RESEARCH AND INNOVATION IN SWITZERLAND 2020

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Table of contents

Preface

Switzerland in the 21st century operates in a highly globalised and competitive environment. To be able to compete internationally, strong performance in education, research and innovation is necessary and important. For this reason, the Federal Council has for some time attached great importance to ERI policy, for which responsibility is shared by the federal government and the cantons, and links it with priorities in financial policy.

Wherever investments are made, it is important to understand their impact. This also applies in the field of education, research and innovation, in which a number of monitoring and impact analysis instruments are employed. The Research and Innovation in Switzerland report is just one of these. The report provides a comprehensive view based on systemic monitoring of the Swiss research and innovation system and the way it functions, with selected comparisons between countries and regions and an in-depth look at specific topics. The report can be understood as a reference tool and basis for discussion, for example for the Federal Council Dispatch on the Promotion of Education, Research and Innovation, which is drawn for four-year periods.

This second edition of the report has again been prepared under the lead of the State Secretariat for Education, Research and Innovation and with the assistance of external experts. It paints an overall positive picture of the achievements in research and innovation in Switzerland. Particular mention should be made of the major initiative by private companies and the overall favourable conditions for both public and private players in the ERI sector. New funding instruments such as the Bridge programme, run jointly by the Swiss National Science Foundation and Innosuisse, and the Swiss Innovation Park are helping to close the gap between research and application.

However, the report also identifies challenges, such as Switzerland's competition with innovative regions, the digitalisation of the economy and the decline in innovation activities among SMEs. The seven studies on specific topics also offer a wealth of information. The example of studies into vocational education and training clearly shows that the success of education, research and innovation lies in an overall competitive system. Another study shows the importance of the humanities and social sciences for innovation, reflected, for example, in the success of the watchmaking industry. The analyses of technology transfer between businesses and scientific organisations are also interesting, showing as they do that it is possible to translate promising research results into applications in an even more targeted manner.

I wish you an inspiring read. I would also like to thank all those who have contributed to the success of this work.

Martina Hirayama
State Secretary for Education, Research and Innovation

Foreword by the Expert Group

The second issue of the Research and Innovation in Switzerland report gives an overview of the Swiss research and innovation system, with country and regional comparisons and a more detailed presentation of selected topics. We the expert group have been involved in the production of this report through all its stages.

Research and innovation are vital to ensuring sustainable social and economic development in Switzerland. From the various analyses in this report it can be seen that the Swiss research and innovation system is currently very strong in an international comparison. However, the analyses also show that the gap between countries is closing and that Switzerland is not as strong in a comparison with the world's major innovative regions (e.g. Baden Württemberg or the Boston area) as in a country comparison.

Ongoing change in all areas of society, the economy, and science and technology creates a constantly fluctuating environment for research and innovation. Nonetheless, there are a number of factors that enable Switzerland to enjoy success in this area, and these are described in this report. We also highlight the challenges currently facing our research and innovation system and the challenges it can expect to face in the future.

Success factors for Switzerland

Among the success factors in Swiss research and innovation are the innovative private sector, a differentiated education system, efficient use of public money to promote research and innovation and an overall sound policy framework.

Competitive and innovative businesses

In 2017 Switzerland invested 3.4% of its gross domestic product (GDP) in research and innovation. Two thirds of this amount was contributed by the private sector (2.3% of GDP) (FSO, 2019).[1] A handful of international corporations in the pharmaceutical, chemical, machine engineering and food industries contribute the lion's share of this funding and conduct the most research and innovation. Although the number of small and medium-sized enterprises (SMEs) conducting R&D has declined since the first decade of this century, these businesses also play an important role in innovation in Switzerland. In a comparison with other European countries, they are particularly strong in introducing innovations in the areas of marketing and organisation (European Commission, 2019). Start-ups also make a significant contribution, for example in the life sciences and in financial services.

[1] See Part A, Section 4.1.

Further important success factors are partnerships between companies and the involvement of clients and universities in research and innovation processes. The variety and concentration of local economic systems and the favourable conditions under which they operate are further contributors to the innovative strength and high degree of competitiveness of Swiss businesses.

Differentiated education system

Switzerland has an education system offering both vocational and academic career paths, and considerable flexibility within and between the two. This ensures that there is a sufficiently skilled workforce along the whole of the increasingly complex innovation and value-creation chain.

The higher education sector[2] provides undergraduate and post-graduate teaching, conducts research and knowledge and technology transfer and provides services for third parties. Its contribution to research and innovation depends in large part on international cooperation. It is essential for a small country such as Switzerland to be able to recruit the best international researchers and students, to take part in international research programmes (e.g. the European Union Framework Programmes for Research and Innovation) and to be a member of international research organisations if its higher education institutions are to remain leaders in international research and participate in knowledge sharing at global level.

Switzerland's dual vocational education and training (VET) system is another key factor in the country's innovative success. Around two thirds of school-leavers choose this pathway, which gives them practice-oriented education and training tailored to the latest requirements of the workplace. Moreover, this pathway allows them to go on to pursue studies at tertiary level.

Efficient research and innovation promotion

State promotion of research and innovation is conducted on a competitive basis: that is to say, funding applications are, whenever possible, assessed according to excellence. The funding instruments allow researchers to select their own topics and projects to a large extent. Operating on this principle, the Swiss National Science Foundation (SNSF) funds basic research and Innosuisse promotes science-based innovation.

Quality of framework conditions

Switzerland provides some of the best framework conditions for research and innovation in the world. The infrastructure available is of the highest quality. The country has generally low taxation, a flexible labour market, a stable political environment and good quality of life.

[2] The cantonal universities and the two federal institutes of technology, the universities of applied sciences and the universities of teacher education.

Challenges for Swiss research and innovation

Digital change in the interests of society and the economy

One overarching challenge facing society and the economy is the continued development, introduction and application of digital technologies. Several questions arise in this regard: How can the requisite digital skills be acquired in all areas of society and in all generations and socio-economic groups? How can the opportunities that digital change affords be exploited, and how can we ensure at the same time that we approach them sensibly and responsibly? How can businesses, and SMEs in particular, keep up with technological developments and help to shape them? How can we keep up the rate of innovation and so remain competitive on the international stage?

These and other questions on digital change are reflected in some of the challenges outlined below that we have identified in the context of Swiss research and innovation. We believe it is very important to mention that the greatest challenges and opportunities arise at the interface between digitalisation and other technologies, for example between big data and technologies in the health sector.

Developing expertise to deal with digital change

Digitalisation skills must in future be taught at all levels and in all curricula of the formal education system and in continuing education and training.[3] Things are moving in this direction;[4] however, efforts must be increased and accelerated. In the context of digitalisation, life-long learning also plays a key role. Besides integrating new content into formal education, there needs to be targeted training for people in the work process and for people with interrupted employment and in retirement.

All of us will need new digital skills to cope with an increasingly digitalised world. There will be new, unprecedented opportunities such as better medical care, new mobility concepts and new forms of learning and leisure activities. It will therefore be necessary to define the requisite digital skills for all types of education and target groups and – where these do not yet exist – develop strategies for ensuring they are acquired within a reasonable period of time.

[3] Formal education involves compulsory schooling, upper secondary schooling and tertiary education. Continuing education and training (CET) is non-formal education, e.g. conferences, seminars and courses. There is also informal learning, which includes work in the family, volunteering and learning through reading specialist literature.

