bound up with the research skills of the teaching staff ("Humboldtian model"). Thirdly, due to their regional presence, the UAS are also regarded as important actors in disseminating research findings to the business sector and society. The reasons differ from one country to another: in Norway, for instance, practical education is paramount while in Finland and Switzerland, the transfer objective takes precedence. This results in differing organisational and financing models for aR&D.

Despite these differences, the UAS are faced with similar challenges: firstly, the definition of research adopted by universities is problematic. Accordingly, efforts are being made to add creative activities (e.g. in the arts) and practical research (social work, health, education) to that definition. Secondly, in light of the small research volumes compared with the universities, it is difficult to reconcile the desire to extend research to all areas of the institution with the need to concentrate research at centres of excellence that have the critical mass. Finally, the financing of research presents a problem in every country: the UAS receive little, if any funding for R&D from their local or regional authorities and in most countries struggle to successfully apply for project funds in competition with universities.

forms of financing. Institutional financing is especially necessary in new areas, in order to build up skills and cover general overheads. Private sector aR&D contracts are intended to cover all the costs - including the UAS' overheads -, if only to prevent unfair competition with private providers. By contrast, public project funds (from the CTI, SNSF or from EU programmes) usually only cover the direct costs, such as personnel costs for specific projects, and a fixed amount to cover overheads. Nowadays, however, this amount, which ranges from 15% (SNSF) to 20% (FPs), is significantly below the actual overheads incurred by universities for the projects. At the present time, full costing is only permitted at the CTI; for the upcoming financing period, a switch to fixed overheads is planned (the same as the SNSF model; SSTC, 2013a).

The effects of this financing model are twofold: firstly, raising public-sector third-party funds increases the need to obtain funds from local and regional authorities (to cover overheads) and secondly the different financing systems of universities and UAS also affect the universities' competitive position with respect to the public funding bodies. Universities are better placed in this regard, because they receive significantly more financing from their local and regional authorities.

In summary, the federal government and the cantons granted the UAS funds in order to fulfil the mandate conferred upon them by the 1995 Act and enable them to expand their educational programmes. The financing of UAS is based partly on the number of students (teaching) and partly on third-party funds (research). Teaching-wise, the UAS are in a more favourable position – as one might expect, given the political priorities. Research-wise, however, there is conflict between the limited funds from local and regional authorities and the requirement to raise external funds to develop research.

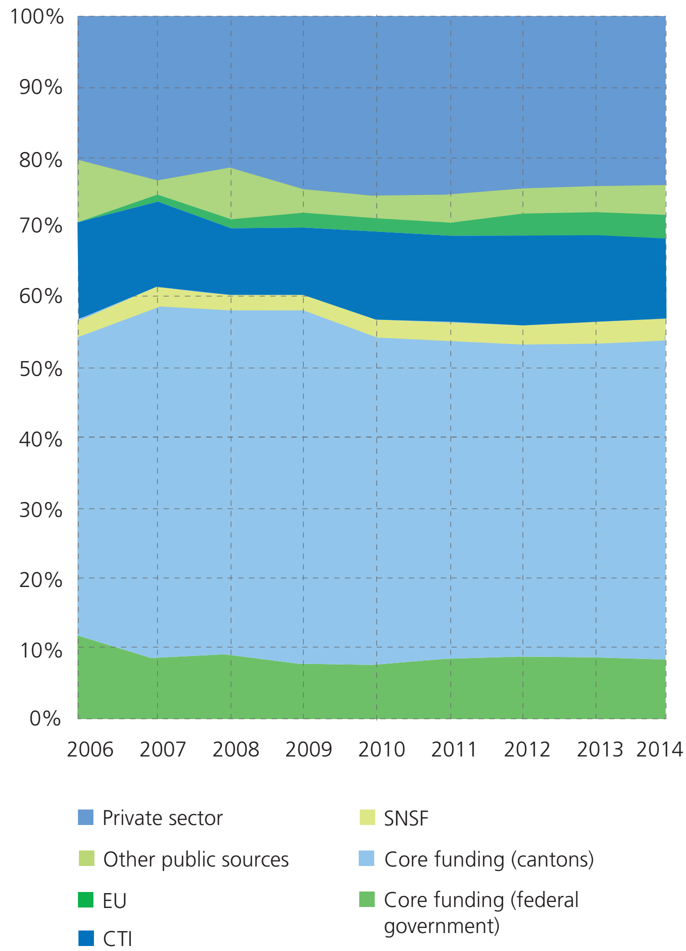
The use of public funding bodies (SNSF, CTI) to cover overheads will remain a focus of discussion. The current financing model relies on projects being partly co-financed by the relevant authorities. Due to the different mechanisms for and levels of financing at universities and UAS, the conditions for access to R&D financing vary greatly.

4.2.4 Competition for project funds

Funds for research projects are usually awarded in competitive procedures, in which the UAS compete with the other universities. The quality of the applications is not the only criterion for success; the type of research conducted must also be consistent with the objectives of the funding body.

Typically, the public project financing environment gives priority to supporting knowledge-oriented research. Since the National Research Programmes (NRP) were introduced in the 1970s and the CTI was consolidated in the 1990s, the applied aspect of research has been expanded. aR&D funds are concentrated on natural sciences and engineering. There are two notable gaps: firstly, relatively few funds are allocated to applied research by UAS in the social and artistic disciplines (the Do-Research Programme DORE launched by the SNSF and CTI in 2000 went some way towards closing that gap); secondly, there is a deficit in public financing of applied projects before the competitive phase – projects that are not of immediate interest to private enterprises. To remedy this, in 2011 the SNSF launched a new, experimental funding system ("Broader Impact").

Figure C 4.5: Funding sources for R&D expenditure at UAS



Source: FSO, Lepori & Müller

The research profiles of the UAS and the research financing criteria combine to create a financing structure that is specific to UAS. In 2013, 60% of third-party funds for aR&D originated from private enterprises and 24% from CTI collaboration projects, chiefly with partners from private industry. At the CTI, the UAS received the lion's share (45%) of project funds granted, ahead of applications from the ETH (federal institutes of technology) Domain (30%) and cantonal universities (13%). The technology segment predominates in both third-party funds from private parties and the funding from the CTI. In 2013, a total of 75% of CTI funding went to engineering, micro and nanotechnology and life sciences. The reality is that the CTI's innovation model, which aims to create commercial value and employment in the private sector, and the rules on co-financing by partners impose tight constraints on potential projects – particularly when the partners are government or charitable institutions and when the innovation yields social benefit but not necessarily commercial benefit.

With respect to the SNSF, the UAS are in a more difficult position than universities, because the SNSF primarily promotes basic research and requires scientific publications as proof of track record. Furthermore, the SNSF financing model mainly promotes young researchers: it is assumed that the main applicants (usually the professors) finance their work through their appointment at the university. SNSF projects thus require the universities to provide additional funds from local and regional authorities. This makes life harder for UAS, because they receive less local and regional authority funding for research.

In order to make up the financing shortfall for practical research in the social sciences and promote the development of research in the new UAS fields, in 2000 the CTI and SNSF launched the DORE programme (Do-Research, managed by the SNSF since 2004). Between 2000 and 2010, the UAS were allocated project funds totalling CHF 48 million, a third of which were for projects in the social work discipline. In 2011, the SNSF introduced a specific label for the financing of use-inspired basic research. The new label was intended partly to replace the DORE programme but also to support applied projects by the conventional universities (in areas such as clinical medicine). In 2011–2012, this label was assigned to around 20% of applications; two thirds of the applications submitted were from UAS. Overall, applications with this label were less successful over that same period than the conventional, science-oriented applications. Moreover, submissions from the UAS for both project types were less successful than those from universities (SNSF, 2013). Nonetheless, SNSF financing for UAS rose from CHF 7.6 million in 2005 to CHF 15.4 million in 2013 – proving that the SNSF has become an important source of financing for UAS and for the social disciplines in particular. However, research groups must still be carefully assembled in order to access SNSF funds, because a certain academic reputation and academic publications are required as proof of track record.

Finally, the EU Framework Programmes (FPs), with their emphases on use-inspired research and technology, are a potentially important financing source for the UAS. Between 2008 and 2013, the participation rate and scope of financing from the FPs shot up from less than CHF 5 million to almost CHF 18 million. What makes this particularly noteworthy is that, according to comparative international analyses, participation in FPs is clearly dominated by research universities, with very little participation by UAS (Lepori et al., 2014). The opening up of the Horizon 2020 programme to projects geared towards economic innovations presents good opportunities, in principle, for greater participation by UAS. However, since the vote on the popular "Stop mass immigration" initiative in 2014, it has become much harder for Swiss project partners to access such initiatives.

In this financing context, the availability of external funds varies from one discipline to another. In 2013 the share of third-party funds for aR&D in the chemistry discipline was 47%, for technology and IT it was 53%, but for health just 26% and for applied linguistics 31%. Bearing in mind the total volume of funds for aR&D, these differences are even more marked. Compared with earlier data (Kiener et al., 2012), the differences between the disciplines have lessened, due chiefly to the efforts of the non-technical disciplines to acquire more funds from private and public-sector contracts and from the SNSF. Despite this, for quite a number of disciplines, resources are harder to access and depend to a greater extent on local and regional authority funding. The situation is particularly difficult in disciplines geared more towards basic research, such as art, in which the availability of external research funds is very limited.

In summary, the UAS have generally positioned themselves successfully on the R&D financing scene and raised more and more funds for their R&D activities. The remit of concentrating on aR&D is accompanied by a marked bias towards contracts with private enterprises and the CTI; SNSF funds are harder to access. The financing options are more favourable in technical disciplines. Taking a purely economic, market-oriented view, this does not present a problem, as the limited demand reflects the lack of need for aR&D activities. However, the approach does present a problem when there is a political requirement to undertake R&D in all disciplines (including those that do not involve comparable markets) in order to meet wider needs, help solve social problems and impart skills through teaching, particularly at Master's level.

4.3 Profiles, collaboration and competition

When the UAS were established, in 1995, the intention was that they would be very distinct from the universities, as expressed in the principle of "equal, but different". The UAS were to develop their own profile, on the principle that functional differentiation offers a better response to social needs. However, experiences in the countries that introduced similar binary systems in the 1960s and 1970s present a more complex picture of the reality (Kyvik, 2006; Meek et al., 1996).