[4] For example, in 2018 the Federal Council and the Swiss Conference of Cantonal Directors of Education (EDK) decided that Information Technology should become a compulsory subject in academic baccalaureate schools from 2022/2023 at the latest. Furthermore, the Swiss Conference of Rectors of Higher Education (swissuniversities) has launched the Strengthening Digital Skills in Teaching programme. In vocational education and training, the 'digitalinform.swiss' initiative supports all players in exploiting the opportunities presented by digital change according to their needs.

Creating new knowledge and basic research in the fields of IT and computer science is also key to dealing with digital change in the future. Skills need to be built up not just in core areas of IT – e.g. technological components of the field – but also in transversal aspects of digitalisation, e.g. data protection. In basic research, people working in all disciplines must acquire and maintain a solid foundation in digital essentials.

Fostering knowledge and technology transfer

Innovation relies to a large extent on new knowledge and findings, which are then translated into new products and processes. Not least because of its small size, Switzerland is not able to generate enough of the required knowledge itself; it needs to exchange expertise with other countries.

This happens primarily in higher education institutions. A major role is played by the large number of internationally recruited scientists[5] teaching and conducting research in Swiss universities. International openness and networking are central elements in successfully promoting knowledge and technology transfer (KTT). The best scientists and academics can be recruited from abroad, and bring their knowledge, experience and contacts to Switzerland, thereby making a significant contribution to the country's innovative potential.[6]

The physical proximity and regional character of the universities of applied sciences are also very important, as is their cooperation with local and regional economies. Despite the growing use of digital tools (internet, social media etc.), it should be noted that the role of informal, face-to-face contact and individual expertise is still a key factor in KTT. It is therefore still very important to foster networks and the opportunities for face-to-face exchanges that these afford.

Depending on the discipline, KTT can be further encouraged when academic staff increasingly bring their experiences from the private sector into universities, and when there is a greater exchange of personnel between universities and business in general. In particular at the universities of applied sciences, which – as the name suggests – are application-oriented institutions, no compromises should be made over the recruitment criterion 'practical experience' – despite the trend in this direction that can be currently observed in some contexts.

Halting the decline in innovation by SMEs and boosting their ability to innovate

The proportion of companies in Switzerland conducting R&D has almost halved in the past 20 years. In SMEs in particular, which make up 99% of businesses in Switzerland, R&D activity has decreased steadily since the year 2000.[7] This tendency can be seen in a number of European countries. The exact reasons for it are unknown and need to be analysed in relation to Switzerland.

Innovation mechanisms are experiencing rapid and radical changes in the wake of digitalisation. How can companies, and SMEs in particular, adapt to these changes and select what is useful for them, and what will help them to innovate? Knowledge and technology transfer is a strong driver of innovation; one possibility is thus to set up specific KTT platforms for SMEs via which universities and research institutes can efficiently transfer their acquired expertise – e.g. in new digital technologies – in order to encourage SMEs to innovate.

Statutory regulations can hinder innovative developments. This is the case, for example, in the finance and health sectors. For SMEs in particular, the creation of innovation spaces[8] may be helpful, in which companies can experiment and develop their ideas without restrictions. Studies should be carried out into how and where such spaces could be set up, what criteria need to be considered and what the associated benefits and risks are.

Fostering a culture of start-ups and entrepreneurship in all fields

Around 300 start-ups are founded each year in Switzerland (start-upticker.ch, 2018).[9] This figure has remained fairly constant for several years. In recent years, around 40 000 new companies have been founded annually (FSO, 2019). Setting up companies that hope to be successful with innovative business models often based on new technologies is an important way of launching new knowledge and new technologies on the market and of creating new sectors in the economy. Entrepreneurship should thus be promoted in higher education institutions and across all disciplines, in particular in the humanities and social sciences.

Securing Switzerland's role in research and innovation activities at international level

International R&I funding instruments complement national ones. For a small country such as Switzerland, international networking and cooperation are essential, giving Swiss players access to major international infrastructures and networks and bringing Switzerland, as all other participating countries, academic, technological and economic benefits. If Switzerland does not have a firm place in international research organisations and programmes, it will not be able to enjoy these benefits.

[5] E.g. graduate students, postdocs and lecturers/assistant professors.

[6] International openness and networking do not only benefit Switzerland, they also have a positive effect on the innovative performance of all countries involved in KTT.

[7] See also Part A, Section 2.1.

[8] Also known as sandpits or sandboxes.

[9] According to the Swiss Start-up Radar 2018/2019 (startupticker.ch) the following six criteria define whether a young company is a start-up: ambitious growth plans, focus on innovation, science- and technology-based approach, scalable business model, international markets and professional investors.

Keeping abreast of developments in research and innovation promotion policy at international level

Swiss R&I promotion is based on competition, the bottom-up principle, spontaneous entrepreneurial initiatives and coordination. This approach does not exclude a policy-driven focus on strategically important topics such as energy research or digitalisation. However, in general, Swiss R&I promotion is not mission-oriented.[10]

The majority of western countries, the US included, have a mission-oriented R&I promotion policy in addition to a market-driven and bottom-up one. Furthermore, some countries are currently discussing or already implement mission-oriented funding models similar to the American Advanced Research Projects Agency (ARPA).[11]

For example, in 2019 Germany set up the Agentur zur Förderung von Sprunginnovationen für den zivilen Anwendungsbereich based on the ARPA model (EFI, 2019; BMWi, 2019).

Characteristics of the ARPA model are flexibility, openness to risk and a person-oriented and entrepreneurial approach. A key role is played by project managers on fixed-term contracts who have excellent knowledge of the latest technologies and of the market (Azoulay et al., 2018). This approach could be useful in the case of technologies that already exist but that are as yet little researched and that have considerable potential for improvement. The aim would not be to conduct sectoral industry policy but to identify and solve urgent issues (e.g. challenges resulting from climate change) in conjunction with the private sector.

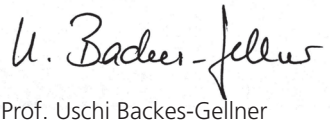
Switzerland is not concerned to create an agency as has been done in Germany. The current research and innovation promotion system functions very efficiently. Public research money is allocated by the SNSF very successfully on the basis of quality criteria. Applied research with direct economic relevance takes place in partnerships between universities and industry, under the umbrella of Innosuisse. However, Switzerland would do well to observe closely how other countries develop their mission-oriented instruments and should consider whether it would make sense to adopt any of these instruments to complement its own.

Improving data

If research and innovation in Switzerland is to be better understood, data bases need to be improved.

As society undergoes digital change, new data sources are required to describe new trends in a meaningful way and provide a basis for impact analyses to assess the effectiveness of economic, social and educational measures. New types of digital data need to be systematically recorded and made available for research purposes. Data sets need to be compiled over long time periods and in such a way that they can be linked (e.g. education data linked with employment, operational and innovation data).

Research data centres that cooperate with statistics offices or other authorities can be very useful in this respect. In some other European countries, e.g. Germany and Denmark, such centres are now standard.[12] They make a major contribution to international comparative studies on economic issues that are of importance to both these countries. Switzerland lags some considerable way behind in this respect, but has, for a variety of reasons,[13] great potential.