International studies show that this development can lead to varying outcomes (Figure C 4.6). In the early days, the UAS and universities formed two closed and distinctly separate groups ("group distinction"). While the two groups are still different, there are now hybrid organisations with features of both types ("blending") and the boundaries between the groups are becoming fluid. In most countries, the UAS sought to approximate the most famous model – i.e. the research universities – in order to earn greater respect and recognition. This phenomenon is known as academic drift (Morphew & Huisman, 2002). The expansion of research activities, upgrading of education to Master's level, and demands for the right to award doctorates are typical of this phenomenon. Their desire to become more like the universities is also expressed symbolically by, for instance, referring to themselves as a "university" or introducing the status of "professor".

This pattern can be observed in countries such as Norway, where some UAS now have the right to award doctorates, or in Ireland, where the Dublin Institute of Technology is retaining its name (an IoT is the Irish equivalent of a UAS), but shares many features in common with the universities. As explained below, these tendencies were less pronounced at Swiss UAS than in most other European countries, on account of the political management of the establishment of the UAS.

Finally, it is possible that the two groups will become so similar that any formal distinction will disappear ("no distinction"). The individual universities may nonetheless be very different. In the UK, for instance, the former Colleges and Universities have had the same mandate and legal status since 1992, but there are marked differences in terms of their research scope and international reputation. Thus the weakening or even removal of formal differences does not necessarily mean that the profiles of the institutions are no longer distinct. The former Polytechnics in the UK (referred to as the "1992 universities") retain a very different profile to this day, with a stronger teaching focus and significantly fewer research activities. The practice of awarding research funds according to competitive criteria is one of the major reasons for the persistent differences between the individual institutions (Whitley & Gläser, 2007).

Summary

The UAS have become an important partner in higher education in Switzerland. Owing to the decentralised structures, they are also present in the regions outside the bigger cities.

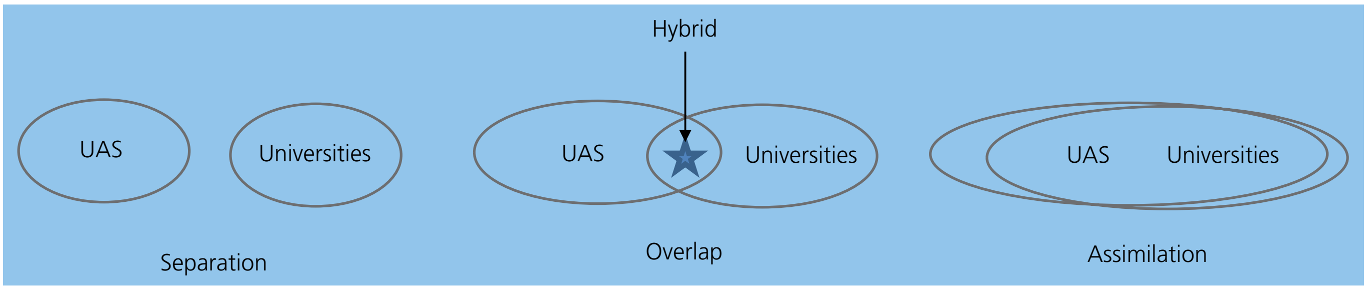
The UAS are geared towards professional education at Bachelor's level, and currently account for over half of new students. The Master's programmes they offer are limited and closely linked with aR&D activities.

At the UAS, the technical disciplines are very heavily involved in aR&D. In other areas such as social work, health and arts, aR&D is a nascent activity.

The establishment of the UAS in 1995 (UASA), in parallel to the existing universities, gave rise to two very distinct management and financing systems. This promoted the development of a specific profile for the UAS. When the HEdA was introduced in 2015, the legal and institutional framework altered.

The financing system for the UAS is geared towards their primary mandate – i.e. teaching – and is largely based on how many students each UAS has. The funds that a UAS devotes to aR&D originate predominantly from private enterprises, EU initiatives and the CTI. Local and regional authority funding is less common than at universities. UAS find it harder than universities to access SNSF funding. There are potentially more funds for aR&D available to the technical disciplines.

Figure C 4.6: Separation vs. assimilation



Source: Lepori & Müller

4.3.1 Overlap and distinction in the Swiss higher education system

In the discussion of the development of the university landscape, this study concentrates on four main aspects: the size and diversity of the disciplines, teaching activity, research activity and knowledge and technology transfer. The entities studied are the individual universities (seven UAS and twelve universities). Interestingly, depending on the aspect under consideration, there are instances of distinction, overlap and no distinction.

Size and diversity of the disciplines

In terms of their size and the fields of education they offer, UAS and universities have become more similar over time. This is apparent from the number of undergraduates (Figure C 4.7).

In 2000, the UAS were of a similar size to smaller, specialised universities (e.g. Neuchâtel, St. Gallen, Lugano and Lucerne), but much smaller than big universities (e.g. Zurich, Bern and Basel). In 2012, in contrast, there are no discernible, systemic size differences between the two types of university; the variations chiefly correlate to their geographical location. A similar convergence pattern can be seen in regard to the fields of education offered: in 2000, the UAS specialised mainly in the technology and economics disciplines; by 2012, they had all evolved into generalist, multi-sector universities, similar to the big universities. On the other hand, there are still a number of heavily specialised universities among the universities, such as the two ETH and smaller cantonal universities.

The pattern of consolidation from smaller, specialised institutions to larger UAS covering virtually all fields of education is familiar to most European countries. There are a number of reasons for this development, such as the fact that a system with fewer actors is easier to manage from a political perspective; the assumption that larger institutions are better able to develop their strategies and can compete more successfully; and the underlying model of the "universal" university, covering all fields of education. To a certain extent, this consolidation is essential if UAS and universities are to form part of the same system.

Teaching activity

The patterns of teaching activity are complex. While some are indicative of overlap, others point to a persistent distinction. At the end of the 1990s, the two types of university differed both in terms of the type of qualification (UAS degree in three years versus a "licentiate" at a university in four to five years) and in terms of the differing student population; it was practically impossible for there to be any crossover between the two types.

When the Bologna system was introduced and Master's programmes were approved at the UAS, the qualifications offered by UAS and universities became more similar, increasing the "permeability" between types of university. Subject to certain requirements, a UAS Bachelor qualification now opens up the option of attending a Master's programme in the same field of education at a university (and vice versa).

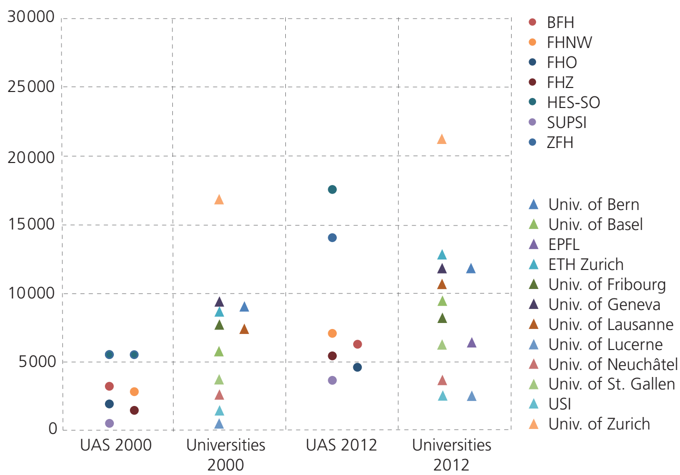
A number of significant differences remain, however: Teaching is still the primary activity at UAS. The range of courses offered at UAS still focuses primarily on Bachelor level (only in music do the majority of students study to Master's level), and Master's degrees are only offered in a select few areas and only for the best students. At universities, in contrast, a Master's is not only the standard qualification (in 2010, 87% of students with Bachelor's degree from a university enrolled on a Master's programme), but also serves as the basis for selecting suitable candidates for doctoral programmes and helps attract more students. So there are still some key differences between universities and UAS in terms of level of qualifications (Figure C 4.8).

Essentially, it is the differing admission conditions that distinguish the student populations at the two types of university: in 2012, almost all students at universities held an academic baccalaureate, while at UAS half held a vocational baccalaureate. UAS still have a substantial proportion of mature students (although that share is declining): in 2012, 21% of new students at UAS were aged over 24, compared with 7% at universities. Many of them are studying part-time alongside work or completing a second degree.

At the same time, however, there are signs of convergence and overlap: in 2012, as many of a fifth of UAS students began their studies with an academic baccalaureate and another fifth were from abroad (SCCRE, 2014). Both of these statistics suggest that the UAS are competing more with the universities. The change in the student population at UAS is most apparent in new fields such as health, in which students with an academic baccalaureate form the majority.

These developments indicate that the UAS hold a strong position in Bachelor's programmes, regardless of students' backgrounds. The universities, in contrast, continue to place the emphasis on longer programmes, as illustrated by the high rates of transition from Bachelor's to Master's programmes (2010: 87%) and from Master's level to a doctorate (2010: 20%). The distinction

Figure C 4.7: Number of undergraduate students



Source: FSO, Lepori & Müller calculations between the types of university thus correlates more with the duration, nature and level of skills acquisition than with professional or vocational orientation. Finally, universities are also gearing their courses to some extent to the job market, as they have always done with medicine or law.

This is largely in line with international developments. In the Netherlands, for example, most Bachelor students study at Colleges (UAS) and then move to a university should they wish to complete a Master's programme.

Research and knowledge and technology transfer
The data reveal a marked difference with regard to these two aspects: UAS and universities systematically exhibit differing profiles, although they have become more uniform over time.

The personnel of universities routinely devote more of their working time to R&D and the universities receive significantly more research funds from the SNSF, which is also a reflection of their basic research bias. Interestingly, the indicator "share of working hours devoted to R&D" is similar at the SUPSI and the University of St. Gallen. This is due to the SUPSI's Department of Innovative Technologies, which engages in a large amount of R&D and attaches great importance to R&D (Figure C 4.9). It is also interesting that universities are becoming more homogeneous in regard to the use of staff resources for R&D. This may be interpreted as a sign that the development of the UAS has prompted the universities to focus more on basic research as one of their strengths.