Prof. Uschi Backes-Gellner

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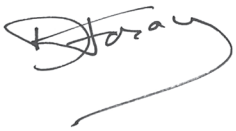

Prof. Dominique Foray

Prof. Joachim Henkel

Dr. Reto Naef

Prof. em. Ulrich W. Suter

[10] Mission-oriented R&I promotion policy pre-defines objectives and the technological developments required to achieve these objectives. Compared to a funding approach based on the creation of conditions that favour research and innovation, the mission-oriented funding is a centralised approach with more precisely defined objectives and priorities (EFI, 2019).

[11] The acronym ARPA has been used in various ways over the years. The acronym DARPA (Defense Advanced Research Projects Agency) also exists (Azoulay et al., 2018). As this report deals with research and innovation in a civilian context, we employ the acronym ARPA.

[12] E.g. the research data centres Statistics Denmark, the Institute for Employment Research (IAB) at the German Federal Institute for Vocational Education and Training (BIBB) and the Deutsche Bundesbank.

[13] In Switzerland, federal structures, direct democracy and the varying nature of the language regions mean it is possible to conduct causal economic analyses of topics such as education, the labour market or fiscal policy in different contexts (e.g. according to cantonal conditions, different social norms or language regions).

Remarks to the English-speaking reader

This is a short version of the 2020 edition of the Report on Research and Innovation in Switzerland. The report is published every four years and is used to monitor the performance of the Swiss research and innovation system, serving as a basis for discussion. The report also highlights various challenges affecting research and innovation and provides an overview of research and innovation activities in Switzerland.

Intended primarily as a reference tool, it is aimed at policymakers to support discussions on the Federal Council Dispatch on the Promotion of Education, Research and Innovation for 2021-2024. The report is also written with research and innovation funding agencies in mind, as well as all individuals, organisations and companies interested in research and innovation in Switzerland, whether at national or international level.

The preparatory work for this report was coordinated by the State Secretariat for Education, Research and Innovation (SERI), which called on outside experts from the Swiss research community and the private sector, as well as other key players.

The long version of the report is divided into three parts:
– Part A: Swiss research and innovation system (description of the system);
– Part B: International comparison of Swiss research and innovation (based on around 90 indicators);
– Part C: Specific topics (in-depth coverage of key issues affecting Swiss research and innovation).

The present short version of the report includes a Management Summary covering the three parts mentioned above, and Part A. Parts B and C are not available in English. The long version of the report containing these two parts is available in German and French.[14]

[14] www.sbfi.admin.ch/f-i_bericht


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MANAGEMENT SUMMARY (PARTS A, B, C)

Established in 2016, the Swiss Innovation Park plays an important role in science and technology transfer. It provides a link between the science community and the business world at sites near each of the federal institutes of technology and at three other locations. The Switzerland Innovation Park Basel Area focuses on the healthcare and med-tech fields. In the Miracle project, researchers at the University of Basel are seeking ways to conduct minimally invasive surgery using laser technology and robotics. They are also developing new navigation techniques with which the robot-guided laser system can be precisely controlled during the surgical operation.
Image: S-GE, Daniel Winkler

The management summary applies to the whole of the 2020 Research and Innovation in Switzerland report including Part B International Comparison of Swiss Research and Innovation and Part C Specific Topics, although these two parts do not appear in the English version of the report.

Part A: The Swiss research and innovation system

Part A provides an overview of the Swiss research and innovation system. It describes the framework conditions, the stakeholders, the areas of government authority and the legal basis. It also explains how research and innovation are funded and describes the main national and international funding mechanisms used to support research and innovation as well as knowledge and technology transfer.

Framework conditions

The distribution of research and innovation tasks between the private and public sectors rests on two fundamental principles of Swiss policy: subsidiarity and a liberal economy. The private sector therefore plays an essential role. In principle, research and innovation activities are pursued within a complex system where respective responsibilities partly overlap.

With regard to the general conditions applying to research and innovation in Switzerland, the salient features include political stability, security and high living standards. Moreover, research and innovation are driven by the market and private initiative. State regulation and intervention are limited. The markets for labour, capital, goods and services are based on competition. Access to international markets is made possible thanks to multilateral and bilateral agreements. This makes the Swiss economy highly flexible and versatile. Switzerland also boasts a highly developed and modern infrastructure by international standards. Finally, taxation levels are relatively advantageous.

One of the specific conditions for research and innovation is freedom of research. The Confederation and the cantons also maintain an education system that offers a complementary range of vocational and academic pathways and ensures permeability both within and between these two pathways. The result is high-quality training of professionals and managers along the entire value chain, making it a key factor driving Switzerland's research and innovation performance. Other specific conditions include established funding mechanisms for research and innovation, and clear rules on the protection of intellectual property.

Players

Switzerland's innovative strength is largely driven by the private sector, which plays a key role in R&D activities. Around two-thirds of research and development activities in Switzerland are funded and pursued by large companies, as well as by SMEs. The Swiss private sector, whose companies often operate internationally, mainly engages in applied research and technological development, often in partnership with higher education institutions, and universities of applied sciences in particular.

The Swiss higher education landscape offers a wide range of study and research opportunities, including study programmes at two federal institutes of technology (one in Zurich and the other in Lausanne), ten cantonal universities, universities of applied sciences and universities of teacher education. Swiss higher education institutions have made internationally recognised achievements. Federal institutes of technology and cantonal universities mainly pursue basic research and research-based teaching. In contrast, universities of applied sciences focus more on research and development. In addition to teaching (incl. continuing education and training) and research activities, Swiss higher education institutions are also involved in knowledge and technology transfer and the provision of services to third parties. All Swiss higher education institutions are part of international networks, which is important for Swiss research and innovation.

In addition, numerous independent, federally funded research institutions help to bring added value to research. The Federal Administration itself is also a further player of research and innovation with its Federal Government Research, which is either conducted by federal agencies directly, or is outsourced to higher education institutions or private companies.

Government support

Public funding of research and innovation is essentially the responsibility of the federal government. It is mainly coordinated by the Federal Department of Economic Affairs, Education and Research (EAER) and its State Secretariat for Education, Research and Innovation (SERI).

The Federal Act on the Promotion of Research and Innovation (RIPA) generally regulates the tasks and structure of federal support for research and innovation at both national and international level. RIPA also sets out the tasks, procedures and responsibilities of funding institutions.

Under the Federal Act on the Funding and Coordination of the Higher Education Sector (HEdA), federal and cantonal authorities work together to ensure the coordination, quality and competitiveness of the entire Swiss higher education sector, whose upstream research endeavours contribute significantly to downstream innovation activities.

As sponsors of cantonal universities, universities of applied sciences and universities of teacher education, cantonal authorities also support research and innovation. Moreover they promote business start-ups and regional networks, either at their own initiative or in partnership with other cantons. At local level, municipal and communal authorities support innovation by creating technology and innovation parks, for example.

Finances

In 2017, a total of CHF 22.5 billion, roughly 3.4% of gross domestic product (FSO, 2017), was spent on research and innovation in Switzerland, making the country one of the world's top investors in R&D in relative terms.

Most of this expenditure came from the private sector, which funds and conducts around two-thirds of total R&D activities. Federal and cantonal authorities account for roughly a quarter of R&D spending. Most public funding is allocated to the ETH Domain, to cantonal universities and to universities of applied sciences.

Branches of Swiss companies abroad also have significant R&D expenditure, which in 2017 was only slightly lower than the domestic R&D expenditure of Swiss companies.

Public funding of research and innovation

The bottom-up approach is a key guiding principle in the public funding of research and innovation: researchers and companies pursue research and innovation activities at their own initiative, assuming responsibility and the associated risks. Compared to other countries, Switzerland is cautious about top-down imposition of areas and programmes that are eligible to funding. Another basic principle is that public funding must be competitively awarded on the basis of excellence. Grants are not usually awarded directly to companies. Other basic features include freedom of action of the private sector and the autonomy of higher education institutions, the rapid dissemination of innovations through networks and Switzerland's appeal as a location for education and research for talented researchers and specialists from all over the world.

There are two federal institutions that fund research and innovation in Switzerland: the Swiss National Science Foundation (SNSF) and the Swiss Innovation Agency (Innosuisse). Both institutions review and select projects on a competitive basis. The SNSF is the most important Swiss institution supporting scientific research. It also devotes particular attention to the advancement of young scientists. Innosuisse, on the other hand, is the federal institution responsible for supporting research-based innovation and encouraging the transfer of knowledge between public research institutes and industry. Among other things, Innosuisse supports science-based start-up companies.

Through the federal government's new Regional Policy, the State Secretariat for Economic Affairs (SECO) seeks to improve the competitiveness of Swiss regions by supporting local entrepreneurial initiatives and innovation. The cantonal authorities also pursue similar endeavours – some within the framework of SECO's regional policy – to encourage innovation and economic growth. Finally, there are numerous foundations that play a significant role in promoting research and innovation.

International cooperation

Cross-border cooperation gives Swiss players access to international networks and brings scientific and economic benefits to Switzerland.

Switzerland's participation in the EU framework programmes for research and innovation is essential. Researchers in Switzerland have been taking part in the EU research framework programmes since 1988, either under the terms of Switzerland's third country or associated partner status. Today, Swiss companies, particularly SMEs, report that EU research framework programmes are the main source of public funding for research and innovation.

Switzerland is a member and partner of other international research programmes, infrastructures and initiatives. For example, it is a member of the European Space Agency (ESA) and is both a host country and member of the European Organization for Nuclear Research (CERN) in Geneva. As a result, the Swiss research and innovation community is able to conduct experiments at cost-intensive research infrastructures and gain access to a broad range of knowledge.

In addition, Switzerland works bilaterally with non-European countries and maintains a global network of Swiss consular offices and counsellors devoted to science and technology.

Knowledge and technology transfer

Knowledge and technology transfer (KTT) between companies as well as between companies and higher education institutions is becoming increasingly important for successful innovation. This entails the exchange of information, skills and R&D findings as well as their transformation into marketable products and services.

Over time, technology transfer offices have been established at various institutional levels with different remits to promote and support KTT. The Swiss Innovation Park plays an important role in fostering KTT in Switzerland. There are two hub locations, one near the ETH Zurich and the other near the EPF Lausanne. There are also three other sites devoted to science and business that are joined together within the same network. Finally, most cantons and many urban areas in Switzerland have technoparks where KTT takes place.

Part B: International comparison of Swiss research and innovation

Part B examines how well research and innovation in Switzerland compares to that of other industrialised and emerging countries.[1] Overall, the analysis shows that Switzerland is well-positioned at international level. Most of the indicators measuring investment, synergies and performance of the research and innovation system place Switzerland in pole position.

Gaps between the countries considered in the comparison, however, are generally closing. At the same time, countries that have established themselves as research and innovation leaders in recent years (including Switzerland) now have to compete with countries such as China, Israel, Singapore and South Korea. Particular attention should therefore be paid to areas where Switzerland could potentially gain or lose ground.

Framework conditions

Favourable framework conditions are an essential prerequisite for a country's success in research and innovation. Together with Singapore and Denmark, Switzerland offers some of the best conditions: a high level of political stability, top-notch infrastructure and public services, as well as good living standards in economic hubs. All of these conditions make Switzerland a particularly appealing location for research activities. Low corporate taxation and a flexible labour market are also important considerations for innovative companies.

In terms of e-government, however, Switzerland trailed the other countries: in an international comparison, neither the availability, nor the quality of public online services were found to be convincing.

Education and skills

Swiss research and innovation activities are sustained by Switzerland's high quality education system, which in addition to academic pathways also gives considerable importance to vocational pathways at both upper-secondary and tertiary level. The Swiss population in general is highly educated: in 2018, over half of the population between the ages of 25 and 34 held a tertiary-level qualification. Only South Korea and Japan report even higher proportions. Among those holding a tertiary-level qualification, a noticeable shift in trend was observed among young women and men in Switzerland over the past 15 years: while in 2005 only 25% of women aged 25-34 held a tertiary-level qualification (37% of men), that share has now risen to 54% (49% of men).

Tertiary level education in Switzerland is highly internationalised. Together with the UK and Austria, Switzerland is one of the most desirable destination countries for foreign students pursuing tertiary-level education. This is particularly true of PhD students: over half of PhD students are foreign and over three-quarters of those are from the European Union.

Research and innovation staff

Switzerland has outstanding human capital: over 40% of the Swiss working population is involved in the creation, dissemination and application of scientific and technological knowledge. In terms of the share of R&D staff in total employment, however, Switzerland is only average among peer countries and, in particular, has a relatively low proportion of researchers. For these indicators, Nordic countries clearly come out on top.

Recruiting foreign researchers, technicians and R&D support staff by private companies and higher education institutions is essential for the development of research and innovation activities in Switzerland. Between 2000 and 2017, the number of foreign R&D staff working at higher education institutions and companies doubled. In 2017, foreign R&D staff accounted for 43% of total university R&D staff (28% in 2000) and 42% of R&D staff in private companies (32% in 2000). In addition, over half of researchers working at higher education institutions (52%) and in the private sector (51%) were foreign nationals.

Women account for 35% of researchers working in Switzerland, which is a high figure compared to the other countries considered in the comparison. However, the 'leaky pipeline' phenomenon is still apparent: Although 53% of master's degree students are women, only 23% of all professorships and senior research positions are held by women. In Switzerland, the proportion of female professors and senior researchers in the medical sciences, health and natural sciences is lower than in the European Union.

R&D expenditure and funding

Switzerland remains one of the countries with the highest level of R&D expenditure in relation to GDP, behind South Korea and Israel. In Switzerland, as in most peer countries, private companies account for over 60% of the total expenditure concerned. Swiss higher education institutions also play an important role, accounting for nearly a third of total R&D expenditure.

[1] The following countries were considered in this analysis: Austria, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, the Netherlands, Norway, Singapore, South Korea, Sweden, the UK and the USA.

For the first time since 2000, growth in total intramuros R&D expenditure (i.e. expenditure on R&D activities in Switzerland) slowed down significantly in 2017. Sector-by-sector analysis reveals for the first time that companies with at least 100 employees did not increase their R&D expenditure.

As in most of the countries considered in this comparison, the private sector was the main source of R&D funding in Switzerland.

Despite this, top priority is given to public sector funding of intramuros R&D expenditure in Switzerland. Within the space of ten years, the increase in public sector funding of R&D expenditure (Confederation and cantons) – measured in terms of the ratio of total public funding to GDP – in Switzerland has been higher than in peer countries.