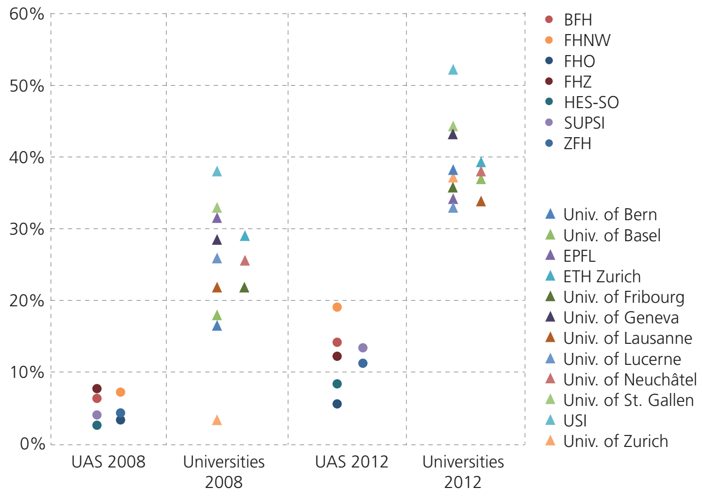
As revealed by Figure C 4.10, all UAS significantly increased the share of revenues from transfer services between 2000 and 2012. The increase is much smaller at universities; although revenues from transfer services are also relevant here, they are secondary to teaching and basic research. The surprising exception to this pattern is the University of St. Gallen, which offers a large number of continuing education and training programmes chiefly in business and management (EMBA) and traditionally fosters close ties with the private sector.

4.3.2 Differences between the disciplines and collaborations with universities

This general picture conceals substantial differences between disciplines. However, this is true not only of UAS, but also of universities, where natural sciences and engineering sciences differ greatly from social sciences and humanities (Lepori, 2007). The heterogeneity of disciplines and, as a result, the differing positions in the education system and in relation to the economy and society must always be taken into account when considering the impact of UAS on the Swiss research and innovation system (see Chapter 4.4).

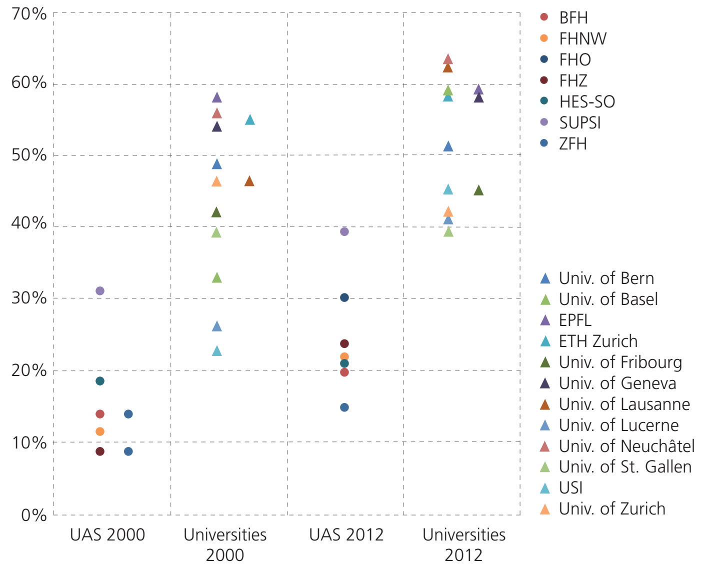
When comparing the UAS disciplines, it is important to consider the following relevant aspects: (1) the balance between teaching and research, as measured by the distribution of working time of personnel (Figure C 4.11); (2) the target public of the UAS (economy, society and public institutions); (3) the relationships

Figure C 4.8: Share of students on Master's programmes as a percentage of all undergraduate students



Source: FSO, Lepori & Müller calculations

Figure C 4.9: Share of working hours devoted to R&D

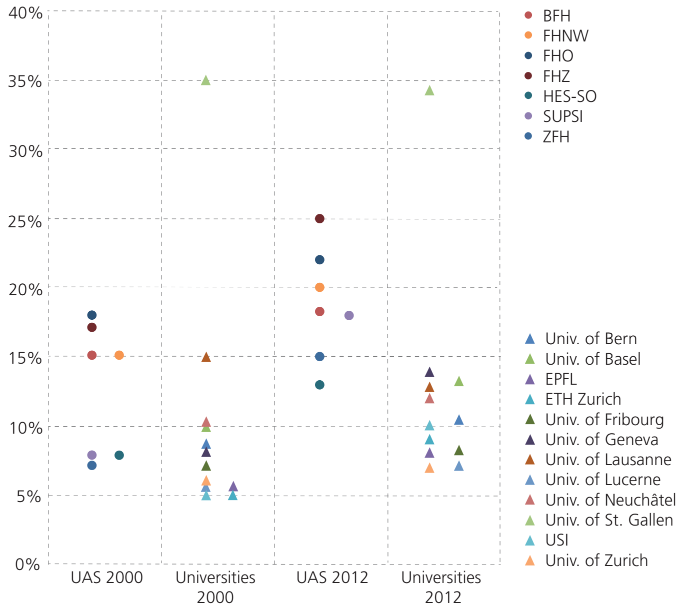


Source: FSO, Lepori & Müller calculations

with the universities and, in particular, the balance between complementarity and competition. As well as the importance of the specific characteristics of the disciplines, however, it must also be borne in mind that the applied and problem-solving orientation of research and innovation at the UAS usually requires skills from various disciplines and interdisciplinary approaches.

Figure C 4.11 reveals major differences in regard to the working time spent on the various areas. In a number of disciplines, initial education takes centre stage (music, theatre, arts and design) while others place the emphasis on continuing education and training

Figure C 4.10: Share of knowledge and transfer activities (public and private contracts, CTI projects, continuing education and training, services) in total revenues



Source: FSO, Lepori & Müller calculations

(applied psychology, economics) or services (applied psychology, applied linguistics); in the technical disciplines, the high percentages for the aR&D area are striking.

Generally speaking, the fields of education can be divided into four main groups (see Kiener et al. 2012; the field of sport is disregarded here):

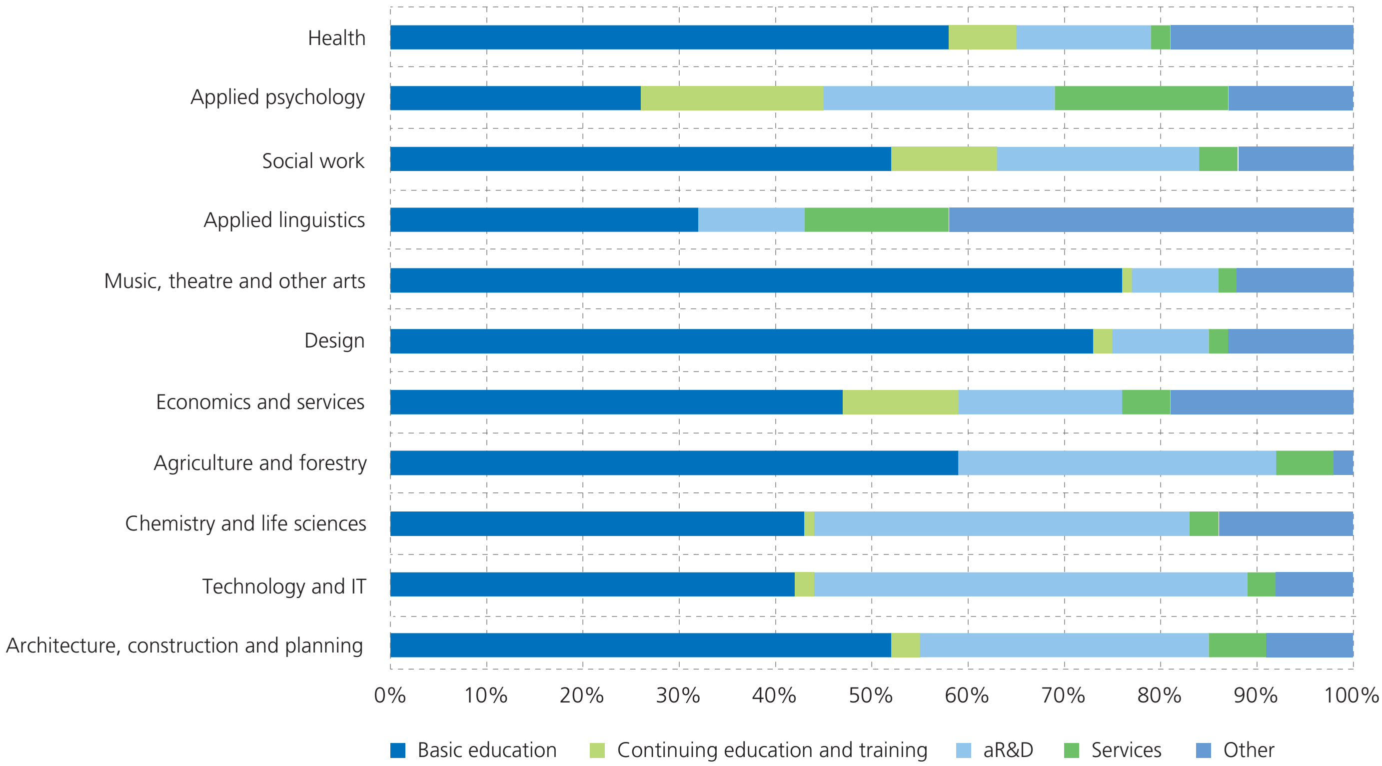
- Group A comprises the "old" engineering fields of architecture, construction and planning, technology and IT (engineering and information technology), chemistry and life sciences and agriculture and forestry. It accounts for 27% of all UAS students, but also 60% of total aR&D expenditures. Research intensity is high (45% of staff time devoted to aR&D in the technology and IT discipline). It is the only group that intensively engages in aR&D as a key UAS activity. These disciplines are notable for their strong applied bias and cooperation with private enterprises. Research takes places at relatively large entities. The majority of the research is undertaken by assistants trained and employed by the institution and the research associates, overseen by the UAS professors. Much of the financing is provided by third parties – chiefly private enterprises – and the CTI (see Chapter 4.4). The relationship with universities can be described as pragmatic "complementary collaboration". The definition of research is hardly ever a subject of debate in this group; the UAS are clearly positioned.

- Group B comprises the economics and services discipline (dominated by business administration). It accounts for over a third of students (35%). aR&D intensity is low (17% of staff time devoted to aR&D) and the level of third-party funds for aR&D is average. These funds originate from public administrations and private enterprises, and more rarely from the CTI or SNSF. The relationship with universities is typified by competition, as certain management and business administration departments at universities also have an applied bias. aR&D is undertaken primarily by professors who were recruited at universities and often have a university degree. The definition of research and innovation is a subject of debate. The boundary between aR&D and services is not always clear – leading to a certain amount of competition with private service providers.

- Group C comprises the "new" disciplines of applied linguistics, social work, health and applied psychology. In research and teaching, the primary focus of these fields is on society and public institutions. Although they account for virtually the same percentage of students as Group A (27%), they make up just 17% of total aR&D expenditures. The research intensity is comparatively lower than in Group A (21% of staff time devoted to aR&D in social work, less than 15% in the other fields). The share of third-party funds for aR&D is on the low side; these funds originate chiefly from public administrations and NGOs, partly from the SNSF, and seldom from the CTI and private enterprises. Research is chiefly undertaken by professors, who often have a university degree. There is clear competition with the universities, especially in psychology. The definition of applied research and the dividing line with basic research are considered problematic, the argument being that the generation and application of knowledge in these fields cannot easily be separated and there is often a long delay before the impact of research findings becomes apparent.

- Group D, comprising music, theatre, arts and design, shares most of the features of Group C, described above. One major difference is the lack in this group of comparable teaching and aR&D activities at universities in Switzerland. These disciplines rely more heavily on Master's programmes and basic research, but they face three major challenges in this respect: firstly, the actual definition of research is the subject of much controversy, because of the sometimes blurred boundaries with creative activities. Secondly, the lack of research traditions at universities causes difficulties with training, recruitment and career planning for aR&D staff and when developing basic knowledge. Thirdly, the availability of external funds is very limited for music, theatre and arts.

Figure C 4.11: Share of working time of UAS personnel by field of education and activity, 2014



Source: FSO, Lepori & Müller illustration

4.3.3 Complementarity and integration

In all countries, the starting point for the establishment of binary systems was the clear distinction between the two types of university; it was the same in Switzerland, where the prevailing notion was that the UAS would join forces and collaborate with each other rather than with the universities. However, it soon became apparent that the different profiles by no means preclude cooperation across types, and various forms of complementarity have arisen between the UAS and the universities. The issue of equilibrium between collaboration and competition is likely to remain a focus of discussions about the future of Switzerland's higher education system.

In teaching, the complementary aspects are emerging relatively slowly; the UAS devised their own educational paths, such as introducing collaborative Master's programmes with the involvement of a number of UAS. The alternative, i.e. UAS Bachelor graduates moving on to Master's programmes at universities, was seldom chosen, although this option does, in principle, exist within the same field of study. In 2012, just 4% of new Master's students switched to another type of university, which is indicative of the generally low mobility of students in Switzerland (geographically and in relation to the type of institution).

Examples from abroad suggest there is great potential for complementarity in teaching. The Dutch UAS, for instance, restrict the Master's programmes they offer to a few, specific subjects while allowing their Bachelor's graduates to transfer to a Master's programme at a university. In Switzerland, the integrated management of the UAS and university segment introduced by the new HEdA will simplify the process, thanks primarily to common guidelines on the accreditation of both types of institution (see Section 4.3.4). It is likely that cooperation between UAS and universities in their teaching activities will increase further in future. Some examples are the training of teachers in Basel at Master's level and the Master's programme in biomedical engineering offered by the University of Bern, in close partnership with the Berner Fachhochschule.

In research, collaborations and areas of complementarity are mostly emerging bottom-up, at the level of individual research groups or institutes. Engineering in particular, an area in which the both types of university have markedly different profiles, offers numerous examples of successful collaborations. This complementarity and "division of labour" is based on basic research at universities and applied research at UAS. Research cooperation between institutions is particularly widespread in Ticino. The canton promotes a policy of cooperation; the Università della Svizzera italiana (USI) and the SUPSI have a joint Institute of Artificial Intelligence. Another example in Northwest Switzerland is the joint Institute of Education, established in 2014 by the University of Basel and the FHNW.

The training of research personnel is another area in which there is complementarity. The UAS are in a unique situation here, in two respects: firstly, they do not have the right to award diplomas for research qualifications (doctorate, "habilitation"). Secondly, to fulfil their research mandate they are reliant on personnel with research training as well as experience of aR&D and of cooperating with the private sector and society. Accordingly, the establishment of coherent research careers continues to present a major challenge for the UAS (Federal Council, 2014; Lepori & Attar, 2006).

The data on the formal qualification of UAS personnel (2012) show the extent to which the UAS are reliant in this regard on complementarity with universities (Figure C 4.12). 70% of UAS professors have a university degree, and just over a quarter have a doctorate. Typically, their careers begin with a university education, followed by experience in the public and private sector and, finally, a managerial role at a UAS.

Of the research associates at UAS (particularly in engineering), the majority – around 30% – have a UAS degree and roughly a third have a university degree. The appointment of young researchers with a UAS degree is especially typical of the engineering fields. After working on research projects for a few years, they usually switch to roles in the private sector. In this way, the UAS play a part in training human capital in the private sector.

The appointment of researchers with a doctorate is comparatively rare at the UAS, although there is an upward trend because – from the UAS' perspective – such people benefit from thorough research training. A research career at a UAS can be a very attractive prospect for doctoral students who are not interested in an academic career. As long as a UAS selectively chooses such personnel according to criteria that fit the UAS profile of aR&D, this model presents no problems and does not automatically entail academic drift.

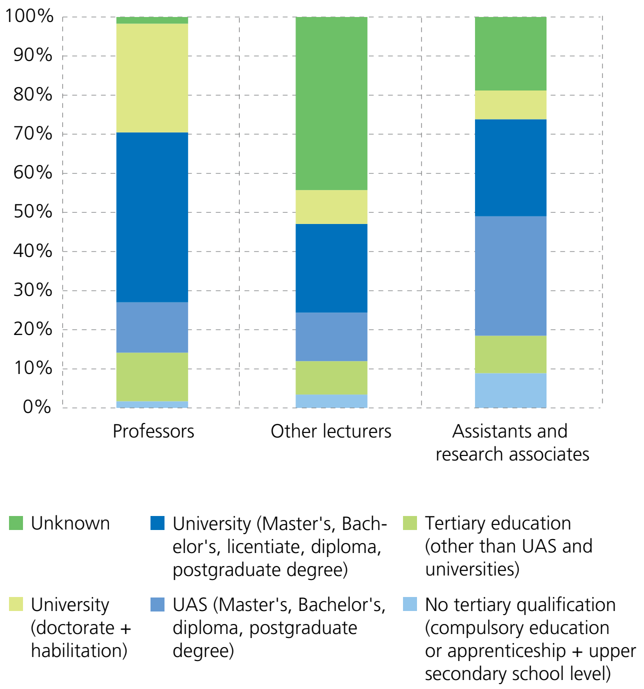
Generally, the data show that the recruitment of research personnel at UAS is based less on UAS-specific careers than on exploiting complementarities with universities and with firms in the private sector. The universities usually provide research training through their thesis programmes and the UAS selectively choose research associates with an applied research orientation. Particularly in the case of professorships, permeability with respect to the private and public sector is crucial to the UAS, in order to ensure sufficient contact with the professional realm. UAS graduates at Bachelor level (and, to some extent, at Master's level) are an important source of trained R&D specialists for companies (see Section 4.4.1).

A complementary model is also emerging in the training of doctoral students. The doctoral thesis is a key requirement, particularly for a research career in the academic sphere. Therefore, the opportunity to obtain a doctorate is critical not only for young researchers at the UAS but also for research in general at UAS (Federal Council, 2014). In some European countries, this has led the UAS to demand the right to award doctorates, akin to the UK and – on an individual accreditation basis – Norway. It was also argued that supervising theses presupposes a higher skill level for the professors involved, which is not always consistent with the UAS' mission. Another model are "professional doctorates" (doctorate qualifications that are distinct from an academic PhD), which are increasingly widespread in countries such as the UK.

In Switzerland, meanwhile, a growing number of young researchers at UAS enrol on doctoral programmes at a university in Switzerland or abroad, either on an individual basis or as part of a structured collaboration with, for example, SNSF-funded projects. In 2011, this was true of roughly 10% of young researchers at UAS (Böckelmann et al., 2012; Federal Council, 2014). For the period 2017–2020, swissuniversities is developing a targeted programme to promote postgraduate programmes that are coordinated between universities and UAS.

Although the HEdA no longer explicitly excludes UAS from the right to award doctorates, it leaves the decision to the Swiss Conference of Higher Education Institutions. Therefore, as is the case in other countries with a binary system, the subject is likely to be a recurring topic of discussion over the next few years. At present, however, the main focus is on consolidating and formalising cooperation between UAS and universities at doctoral level. Fields such as art, in which the Swiss universities do not currently offer the opportunity to write a thesis, may be the exception to this.

Figure C 4.12: Qualification of UAS personnel, 2012



Source: FSO, Lepori & Müller illustration

Summary

Unlike other countries, Switzerland has successfully retained the specific profiles of UAS and universities, particularly where research is concerned, and at the same time integrated them into a single system. With respect to teaching, the Bologna Regulation resulted in some overlap between UAS and universities.

As regards the training of human resources and doctoral programmes, new collaborations and complementarities are emerging between the universities and UAS. In terms of initial education, however, the UAS and universities are increasingly competing with each other. Both types of university offer high-quality courses with differing profiles. Consequently, students have more choice and can make decisions which better reflect their own preferences and abilities. In some disciplines, there is also competition for research, a prime example of this being the economics discipline, in which the two profiles are similar.

The HEdA, adopted in 2015, for the first time creates a basis for the institutional integration of the two types of university. The guiding principle is the aim of establishing a delicate balance between common rules and differing profiles. At this stage, the impact of this reform on the division of labour between universities and UAS remains largely unknown.

4.3.4 Equilibrium between integration and profiling

Article 63a of the Constitution, dating from 2006, enshrined in law the concept of a higher education system jointly coordinated by the federal government and cantons. This decisive step towards the integration of the political management of universities reflects the trends in other countries (Kyvik, 2009) and, in general terms, the notion that the education provided by universities is a uniform system, albeit with internal differences. The article also makes a clear distinction between political management on the one hand and the autonomy of UAS on the other. This lays the foundations for a dynamic model in which the universities are in competition with one another and each develop their own strategies and individual profiles.

Moreover, in 2013 all the federal government's responsibilities for research and higher education were brought together within the newly created State Secretariat for Education, Research and Innovation (SERI) within the Federal Department of Economic Affairs, Education and Research (EAER). As a result of the new Higher Education Act, since 2015 political coordination (Swiss Conference of Higher Education Institutions) and coordination among the universities (Rector's Conference of Swiss Universities, swissuniversities) has been unified.

The HEdA forges a delicate balance between integration and differentiation. It makes it clear that all universities are part of the same system, but that the differences between the types of university are (potentially) dynamic. At the same time, the Act stresses the importance and necessity of differentiation between types of university, laying the foundations for differing regulations and financing systems. Thus a paradigm shift is occurring, away from a rigid concept with policies which set in stone from the top down the differences between the two types, towards a more dynamic approach whereby the profiles are also based on strategic decisions by the universities and discussion with stakeholders.