Participation in EU framework programmes

Participation in the EU research framework programmes is a priority of Swiss research and innovation policy. By taking part in the FPs, institutions, companies and researchers in Switzerland are able to work with leading foreign partners, exchange knowledge and share access to world-class infrastructure.

Since 1992, the number of instances of Swiss participation in the FPs has increased six-fold. Such participation is particularly important for research projects carried out by ETH Domain institutions and cantonal universities. Since 1992, ETH Domain institutions have secured a total of CHF 2.3 billion in EU funding and Swiss cantonal universities have secured CHF 1.7 billion. Moreover, the FPs are the main source of public funding of research and innovation activities of Swiss SMEs (CHF 820 million since 1992) and industrial companies (CHF 638 million since 1992).

Due to the adoption of the popular initiative against mass immigration in 2014, Switzerland was less active in FP8 Horizon 2020 (2014–2020) than in FP7 (2007–2013). However, if we consider the number of instances of Swiss participation in Horizon 2020 and the total amount of funding awarded to Swiss institutions, Switzerland is the most important non-EU partner for EU research activities. Moreover, the high success rate of Swiss project proposals in FPs confirms the high quality of Swiss research.

Scientific publications

Switzerland and Denmark have the highest volume of publications per capita. Despite increasing competition from countries such as China and Singapore, Switzerland continues to produce a considerable volume of high-impact research publications relative to its small size.

In terms of the number of publications output and their impact, it can be said that research in Switzerland tends to focus mainly on 'Clinical Medicine', 'Life Sciences' and 'Physics, Chemistry and Earth Sciences'. In addition, Swiss publications in the field of 'Technical and Engineering Sciences, Information Technology' have a high impact at international level despite their small share as a proportion of the total number of publications.

Switzerland's success in research activities and research output is partly due to the fact that it maintains strong international networking ties and works extensively with foreign institutions. Between 2014 and 2018, 85% of Swiss research output was the result of international cooperation.

Patents

Patent applications provide an insight into the extent of technological and commercial use of research findings in a given country.

Relative to the number of inhabitants, Switzerland has the highest number of international patent applications, followed by Japan and Sweden. As far as patents are concerned, Switzerland is the country that works the most intensively with foreign countries: 42% of internationally patented inventions are the result of international cooperation, with 30% being from cooperation with researchers from the European Union.

The knowledge gained in Switzerland is also used by foreign companies: around a third of all international patent applications filed by researchers working in Switzerland are owned by foreign companies. Switzerland is therefore one of the five most preferred countries in terms of foreign investment in research.

In the technology sectors, Switzerland is particularly specialised in health and biotechnology. However, its specific areas of specialisation do not include environmental technologies (in which Japan is the leader), nanotechnologies (dominated by Singapore) and information and communication technologies (where China is the leader).

Information and communication technology

Compared to other countries, Switzerland's strong digital orientation is striking. A significant portion of the labour force is employed in the production of goods and services relating to information and communication technology (ICT), and particularly in the development of software and databases. These ICT activities are due in part to the fact that a large number of ICT specialists have completed vocational education training programmes in the IT field since the early 2000s.

Compared to the leading countries in this comparison (USA, Israel, South Korea), Switzerland's ICT research and innovation expenditure and venture capital investment in the ICT sector are relatively low. However, in terms of quality, Switzerland's IT publications and artificial intelligence patents are among the world's best.

In the area of cybersecurity, however, Switzerland is one of the least well-prepared countries in the comparison. Swiss companies, especially SMEs, are also less likely to use cloud-based computing services than companies in most of the countries considered (especially Nordic countries).

Knowledge and technology transfer

In Switzerland, close ties between higher education institutions and companies are a success factor for research and innovation. Knowledge and technology transfer (KTT) ensures that knowledge flows between these two partners. Such KTT activities are a prerequisite for creating the cooperation networks that give rise to innovation, enable the economic potential of research findings to be tapped and bring real-world knowledge to academic research.

About one in four Swiss companies is involved in KTT activities. These activities are mostly informal in nature (e.g. attending conferences or reading scientific publications) and also take place through direct contact between companies and higher education institutions (students, graduates or researchers). Companies mainly take part in KTT activities to recruit human capital and – to a lesser extent – to gain access to research findings. In Switzerland, universities of applied sciences and federal institutes of technology are the main partners for companies involved in KTT.

However, in Switzerland as in other countries, company size is closely correlated with the intensity of KTT activities. Moreover, a significant proportion of companies state that a lack of interest and internal resources to pursue R&D is one of the main obstacles to taking part in KTT activities. Additional factors hindering KTT activities include a lack of interest on the part of higher education institutions in business-related R&D and their limited entrepreneurial drive.

Entrepreneurship

Start-up companies can offer new or improved products and provide support to already established companies in specific areas of expertise. Therefore, entrepreneurial activity and entrepreneurship within the population is crucial for the development of innovation.

In Switzerland, those most likely to start an entrepreneurial activity fall into the 25-to-34 or 45-to-54 age category. However, the proportion of the Swiss labour force that has either started or managed a new business is lower than in the USA, South Korea and Israel. The working population in Switzerland primarily states that they do not have the required skills to start a business and are afraid of failing. Moreover, entrepreneurship as a career step seems to be less highly regarded in Switzerland than in the vast majority of the countries considered in the international comparison.

Apart from access to venture capital – which is much easier in the USA – Switzerland offers relatively favourable conditions for the creation of innovative start-up companies. In the EU, particularly in the Netherlands and Austria, the general conditions for business start-ups are also promising.

Innovation activities of companies

The proportion of innovative companies is declining in Switzerland. In the industrial sector, it fell from 67% to 55% between 2006 and 2016. In the services sector, the proportion of innovative companies fell from 54% to 44% over the same period. Although these two proportions were the highest among peer countries in the early 2000s and Switzerland remains in the top group today, it lags behind Finland and the Netherlands. These two countries have reported strong growth since 2012. The latest results from 2016 show that gaps between peer countries have narrowed considerably.

However, Swiss companies sell fewer market innovations than most of their peers (especially the Netherlands and Italy). This is particularly true of the services sector. In most cases, the 'innovations' marketed in Switzerland are only novel for the company in question. In other words, only a few companies in Switzerland actually launch entirely new innovative products or services that were not previously available on other markets.

Structural change

Switzerland is among the industrialised countries able to actively respond to new market developments, to tap the potential of technological progress and to adapt to structural changes in demand and competition. Industries with intensive research activities (grouped together in the sub-sectors 'high-tech industry' and 'modern services') account for over half of nominal added value. Only the USA, Germany and South Korea have similarly high proportions.

Since 2000, the proportion of low-tech industry in nominal added value in Switzerland has decreased significantly. In contrast, the proportion of services in nominal added value has risen. This development can be seen in nearly all of the countries compared. As in most peer countries, this increase in Switzerland is mainly due to the higher share of modern services in nominal added value.

Comparison of Switzerland with leading research and innovation metropoles

A differentiated comparison of Switzerland with 21 leading research and innovation metropoles around the world confirms that it is in a very good position overall. However, Switzerland stands out less clearly in this comparison than in the comparison with peer countries.

For example, the ratio of intramuros R&D expenditure to GDP is significantly higher in eight other leading research and innovation metropoles, including the San Francisco Bay Area and Daejeon. As far as neighbouring countries are concerned, only Baden-Württemberg has a higher ratio of R&D expenditure to GDP than Switzerland.