In summary, the political management of UAS rapidly moved away from a top-down approach which regarded the UAS as a closed, state-regulated sector, towards a system of clearer distinctions between political objectives and coordination on the one hand, and university strategies on the other. According to this concept, universities and UAS are viewed as (different) parts of the same system. The policy is clear: universities and UAS must retain different profiles, but the actual form and implementation of those profiles have become more dynamic. The impact of this changing environment on the future profiles of the UAS, on their position with respect to universities and on their contribution to the Swiss research and innovation system cannot yet be assessed (for more, see the concluding discussion in Chapter 4.5).

4.4 How the universities of applied sciences contribute to the Swiss research and innovation system

Based on their position in the education system, their historical development and their mission, the UAS operate within the general political and economic environment and in keeping with their strategic profiles. The UAS' contribution to research and innovation is discussed below on three levels: initial education and continuing education and training of specialists (4.4.1), activities in aR&D (4.4.2) and knowledge and technology transfer (4.4.3). This discussion is followed by a section on the significance of the UAS for the regions (4.4.4) and a summary of strengths and weaknesses (4.4.5). There are major differences between the disciplines at all levels in terms of size, position in the education system and orientation.

4.4.1 First objective: Adequately trained specialists as future human capital for research and innovation

Initial education and continuing education and training at the UAS must, at every level, be practical, result in a professional qualification and be geared to demand on the job markets. Even the admission conditions are designed to promote close ties with the professional world: a vocational baccalaureate or an academic baccalaureate accompanied with a formal year of practical experience in a field specific to the subject of study, are an entry requirement for a UAS.

The standard qualification is a professional Bachelor's degree (180 ECTS, three years). One sixth of students then go on to attend a Master's programme – significantly fewer than at universities

Challenges when measuring "success"

Although we do have some data on input (e.g. expenditures, number of students, third-party funds) and some data on output (e.g. number of degree qualifications, number of partner projects) for this report, there are no robust data on impact. The situation is further complicated by the fact that some of the effects of the investments in teaching and research only become apparent elsewhere and after a time delay, not all innovations are rewarded by the market and not all the effects can be measured in monetary terms. Moreover, there are no adequate measuring instruments and comparative data for some sub-areas. To make detailed statements about the conditions under which certain models and procedures were more successful than others, we would need to supplement the quantitative information with qualitative data from actual projects.

(87%). There has been a sharp rise in the number of UAS graduates over the last 15 years. In 2000, 2% of the population obtained a UAS degree, compared with just under 15% in 2013 (universities: 10%, 14%). The dropout rate is low. As demonstrated by the nearly 12,000 Bachelor's and more than 2,000 Master's degrees at UAS, there is no doubt that the political objective of tertiarisation and enhancing the status of vocational and professional education and training has been achieved.

Bachelor's degrees as standard qualifications and their value on the job market

Do the graduates go on to find a suitable job after completing their education? According to surveys of graduates by the FSO (2006 to 2013 cohorts), one year after graduating, no less than 96% of UAS Bachelor's graduates were on the job market. Unlike the situation in some other countries, therefore, tertiarisation has not led to an increase overall in unemployment. That said, five years after graduating, just under a third of UAS Bachelor's graduates say that their current professional role does not require any formal university degree (28% among the 2008 cohort, FSO 2015). This share is significantly higher than among people with a Master's degree from a university (15%), with a doctorate (6%) or with a qualification from a university of teacher education (7%).

Differentiation by discipline groups

A more detailed analysis of the data reveals major differences between the disciplines: the number of people who are employed in a role for which they are over-qualified is particularly low for Bachelor's qualifications in architecture/construction/planning and technology/IT and particularly high in design (48%, 2008 cohorts) but also in music, theatre and other arts (31%) and in health (27%). Either there are too few suitable jobs available in these disciplines or those that are available are taken by people with qualifications from different educational levels (e.g. Colleges of Professional Education and Training PET or post-professional Master's) – either because the UAS degrees do not meet the job requirements or because their value is not (yet) recognised. However, it must be borne in mind that the formal qualification mismatch is not necessarily indicative of a skill mismatch: in quite a number of cases, the qualification requirements for a job are a perfect match for the activity it entails, even though a university degree was not a job requirement. Moreover, there are also positions for which graduates are under-qualified, rather than over-qualified (Kiener, 2013).

Differences between the disciplines are also apparent in most other aspects of the FSO's graduate survey, such as the formal professional position. Among the 2008 cohort, one year after graduating, 26% of respondents with a UAS Bachelor's degree held a managerial position, and 41% five years later. The percentage is particularly high in architecture/construction/planning and in economics/services and particularly low in health, design and music, theatre and other arts. In the latter two disciplines, by contrast, the share of self-employed persons is particularly high. The indicators used in the graduate survey therefore also measure the structure of the job market.

The question of whether the UAS are providing the job market with the right number of adequately qualified specialists is discussed below for each the four discipline groups:

- In the engineering disciplines (Group A), the majority of graduates are in permanent employment immediately after completing their studies, are achieving comparatively high earned incomes and are often in managerial roles. Their UAS titles are well-established and are recognised by the market. The very high percentage of graduates who find suitable employment immediately after graduating is indicative of a "tight job market".
- The rate of unemployment is also low in the economics discipline (Group B) and earned incomes are high, particularly for graduates with a Master's degree. The main difficulties cited when job-searching are "lack of professional experience", particularly among Master's graduates.
- The majority of graduates in Group C (social work, health) also find suitable, permanent employment immediately after graduating, often in the public and semi-public sector. Formal acceptance of the degrees is high. There are strong similarities with other heavily state-regulated professions in the areas of education, medicine, pharmacy or law.
- Group D (design; music, theatre and other arts) differs markedly from the other groups. The rate of unemployment is higher, many roles are temporary, the graduates are often employed part-time, they seldom hold managerial roles and their earned incomes are lower. Also striking is the high percentage of people who are in a job for which they are over-qualified, particularly in design. A higher than average number of Bachelor's graduates in design work as interns after completing their studies. The job markets in design and music, theatre and arts differ greatly from those of the other groups and are highly fragmented. The creative economy, as it is known, is dynamic, fast-paced and typified by small structures, with a lot of freelancers and micro-enterprises.

In the wake of the Bologna reform, since 2008 the UAS have been selectively introducing Master's programmes. These must be research-based and teach students to apply scientific methods or creative and artistic skills (CRUS et al., 2011). Accordingly, the creation of the Master's programmes was accompanied by the expansion of activities in aR&D. In total, nearly one in five students with a Bachelor's degree switched to a Master's programme in 2013 (universities: around 70%), half of them in the music discipline, in which a Master's is the standard qualification (concert diploma). Overall, the standard qualification at UAS is still a Bachelor.

Continuing education and training

The purpose of continuing professional education and training is to specialise and to consolidate existing qualifications or obtain qualifications for new professional roles. It is highly segmented and predominantly demand-led (Weber & Tremel, 2008). In 2014 the UAS (excluding universities of teacher education), alongside CAS and DAS, offered 302 accredited MAS and EMBA programmes (own calculations by Lepori & Müller based on data from the KFH[4]). Nearly half the courses are in the economics discipline (132 courses, 44%, mostly EMBA) and 15% from technology/IT. An overview of students completing Master's continuing education and training courses at UAS for the last eight years reveals a slight increase in demand from 2,436 (2005) to 2,667 graduates (2013). Two thirds of the degrees obtained were awarded in economics (1,728, 65%), 347 in technology/IT (13%), 188 in social work (7%), and 144 in applied psychology (5%). As continuing education and training at UAS is required to be self-supporting, there is strong competition, including from private providers and universities.

To what extent can the continuing education and training programmes offered by the UAS contribute to innovations? The first, and most direct way in which they contribute is by promoting knowledge and skills among participants. Second is the transfer of knowledge and the sharing of practical experiences among the universities and students, but also among participants in general. Thirdly, the courses provide a platform for encounters and networking, i.e. for forging and nurturing relationships between the UAS and third parties, thus promoting knowledge and technology transfer (see the KOF surveys by Arvanitis et al., and Chapter 4.3).

Conclusion

The aim behind the upgrading of the UAS – namely, to supply the job market with adequately qualified specialists – has largely been achieved. It has not been achieved in those disciplines in which demand exceeds supply and too few specialists are being trained (skills shortage), i.e. the engineering disciplines and, possibly, health. Conversely, the aim is not achieved if the supply of specialists exceeds demand. This is particularly the case in design and in music, theatre and other arts. There are various reasons for this, such as the training taking insufficient account of the needs of the markets, the value of the degrees not (yet) being recognised or the presence of too much competition from people with different qualifications.

[4] 312 courses according to http://fhmaster.ch and 163 courses according to swissuniversities (2015).

However, it should be borne in mind here that not all the people who have qualifications in science and technology later go on to work in this field and that some people employed in science and technology do not have the required formal education - which explains the high relevance of permeability in teaching and continuing education and training.

4.4.2 Second objective: development research projects in partnership with third parties

The political aim is that research at UAS should be applied and practical and "usually carried out in close cooperation with the professional realm or other interested circles" (Universities of Applied Sciences Ordinance UASO, Article 7). In reality, however, because of its specificity, every discipline is positioned differently along the use orientation vs science orientation axis (KFH, 2013; Kiener et al., 2012). Once again, there are substantial differences between the disciplines, which have different stakeholder groups and operate in economic sectors with differing structures.

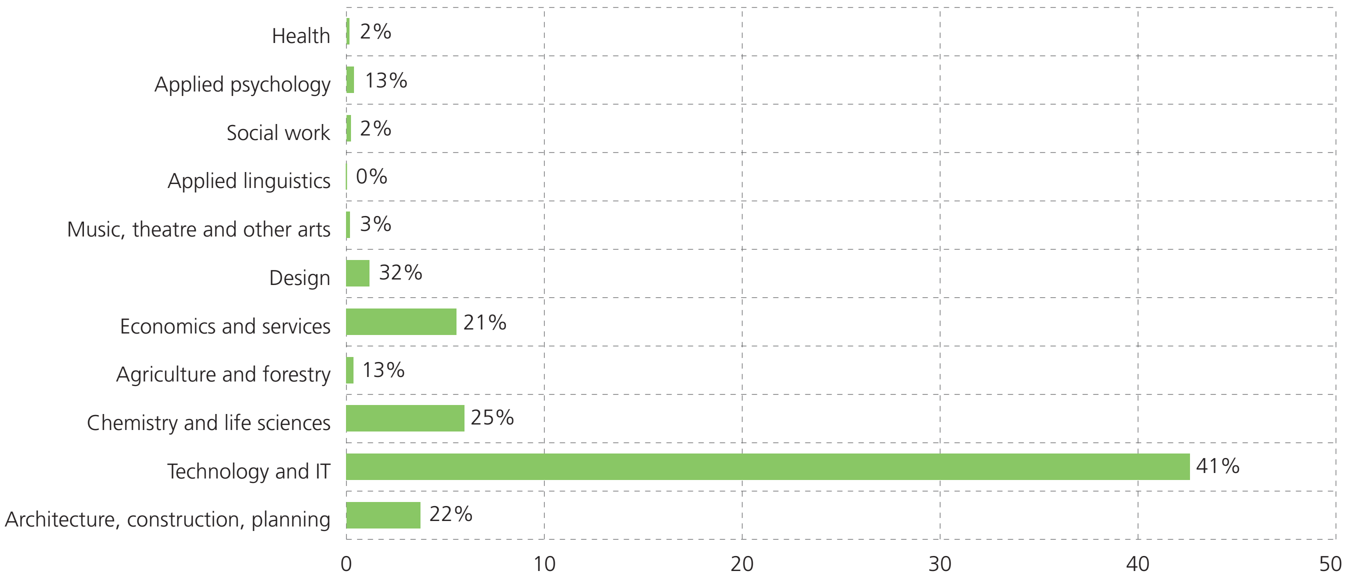
Overview

Although there is no systematic overview, numerous examples from the UAS' activity reports or from publications by the CTI demonstrate the existence of successful collaborations with private enterprises, NGOs and government agencies. In the engineering disciplines, practice partners are often SMEs and in economics they may also be public and semi-public bodies, one example being research on tourism or the regional economy. In the other fields of education, the practice partners are usually public institutions or NGOs (e.g. social work, health) but, on occasion, are very small enterprises from the private sector or freelancers (e.g. in design).

Publications, patents and prestige as indicators of success

Two widely-used indicators for measuring the "success of research" are not adequate parameters where UAS are concerned. "Number of publications and citations", which is the usual set of indicators used in the context of UAS, is not suitable. This is because aR&D does not fit with the publication schedule of the scientific journals. Firstly, the research personnel at UAS has virtually no resources to use research results in this way. Secondly, these indicators are not criteria of success for researchers in the engineering fields. This is partly because, in this field, the results of research with project partners are often subject to a confidentiality obligation - meaning that number of patents - a third, widely-used indicator - is not a suitable indicator either. The more appropriate success criteria in this field are the volume of third-party funds obtained, the number of successful project partnerships and whether the graduates are a good match for the requirements of the job market. In disciplines geared more heavily towards basic research, however, publications are highly relevant, one such discipline being social work. In music, theatre and other arts, status and prestige are better indicators of success. Thus the success criteria differ depending on the orientation of the disciplines.

Figure C 4.13: CTI contributions for aR&D at the UAS, by field of education, in CHF million and as a percentage of income from third-party funds, 2013



Example: In the Design department, 32% of revenue is generated by CTI third-party funds
Source: SERI

Large projects typically involve several partners, including from universities. Two well-known examples are the development of solar vehicles or the erection of the new Monte Rosa hut, which is commonly associated with ETHZ and is often cited as a "flagship project".

Often, the partner projects are based in a particular region and the UAS' thematic orientation reflects the needs of local and regional practice partners. The more specialised an institution is, however, the more frequently it is involved in cross-regional or international collaborations, including with universities at home and abroad.

Cooperation with practice partners, as well as other UAS and universities, usually takes place when the institutions have complementary specialisations and are not competing in the same fields. Competition between UAS and private-sector enterprises is particularly common in consultancy mandates and, in a general sense, contract research – i.e. in areas that are sometimes barely discernible from services.

Partner projects with firms from the private sector

The aR&D projects supported by the CTI are an initial indicator of the extent of cooperation between UAS and firms in the private sector. These projects necessarily entail substantial involvement by the project partners. Typically, these are companies from the private sector. They must bear at least 50% of the project costs, at least 10% of that in the form of a monetary contribution. Although the CTI's four funding areas are, in principle, open to all disciplines, the majority of the approved applications are from the engineering disciplines.

In 2013, 47% of the CTI's project contributions went to UAS, 30% to institutions in the ETH Domain and 13% to cantonal universities. For the engineering disciplines at the UAS, these contributions are very important indeed. In technology and IT, they account for two fifths of all third-party funds; in design, the share is a third, in chemistry/life sciences a quarter and in economics and architecture/construction/planning around a fifth. According to this indicator, collaborations between UAS and firms in the private sector are most widespread in these disciplines – although there are private enterprises and therefore potential project partners in other disciplines too, particularly in the health segment.

The number and financial volume of the CTI project contributions is, however, only an approximate indicator of cooperation between UAS and companies: firstly, the number of partner projects in which the CTI is not involved is not known and secondly this is an input indicator which – based on project concepts – measures success in raising third-party funds. The satisfaction of firms with the results of the projects would be an example of an output indicator. The subsequent launch of more partner projects might serve as a measure of positive satisfaction, for instance.

Figure C 4.14: DORE projects, 2000–2010

Department	Accepted projects	in %	Project total in CHF million	in %
Social work	134	34%	13.5	28%
Health	71	18%	7.6	16%
Art/design	69	17%	10.6	22%
Education	57	14%	7.8	16%
Music, theatre	46	12%	6.0	13%
Applied psychology	11	3%	1.0	2%
Applied linguistics	9	2%	1.2	3%
Total	397	100%	47.7	100%

Source: based on Kiener et al., 2012

Partner projects with public institutions and NGOs

The number and extent of the projects funded as part of the DORE programme is an indicator of partner projects with government institutions and with NGOs. Involvement in this programme was open only to the disciplines that have been newly integrated into the UAS. A practice partner was a mandatory requirement; that partner had to bear at least 30% of the project costs, either in cash or in the form of personnel or contributions in kind. Between 2000 and 2010, the DORE programme supported a total of 397 projects from UAS with contributions totalling CHF 47.7 million. As shown by Figure C 4.14, a third of these projects originated from the social work discipline and just under a sixth in each case from health, art/design, education and music/theatre.

As with the CTI projects, the number and extent of the DORE projects is only an approximate indicator of research cooperation with third parties. Firstly, the list is incomplete because there were also partner projects of this type involving direct contracts. This was partly because practice partners were unable to satisfy the DORE criteria, namely the required financial contribution, or wanted to keep the administrative input low. Furthermore, this indicator measures an input, not an output. Another difficulty when measuring the success of partner projects in the "new" disciplines lies in the time lag before the impact of much of the research becomes apparent and the long chains of effects. Some projects are directly relevant from a business perspective, such as the optimisation of business processes in the care sector, social work or design. In other projects, however, there is a long time lag before the consequences become apparent, or the impact may only be evident elsewhere, as is the case with concepts to promote tourism in the peripheral regions (economics), preventive healthcare or rehabilitation (health), AIDS prevention or integration in the job market (social work). Finally, it should be borne in mind that not all innovations can be precisely measured in quantitative terms, nor do they exclusively pursue commercial aims. As well as technological innovations, there are also artistic and social innovations, the added value of which is non-monetary. Some examples are the value of musical interpretations, works of art, landscaping or the satisfaction of residents in a care home, for which there are simply no reliable indicators.

4.4.3 Third objective: UAS as knowledge and technology transfer interfaces and hubs

Besides jointly financed partner projects, there are many other forms of formal and informal collaboration between UAS and firms from the private sector, with public institutions and NGOs, as well as with other UAS and with universities.

Liaison, institutional networks and knowledge and technology transfer (KTT) support centres

In recent years, the UAS have (like the universities) broadened their PR work and created liaison points which arrange contacts with professional experts and with research centres. Their role is to raise public awareness, specifically among potential customers, of the courses and competencies offered at the UAS and to serve as an easily accessible point of contact. In parallel, career centres and alumni organisations have been created or upgraded. Lastly, the continuing education and training programmes offered by the UAS are also important for networking and transfer: the KOF survey (see below, Firms' perspective) reveals that continuing education and training is one of the most important forms of contact between firms and universities. The CTI supports KTT in various ways, including "innovation mentors", funds eight national thematic networks (NTN) and – together with the SNSF – seven centres of excellence for energy research (SCCER).

Personal networks: lecturers and researchers as interfaces

Networking between UAS, universities and firms is largely conducted through the people involved, who share knowledge and experiences. Professors and lecturers play a vital role in two respects:

- Firstly, through their career: as a rule, lecturers at the UAS have both a university degree and several years' professional experience. As a result, they have forged contacts in both domains, which they then introduce to the UAS. Many employees – including among the non-professorial teaching staff – move between UAS and universities, firms or other institutions over the course of their careers. Each time they move, they take contacts with them. Over time, extensive personal networks form, which also involve people outside their own institution.
- Secondly, through interfaces in their current role: the majority of the staff at UAS are employed part-time at the university and concurrently hold professional roles or work at another educational establishment. More than half of employees in the (biggest) category, "other lecturers" work less than 50% hours and a quarter even work less than 5% of full-time hours (FSO, 2013). Employees are able to contribute their applied, practical knowledge to the university's teaching, research and continuing education and training and apply knowledge from the university to their work in the professional field. Moreover, some lecturers work part-time at several universities at once (UAS and universities), which can facilitate exchanges and work on joint projects.

As such, lecturers are important "nodes" in the network of UAS, universities and professional practice. From personal experience and thanks to their regular contacts, they understand the needs and workings of the other fields, making them highly instrumental in knowledge transfer.

Firms' perspective

In the period 2008–2010, two thirds of the private sector firms surveyed by the KOF were engaged in KTT activities with UAS (69%, see Part B, Chapter 9). Informal contacts, education and training and continuing education and training were the most frequently cited. The main reasons are access to human capital and to research results, along with financial motives.

There are no comprehensive data available on knowledge transfer between the UAS and actors outside the population of the KOF survey. Studies of the creative economy in Zurich are an exception: a highly segmented sector with small structures and lots of (part-time) small enterprises and freelancers, who maintain diverse, mostly informal contacts with each other and with the UAS (Wecker & Theler, 2010).

4.4.4 Regional/national/international orientation

In contrast to the universities, which compete nationally or internationally, as a component of regional innovation systems (RIS) the UAS are designed to help preserve added value outside the major centres. A look at a map of Switzerland (see Chapter 4.2) reveals the decentralised geographical organisation of the UAS. This is particularly marked in the biggest disciplines, technology and economics. Some of the courses are geared towards the needs of the regional job markets and students complete their work placements at regional companies. For teaching and continuing education and training, part-time lecturers are recruited from firms in the surrounding area and continuing education and training courses are geared towards local companies. The UAS offer firms their specialised services and develop joint research projects with them. Moreover, many UAS engage in institutional networking, whereby regional companies are involved in the supervisory bodies (UAS councils) and on advisory boards.