In terms of the number of research publications per capita, Switzerland is surpassed only by three North American metropoles: the Boston and New York metropolitan areas and the San Francisco Bay Area. In Europe, the Paris metropolitan area is not far behind Switzerland.

For patents per capita, Switzerland is surpassed only by the San Francisco Bay area. In Europe, the Paris metropolitan area, Bavaria and Baden-Württemberg rank immediately behind Switzerland, but by some considerable way.

Although the number of innovative companies in Switzerland is declining, only Baden-Württemberg has a higher share of innovative companies in the total number of companies. Bavaria and Lombardy/Piedmont are roughly on a par with Switzerland.

Finally, in terms of the share of employment in knowledge-intensive sectors, Switzerland ranks sixth. The first three positions are held by Baden-Württemberg, Bavaria and the Paris metropolitan area.

Part C: Specific topics

Part C presents seven research studies on selected topics deemed essential for the Swiss research and innovation system.

Study 1: Contribution of the Swiss VPET system to innovation

Switzerland's system of upper-secondary level vocational education and training and tertiary level professional education is a major source of innovation for companies and maintains the innovative capacity of the economy as a whole. The Swiss VPET system ensures that workers possess the vocational and professional competence that makes innovation possible and offers workers a wide range of options for continued pursuit of education and training. In this manner, the Swiss VPET system helps to drive innovation and establishes optimal conditions for adaptation to innovation-related changes in the labour market. This study identifies the key features of the Swiss VPET system that are important for innovation and highlights the main challenges. It also shows the impact of the Swiss VPET system at three levels (systemic, company and individual).

Study 2: Contribution of humanities and social sciences to innovation

Nearly two-thirds of respondents in this study stated that they had obtained their higher education qualifications in a field relating to humanities and social sciences. While this category is clearly important for the Swiss education, research and innovation system, its contribution to innovation is often not recognised, or tends to be underappreciated. This study therefore examines the contribution of the humanities and social sciences to both business and social innovation. This study's findings show that innovation is a multidisciplinary endeavour and therefore cannot be viewed solely from the perspective of exact sciences. Through their specific functions - developing and organising, giving meaning, providing a framework and jointly introducing innovations into society - the humanities and social sciences play a key role in the Swiss innovation system.

Study 3: Contribution of the services sector to innovation

The services sector makes a major contribution to innovation within the Swiss economy. However, there is still inadequate understanding of the conditions, processes and effects of innovation from this sector. This knowledge gap is particularly serious at a time when digitalisation is constantly opening up new areas of application. In this study, three selected branches of activity are closely examined in case studies on innovation and structural change. The first two branches of activity are research-intensive services and banking, which are both heavily exposed to competition; the third branch is healthcare. The main lessons learnt from these case studies are 1) innovations in the sectors studied differ markedly from conventional innovations in industry; 2) innovations made possible by digitalisation have various effects in terms of structural change; 3) there is significant potential for innovation, but there are also barriers to increasing the productivity of various services; 4) education and training and more intensive networking can contribute greatly to innovation in knowledge-intensive services; 5) established innovation surveys must be adapted and expanded to enable monitoring.

Study 4: Analysis of company perceptions of KTT in Switzerland

This study examines the extent and effectiveness of knowledge and technology transfer (KTT) between higher education institutions and private companies in Switzerland. The authors sent out written questionnaires to around 6,000 companies and prepared econometric estimates on this basis. The study findings show that KTT is highly relevant in Switzerland. Informal contacts as well as initial and continuing education and training activities are the most important forms of KTT. Technology transfer offices and Innosuisse are the most important KTT mediators and drivers of KTT. ETH Domain institutions as well as universities of applied sciences are the most frequent KTT partners for companies. Factors dissuading companies from taking part in KTT have eased over time. The most frequently cited obstacle to involvement in KTT was a lack of basic prerequisites within companies. Some companies pursuing R&D activities mention higher education institutions as barriers to their participation in KTT: the factors include a lack of information, inadequate conditions for the exchange of know-how among higher education institutions, cost and risk factors, as well as organisational and institutional barriers.

Study 5: Analysis of research community perceptions of KTT in Switzerland

This study focuses on knowledge and technology transfer (KTT) between Swiss higher education institutions and research institutes (i.e. the Swiss research community) and companies in Switzerland. Swiss universities of applied sciences, which work intensively with Swiss SMEs, are the higher education institutions most actively involved in KTT, followed by ETH Domain institutions. The comparably high number of patent applications, licensing agreements and spin-offs from ETH institutions is striking. As for cantonal universities, there seems to be a dichotomy: just under half of university institutes, many of them relating to natural sciences, show behaviour comparable to that of ETH Domain institutions; the other half gives greater priority to basic research, teaching and providing services to society (e.g. medical services). Major inter-

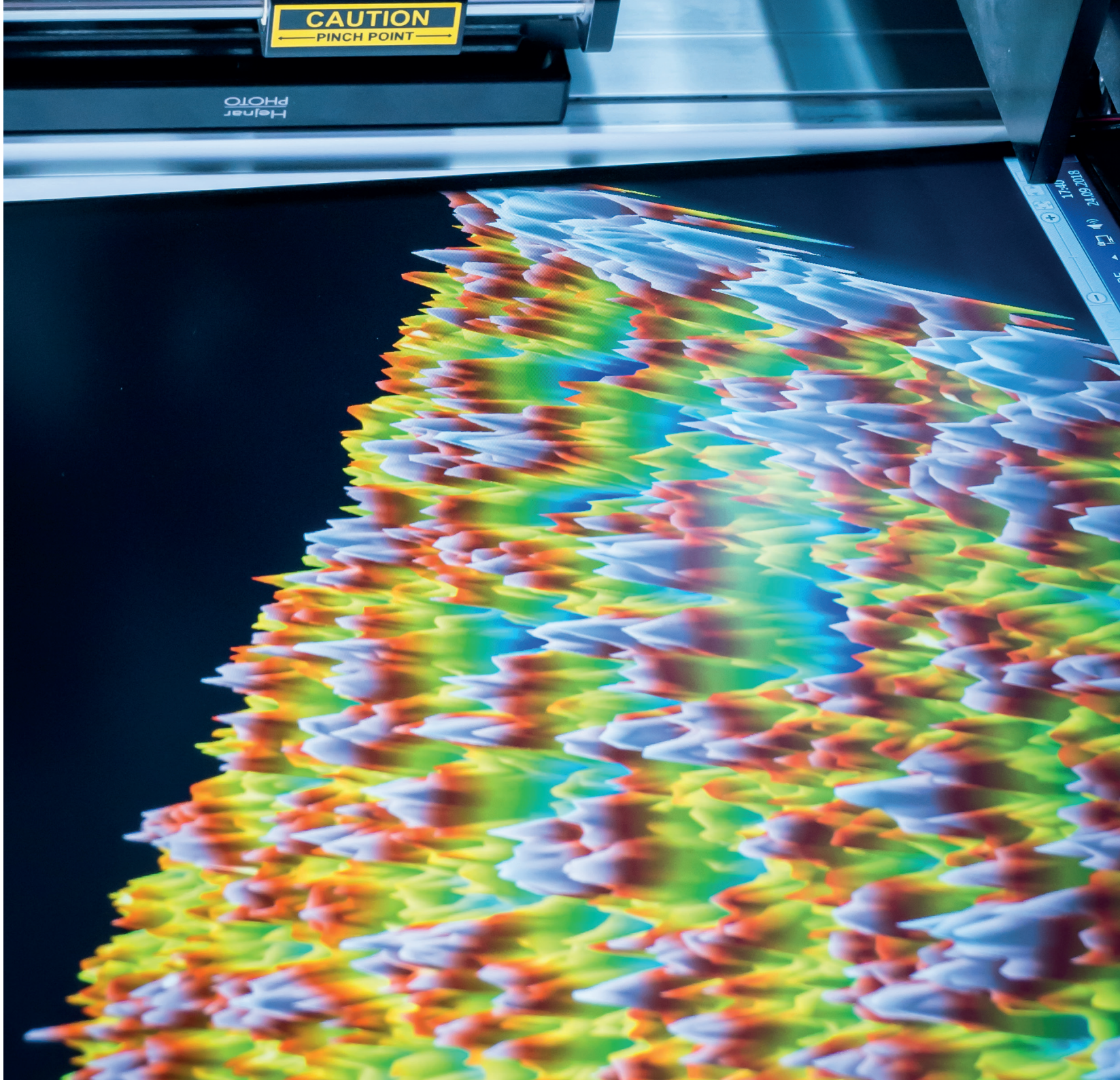
mediary organisations (e.g. public funding agencies, KTT agencies) have stronger internal ties to higher education institutions or research institutes. They also tend to contribute their knowledge of markets and customers.