Smaller disciplines are only offered at a few locations, not least in order to achieve a critical mass. The physiotherapy study programme in the health discipline is one example; another are the courses in music, theatre and other arts. These have a strong national and international bias and a very high percentage of cross-regional and foreign students and lecturers. In specialised areas, networks are geared less towards geographical factors than content-related factors, such as specialist knowledge and complementarities.

4.4.5 Summary and discussion: Strengths and weaknesses

Human resources

Research and innovation rely on the availability of adequately trained specialists. UAS are of great importance to initial vocational education and training, further education and training and continuing education and training. There has been a sharp rise in student numbers since the UAS were first founded, dropouts are rare and, in most fields of education, the three-year Bachelor as the standard qualification leads to permanent employment with commensurate remuneration. In the engineering disciplines in particular, the high rate of absorption by the job market is indicative of demand exceeding supply (skills shortage). Overall, the political objective of tertiarisation with practical, professional training geared towards demand on the job markets has thus been achieved in most fields of education. The majority of UAS titles are well-established and are recognised by the market. However, by their own estimation, five years after graduating nearly a third of all graduates with a Bachelor's degree are engaged in an activity that would not require a UAS degree. This is particularly marked in design and is indicative on the one hand of the different structures on the job markets (e.g. higher proportion of self-employed, low level of government regulation). The lower importance of these Bachelor's degrees on the job market may also indicate that the training does not sufficiently meet the needs of the markets, the value of the degrees is not (yet) recognised or that there is too much competition from people with different qualifications. Generally speaking, the study programmes that are offered along similar lines at a PET college or a university are subject to intense competition (two examples being health and economics). UAS are an important provider of continuing education and training, particularly non-consecutive Master's programmes (MAS, EMBA) in the economics discipline.

Research

UAS research projects cover a very diverse range of disciplines in terms of both scope, financing and orientation. Research is well-established in the engineering disciplines and there are a large number of collaborations with practice partners from the private sector. Here, research is geared mostly towards concrete applications and is largely financed by contributions from the CTI and by private third-party funds. In this respect, UAS are highly instrumental in strengthening Switzerland as a research location. In the other disciplines, cooperation with practice partners is less well-documented. In particular, disciplines that are not represented at universities in Switzerland or in which there is little consensus regarding the basics also engage in basic research. In this research orientation, any contribution to innovations is far less direct than in applied research, is subject to a substantial time delay and is difficult to assess. In all disciplines, weaknesses exist when the UAS' courses are not geared sufficiently towards demand and when firms and institutions are not familiar with or do not consider the courses offered at the UAS.

Knowledge and technology transfer

Exchanges between UAS and other actors take place through concrete R&D projects as well as institutional networks such as alumni organisations and continuing education and training programmes and, to a large degree, personal networks. Owing to the required practical orientation of the UAS, their employees' careers usually involve a mix of UAS, university and professional practice. Most staff are only employed part-time at the UAS and work concurrently at other universities and in the professional realm, giving rise to extensive networks.

Significance for the regions

Particularly in the major disciplines of technology and economics, several decentralised locations and diverse networks involving regional companies and institutions are the norm. Among other things, these enable teaching and continuing education and training to be geared towards demand from the region, the provision of work placements for students and the establishment of joint research projects. Smaller, more specialised disciplines and advanced study programmes are often part of networks extending beyond regional borders to the national or international scale.

Overall, the overview reveals that the UAS make an important contribution to innovation in training and continuing education and training, research and KTT. For a further, more detailed discussion, one would need to develop measurement methods which take due account of the individual profiles of the UAS and the diversity of their fields of education.

Gaps in the recording of innovation

As mentioned in Section 4.4.4, while we do have quite a number of insights regarding the formal transfer of knowledge between universities and third parties, particularly from the private sector – research collaborations being one example -, there are clear gaps with respect to informal transfers and, in particular, in the social and artistic disciplines at the UAS. Furthermore, little is known so far about the effective impact of research findings on the various forms of innovation. Below, we outline two options for a more detailed investigation of the impact on the Swiss research and innovation system of education and research by universities in general and the UAS in particular.

- Firstly, we lack systematic information on the careers of researchers who move from universities to the public or private sector. It would be very helpful to know to what degree they are employed in a position in which the research skills they have acquired are put to effective use. What level of research training contributes most effectively to innovations? The mobility of specialists is a major indicator of collaboration between education, the economy and society.
- Secondly, studies of evaluation research demonstrate the great importance of productive interactions between research and society as an indicator of the future impact of research activities (Molas-Gallart & Tang, 2011). This is especially true of the social sciences and humanities. The concept can be implemented on an empirical basis by analysing the researchers' social networks.

Both approaches could be used to expand the hitherto formal measurement of innovation – on the basis of, for instance, collaboration projects and patent statistics – to include the analysis of less tangible forms of knowledge transfer. These approaches are particularly apt for the social work and arts disciplines, in which the contribution to innovation is almost impossible to trace by relying on standard parameters and economic impact.

4.5 Challenges and future prospects

In conclusion, the introduction of the UAS has had a markedly positive impact on the Swiss research and innovation system with respect to the two main objectives of the 1995 reform: the training of human capital and the transfer of research findings to the economy and society.

Firstly, the UAS have become an important medium for tertiary education with a distinct vocational bias. As such, they have contributed in a general sense to the greater availability of specialists in science and technology on the Swiss job market. The predominantly positive data on the employment situation of UAS graduates demonstrate that, as a rule, their qualification profile reflects demand on the job market. The outcome is particularly positive in the technical disciplines but with certain caveats in fields of education such as social work, health and design, in which the formal training does not always match the requirements of the job. The acknowledged disparity between demand on the job market – skills shortage in technical domains and in the healthcare sector – and the choice of study programme is also apparent in UAS education.

Secondly, the UAS have established themselves as an important partner in aR&D and built close working relationships with the private sector, public administrations and society. This is evidenced by numerous joint projects and the fact that many firms mention the UAS as preferred partners for research projects with universities.

These positive results are to a large extent attributable to the unique profile that the UAS have developed, i.e. rather than imitating the t universities, they have focused consistently on practical teaching and aR&D. Thus the research and innovation system owes its smooth functioning to a clear policy on the structuring and management of higher education. Targets, governance mechanisms and financing systems support and promote the distinctiveness and complementarity of the profiles. Unlike other European countries, Switzerland has thus far successfully avoided convergence between UAS and universities but, at the same time, has also promoted the integration of the two types of university and established the UAS as an important actor in the research and innovation system.

The reform of the Swiss higher education system introduced by the HEdA in 2015 creates opportunities as well as risks. The integration of the management system and the joint rules will presumably eradicate obstacles to collaborations – as with Master's programmes – and stimulate competition among the universities. In future, universities will base their profiles to a greater extent on current demand from the economy and society and their own strategic decisions. The switch from a static to a dynamic definition of the profiles is therefore a groundbreaking step in the reform of the university system. At the same time, it should be remembered that the UAS are tending to align with the universities in every higher education system around the world. There are many sociological and structural reasons for this. It is therefore likely that the task of maintaining the equilibrium between integration and distinctive profiles will continue to be a primary focus of Swiss tertiary education in the future, requiring carefully considered decisions at the political level.

This study adds the following four, key issues to the debate about the future development of the Swiss research and innovation system:

1. The definition and delimitation of research and innovation. The classification of types of research, such as basic research and applied research, has become more nuanced; increasingly complex forms of research and innovation are emerging, with hybrid forms (such as problem-oriented and practice-oriented basic research). It is also increasingly recognised that there are substantial differences between technological innovation and other forms of innovation, namely social and artistic innovation. This begs the question whether, and to what extent, a standard definition of research and innovation for all disciplines is (still) useful and appropriate, or whether the heterogeneity of the individual disciplines needs to be more explicitly acknowledged. This question is intrinsically bound up with the different types of demand from the economy and society. The consequence would be a more nuanced understanding of the content, aims, organisation and significance of research and innovation in the various disciplines, something that the universities embraced a long time ago.

2. The educational programme and the training of qualified, specialist personnel. The UAS reform led to a sharp increase in the availability of qualified workers on the job market, with generally positive results in terms of employability. Two issues, however, require further exploration: firstly, the match between formal qualifications and the requirements of the job market, particularly in the social disciplines and in the arts and design, as well as questions about the status of the degrees on the job market. Secondly, the distribution of students across the disciplines: in some sectors of the Swiss economy, there is a chronic skills shortage (particularly in technology and information technology, but also in education and health). Nevertheless, many students are opting for other fields of education. The easing of government control in the future creates the very real risk that the UAS will increasingly gear their educational programmes towards students' preferences, especially as they bring in additional resources. Particularly important here is the balance between Bachelor's and Master's programmes at UAS and the ability to respond to changing demand (in terms of disciplines and qualification requirements). Bearing in mind the autonomy of the individual universities and without preventing competition, it is possible that, in the future, the introduction of coordinating instruments will be discussed.