Study 6: Protection of intellectual property and innovation in Switzerland

This study deals with the system in place to protect intellectual property in Switzerland, and how this system encourages innovation. The study focuses on a specific type of intellectual property, namely patents. In Switzerland, patenting is relatively rare overall. Due to the globalisation of research and development activities, only a small number of innovations emerging in Switzerland are filed as priority applications with the Swiss Patent Office. Swiss patent applicants often apply for their patents at the European Patent Office first and then have these patents later confirmed in Switzerland. While the industry representatives surveyed generally view Switzerland's patent system in a positive light, many criticise its excessive cost, complexity and slowness. The existence of the Federal Patent Court in Switzerland is also viewed favourably.

Study 7: Digitalisation as a driver of innovative business models

Digital transformation and associated innovations allow companies to continue to grow. This study examines digital business models in the three sectors of 'Banking and Insurance', 'Trade' and 'Manufacturing'. The latter sector is broken down into the 'Chemical and Pharmaceutical Industries' and 'Mechanical and Electrical Engineering Industries' (MEM industries). The results show that the state of digitalisation in these three sectors as well as the general approach to digital transformation differ markedly. For example, MEM industries are already heavily digitalised. The greatest hurdles to digital transformation tend to be regulations and the security concerns of existing customers. In all three of the sectors considered, there is still great potential when it comes to developing new digital products, services and holistic solutions. Many companies in all three sectors find it particularly difficult to fundamentally rethink their business model. Training in digital business models could remedy this situation. It should be noted, however, that digital transformation can follow different paths. Each company must be able to determine its own path and pace of change.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PART A: THE SWISS RESEARCH AND INNOVATION SYSTEM

Technology competence centres are not-for-profit research institutions of national importance. Working with partners from the private sector and cooperating closely with higher education institutions, they conduct innovation projects in the pre-competitive phase. Inspire AG in Zurich, which conducts research into mechatronic production systems and manufacturing technologies, is one of the technology competence centres funded by the Confederation. A strategic partner of the ETH Zurich, it is involved in technology transfer in the field of production technology to the mechanical, electrical and metal industries. The photograph shows the surface analysis of a component produced with a 3D printer. Photo: Inspire AG

Part A contents

Part A[1] provides an overview of the Swiss research and innovation system (R&I system).[2] It describes the conditions in which it functions and the players involved, and explains the role of the state and the statutory framework. It explains how research and innovation is funded, and the main national and international instruments employed to promote research and innovation and for knowledge and technology transfer.

Recent developments in the fiscal sector
In Switzerland, until now there have been fewer fiscal incentives for research and innovation than in other countries. Since 1 January 2020, yields from patents and similar rights may be taxed at favourable rates by the cantons. The cantons can also grant additional tax deductions for expenditure on research and development.[3]

1 Framework conditions

The Swiss R&I system needs favourable conditions in order to thrive and maintain a successful position in face of international competition.

In Switzerland, these conditions include political stability, security and quality of life. These positively viewed elements provide a favourable environment for successful R&I activities with a long timescale and for encouraging innovative companies to become established here. They are also important in attracting talent from abroad. This is particularly vital for Switzerland, a small country with limited personnel resources.

Characteristic for Switzerland are a competition-driven market and the primacy of private initiative, with little state regulation and intervention compared with other countries. The various markets for labour, capital, goods and services are largely competition-driven. Access to international markets is free and open thanks to bilateral and multilateral agreements. This allows the economy to react flexibly, absorb new developments rapidly and be open to innovations.

Switzerland's infrastructure is well-developed compared to other countries', and it is continuously modernised. Moreover, the fiscal environment is relatively good.

The Swiss education system
The cantons and the Confederation operate an education system in which the vocational and academic paths complement each other. These two educational paths are seen as 'equal, but different'. Each individual chooses the path that corresponds to their preferences and abilities.

The Swiss education system also has a high degree of vertical and horizontal permeability, allowing learners to switch from the vocational to the academic path and vice versa. All qualifications lead to new study or employment possibilities, the prerequisite for life-long learning.

The overarching objective of the Swiss education system is to produce a well-qualified workforce to meet the needs of the entire value creation chain; this is vital to the success of R&I in Switzerland.

Academic freedom is also a major element in the favourable conditions for research and innovation in Switzerland. The Federal Constitution (FC) guarantees freedom of research for individuals and institutions (Art. 20 FC; Schweizer, 2011). However, it also requires legislators to set limits on research. For example, Art. 120 FC states that human beings and their environment shall be protected against the misuse of gene technology.

The differentiated education system with its first-class higher education institutions and well-developed, practice-oriented vocational education and training system is a further key success factor for Swiss research and innovation.

Furthermore, Switzerland has well-established R&I funding instruments (see Section 5) and clear rules on the protection of intellectual property.

The success of research and innovation also depends on the perception and evaluation of the Swiss public. People in Switzerland are aware of the value of science and have considerable trust in it (Figure A 1.1).

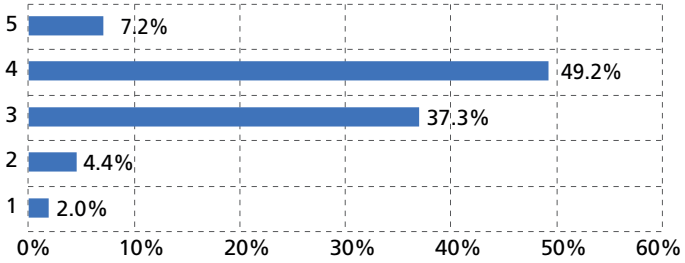
Whereas the private sector funds and conducts around two thirds of R&D activities, the public sector ensures optimum conditions to promote research and innovation.

[1] Part A is based on a text written for the 2016 report by Prof. em. Beat Hotz-Hart (University of Zurich), which has been reworked for this report by SERI and Dr Urs Hafner (science journalist).

[2] For the difference between 'research and innovation (R&I)' and 'research and development (R&D)' see the introduction to the full report.