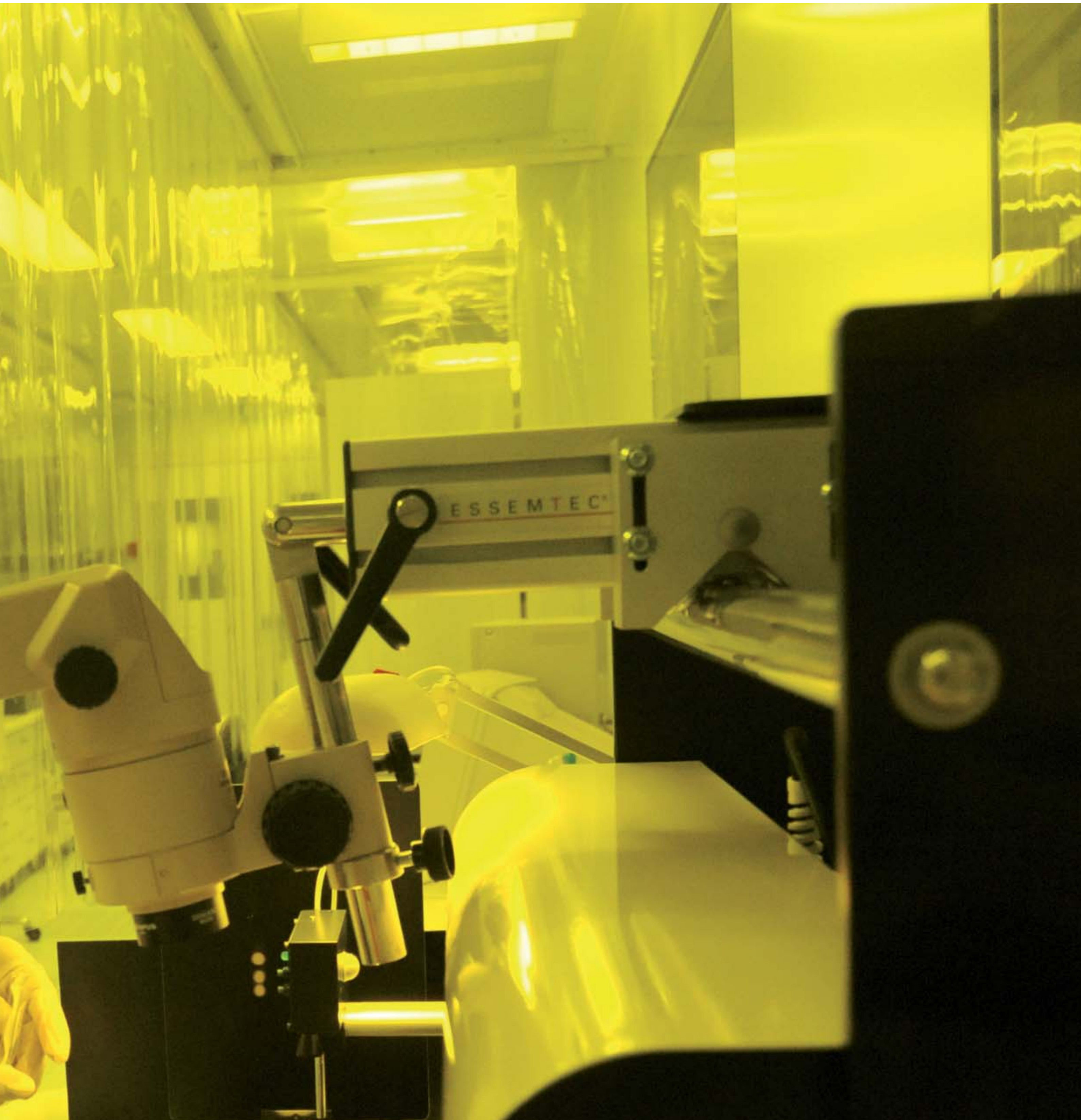
3. The specific profiles of the UAS and the differences compared with the universities. The transition from an absolute to a relative, dynamic differentiation of the two types of university presupposes the following: (a) recognition of the differences that

are essential and of functional relevance to the Swiss research and innovation system and should, as such, be retained; (b) the instances in which more overlap is acceptable or even beneficial to the whole system, including incentives for collaborations, such as the establishment of joint centres of excellence. The balance between teaching and research is a sensitive issue here. The current political framework provides for a clear hierarchy: the primary mandate of the UAS is education, with research ranking secondary. At the same time, however, the UAS are endeavouring to expand their research activities, not least in order to achieve a critical mass. This is resulting in tensions and necessitates an open debate about the extent and significance of research at the universities; whether the different disciplines should pursue different objectives is one of the questions that needs to be addressed. The recruitment and career progression of personnel is a key issue here. How should researchers be trained in order to satisfy the growing demands in terms of competencies while at the same time avoiding academisation? How can permeability for private and public institutions be maintained, as professional experience remains a key requirement for lecturers and researchers at the UAS? How should personnel be managed when the development phase has come to an end? How can the UAS respond flexibly to demand from the economy and society and how should they deal with the shifts in the age structure of their personnel?

4. The fourth issue, which is closely bound up with this, concerns access to resources, particularly for research. Many funding institutions, particularly the SNSF, do not provide for full financing of principal applicants. Under this system, the university funding bodies make individual contributions to basic research. This works better for universities than for UAS, as the latter receive significantly fewer basic subsidies for R&D. While this is in line with the political objective that the UAS should raise their R&D funds primarily from third parties and the CTI, it does create tensions in disciplines in which third-party funds are not readily available and which require a large amount of basic research, which is not directly financed by users. The arts are one example, but also the social disciplines. The configuration of the financing system for R&D, particularly the changes planned from 2017 onwards on the basis of the new HEdA, and the extent of the differences between UAS and universities will therefore be critical to the further development of the UAS and their role in the Swiss research and innovation system.


ROLIC

ANNEX



Rolic Technologies Ltd is an innovative high-tech company that operates worldwide and is based in Switzerland. It develops and sells ready-to-use coating materials and other types of functional foils for screens, security elements and for sealing highly sensitive products. Rolic's core competency is light management. With its patent-protected LCMO technology (Light Controlled Molecular Orientation) Rolic modifies surfaces on a nano scale with polarized light to achieve unique optical effects. As part of a CTI project, Rolic developed a new security element for banknotes and other documents in collaboration with the NTB Technical University in Buchs. Photo: Rolic Technologies Ltd.

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Annex 2 – Abbreviations

AHCI	Arts & Humanities Citation Index
aR&D	Applied research and development
BERD	Business enterprise expenditure on R&D
BFH	Berner Fachhochschule (Bern University of Applied Sciences)
CERN	European Organization for Nuclear Research
CHF	Swiss Francs
CIS	Community Innovation Survey
COST	European Cooperation in Science and Technology
CSEM	Centre suisse d'électronique et de micro-technique
Cst	Federal Constitution
CTI	Commission for Technology and Innovation
CTR III	Corporate tax reform
DETEC	Federal Department of the Environment, Transport, Energy and Communications
DFG	Deutsche Forschungsgemeinschaft
EAER	Federal Department of Economic Affairs, Education and Research
Eawag	Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz (Swiss Federal Institute of Aquatic Science and Technology)
EDK	Swiss Conference of Cantonal Ministers of Education
EEN	Enterprise Europe Network
EIT	European Institute of Innovation and Technology
Empa	Eidgenössische Materialprüfungs- und Forschungsanstalt (Swiss Federal Laboratories for Materials Science and Technology)
EPFL	Ecole polytechnique fédérale de Lausanne (Federal Institute of Technology Lausanne)
EPO	European Patent Office
ERC	European Research Council
ERI	Education, research and innovation
ERI Dispatch	Dispatch on the Promotion of Education, Research and Innovation
ESA	European Space Agency
ESA95	European System of Accounts
ETH	Federal Institutes of Technology
ETH Zurich	Eidgenössische Technische Hochschule Zürich (Federal Institute of Technology Zurich)
EU	European Union
EUR	Euro
FDEA	Federal Department of Economic Affairs (through the end of 2012)
FDFA	Federal Department of Foreign Affairs
FDHA	Federal Department of Home Affairs
FET	Future Emerging Technology

FHNW	Fachhochschule Nordwestschweiz (University of Applied Sciences and Arts Northwestern Switzerland)
FHO	Fachhochschule Ostschweiz (University of Applied Sciences of Eastern Switzerland)
FHZ	Fachhochschule Zentralschweiz (University of Applied Sciences of Central Switzerland)
FP	Research Framework Programmes of the European Union
FSO	Swiss Federal Statistical Office
GBAORD	Government Budget Appropriations or Outlays for R&D
GDP	Gross domestic product
GEM	Global Entrepreneurship Monitor
HEdA	Federal Act on Funding and Coordination of the Swiss Higher Education Sector
HES-SO	Haute école spécialisée de la Suisse occidentale (University of Applied Sciences and Arts Western Switzerland)
ICT	Information and communication technologies
IMD	International Institute for Management Development
IPC	International Patent Classification
IPI	Swiss Federal Institute of Intellectual Property
ITER	International Thermonuclear Experimental Reactor
IUS	Innovation Union Scoreboard
JPI	Joint Programming Initiatives
JTI	Joint Technology Initiatives
KOF	Konjunkturforschungsstelle der ETH Zürich (Swiss Economic Institute)
KTT	Knowledge and technology transfer
MINT	Mathematics, information technology, natural science and technology
NACE	Statistical classification of economic activities in the European Community
NAICS	North American Industry Classification System
NCCR	National Centres of Competence in Research
NRP	National Research Programmes
NTN	National thematic networks
OECD	Organisation for Economic Co-operation and Development
OPET	Federal Office for Professional Education and Technology (through the end of 2012)
PCT	Patent Cooperation Treaty
PISA	Programme for International Student Assessment
PNP	Private non-profit organisations
PPP	Public-private partnerships
PSI	Paul Scherrer Institute
R&D	Research and development
RIPA	Federal Act on the Promotion of Research and Innovation

RIS	Regional innovation systems
RTA	Revealed Technological Advantage
SAHS	Swiss Academy of Humanities and Social Sciences
SAMS	Swiss Academy of Medical Sciences
SATW	Swiss Academy of Engineering Sciences
SCIE	Science Citation Index Expanded
SCNAT	Swiss Academy of Sciences
SECO	State Secretariat for Economic Affairs
SER	State Secretariat for Education and Research (through the end of 2012)
SERI	State Secretariat for Education, Research and Innovation
SFOE	Swiss Federal Office of Energy
S-GE	Switzerland Global Enterprise
SME	Small and medium-sized enterprises
SNSF	Swiss National Science Foundation
SSCI	Social Sciences Citation Index
SSIC	Swiss Science and Innovation Council
SUPSI	Scuola universitaria professionale della Svizzera italiana (University of Applied Sciences and Arts of Southern Switzerland)
SVC	Swiss Venture Club
SwissCore	Swiss Contact Office for European Research, Innovation and Education
swissuniversities	Rectors' Conference of the Swiss Universities
swiTT	Swiss Technology Transfer Association
TA-SWISS	Centre for Technology Assessment
TBS	Temporary Backup Schemes
UAS	Universities of applied sciences
UASA	Universities of Applied Sciences Act
USI	Università della Svizzera italiana
UTE	Universities of teacher education
VDK	Conference of Cantonal Directors of Economic Affairs
VI	Venture Incubator
VPETA	Vocational and Professional Education and Training Act
WEF	World Economic Forum
WIPO	World Intellectual Property Organization
WoS	Web of Science
WSL	Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft (Swiss Federal Institute for Forest, Snow and Landscape Research)
ZEW	Zentrum für Europäische Wirtschaftsforschung (Centre for European Economic Research)
ZFH	Zürcher Fachhochschule (Zurich University of Applied Sciences)

Annex 3 – Project support

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