[3] These result from the adoption of the Federal Act on Tax Reform and OASI Financing by the Swiss electorate in May 2019, while the results of the OECD project 'Addressing the Tax Challenges of the Digitalisation of the Economy' may have an impact on Swiss corporate tax law. The OECD is currently working on adapting the existing principles for the taxation of multinational companies; results are expected in 2020 (OECD, 2019).

Figure A 1.1: Swiss public confidence in the science community in general, 2019



Scale from 5 'very high' to 1 'very low'
Rounding differences possible
Source: Science Barometer survey (2019; n=1043), Adapted by SERI

2 Players

In Switzerland, the main players in research and innovation are the private sector, the higher education sector (the two federal institutes of technology as well as the cantonal universities, universities of applied sciences and universities of teacher education), research institutions of national importance[4] as well as the federal government and the cantons. The VET/VPET sector and its players also have an important role in innovation.

2.1 Private sector

The private sector plays a central role in Swiss research and innovation. It is primarily engaged in applied research and development (aR&D) and in translating knowledge into marketable innovations. It often works with universities and other publicly funded institutions. Some large corporations also carry out basic research.

Two thirds of R&D activities are funded and conducted by the private sector. In 2017, large corporations accounted for 84% of private-sector R&D expenditure and SMEs for 16% (FSO, 2019).[5] However, R&D expenditure is not the only driver of innovation. Partnerships and the involvement of clients and higher education institutions are also factors in innovation.

Nonetheless, the number of companies engaged in R&D in Switzerland has almost halved in recent years; the number of SMEs conducting R&D has been steadily declining since 2000.[6] Large corporations, meanwhile, have been increasing their R&D activities since 2009 and their expenditure is now well above the average for the overall economy.

Start-up-companies[7]

According to the Swiss Startup Radar, currently around 300 start-ups are founded each year in Switzerland, four times more than 15 years ago.[8]

There are start-ups in all of the cantons. The main hubs are the canton of Zurich, where around a third of all start-ups are located; Vaud with around 15%, Geneva with 7%, Zug with 5% and Basel-Land and Basel-Stadt, which together account for 9%.

In an international comparison, Switzerland has a high proportion of start-ups in the fields of medtech; mechanical and electrical engineering; energy and cleantech, biotechnology; and financial services. The share of start-ups in e-commerce and internet marketplaces is, however, smaller than in other countries (startupticker.ch, 2018).[9]

Although the number of companies conducting R&D has decreased, there has been a steady rise in R&D expenditure as a proportion of gross turnover. This means that a smaller number of companies are investing more in R&D, with the result that these businesses have a greater impact on the innovative strength of the economy as a whole (Spescha & Wörter, 2018).

Large corporations that fund and conduct R&D are primarily found in the pharmaceutical industry, the food industry and the machine engineering sector.

The number of SMEs conducting R&D has been declining since the early 2000s (see above), yet these businesses continue to play an important role in Switzerland's innovative performance. In a European comparison, they enjoy top rankings in a number of areas, in particular in the introduction of marketing and organisational innovations (European Commission, 2019). Their cooperation with large corporations in research and innovation is significant; as suppliers of highly specialised components, they integrate their R&D activities into the value creation chains of large corporations, and in this way can occupy niche markets.

Founding innovative companies is an effective way of spreading new knowledge and new technologies on the market.[10] Their

[4] Research institutions of national importance help to generate scientific value in the sectors concerned and complement the research activities at universities and institutions in the ETH Domain.

[5] SMEs are small (1–49 employees) and medium-sized (50–249 employees) enterprises; corporations are companies which employ 250 or more (OECD, Eurostat). Over 99% of businesses in Switzerland are SMEs and fewer than one per cent are corporations.

[6] One reason for this may be that R&D-driven innovation activities have become too expensive and too risky for many companies in recent years (Spescha & Wörter, 2019).

[7] There is no uniform definition of the term 'start-up' in Switzerland. According to the Swiss Startup Radar, the following six criteria are characteristic of a start-up: ambitious growth plans, focus on innovation, science- and technology-based approach, scalable business model, international markets and professional investors.

[8] 550585 companies were registered in Switzerland in 2016. Of these, 39000 were founded in that year, and around 90% of these were in the tertiary sector. More than 80% of these new businesses were still operating a year later (FSO).

[9] According to the Swiss Technology Transfer Association (swiTT), in 2018 54 start-ups arose in the ETH Domain, 8 in the cantonal universities and 16 in the UASs (swiTT, 2019). These figures are not complete.

[10] New companies may be set up freely in the market, be founded via spin-offs from research institutions esp. higher education institutions, or via management buyouts, in which the management obtains the majority of a company's capital or a part thereof from the company's owners.

importance to the economy lies less in the number of jobs created than in the economic dynamism they trigger.

Young businesses rarely have sufficient funds themselves and are therefore reliant on access to venture capital. In terms of investments in venture capital as a proportion of GDP, Switzerland lies far behind the OECD leaders, the US and Israel.

However, Switzerland offers favourable conditions for those wishing to set up a new company. There is a well-developed, soundly financed and thus competitive system of education and research, which provides fertile ground for future innovations and raises awareness of entrepreneurial activity. Entrepreneurship benefits from factors such as streamlined procedures for setting up a company, innovation-friendly corporate and bankruptcy laws, an attractive fiscal system and simple laws on the protection of intellectual property and licences.

2.2 Higher education institutions

Swiss higher education institutions – the federal institutes of technology (ETH Zurich and EPF Lausanne), the cantonal universities, the universities of applied sciences (UASs) and the universities of teacher education (UTEs) – offer a wide range of study and research opportunities.[11] They perform strongly in international rankings[12] and make a considerable contribution to research and innovation.

The curricula follow the Bologna model, with the three degree levels: bachelor's, master's, PhD. Only the cantonal universities and the two federal institutes of technology (FITs), which primarily engage in basic research and research-based teaching, are authorised to award doctoral degrees. The UASs can, however, offer doctoral degree courses in cooperation with a cantonal university or FIT (SKBF, 2018). The UASs' specialisation is applied research and development (aR&D). Degree courses at the universities of teacher education (UTEs) also involve practical research and innovation.

Most of the Swiss higher education institutions have excellent international connections. They are required to engage in teaching (incl. in continuing education), research and development, knowledge and technology transfer (KTT) and services for third parties.

Domain of the Swiss Federal Institutes of Technology (ETH Domain)
There were around 32 000 students enrolled at the ETH Zurich and the EPF Lausanne (EPFL) in 2019, of which 6300 were doctoral students (FSO, 2019). These two institutions belong to the ETH Domain, along with four research institutes: the Paul Scherrer Institute (PSI), Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Institute for Materials Science and Technology (Empa) and the Swiss Federal Institute of Aquatic Science and Technology (Eawag).[13] The ETH Board is the strategic steering and supervisory body of the ETH Domain.

The ETH Zurich and the EPFL are tertiary-level institutes of technology. Their study programmes and research activities focus on natural sciences and engineering, life sciences, mathematics and architecture.

The ETH Domain research institutes focus both on basic and applied research. They also provide scientific and technical services and are involved in teaching and research at the ETH Zurich and the EPFL.

Cantonal universities
Around 120 000 students were enrolled at the ten cantonal universities[14] in 2019, of which 19 000 were post-graduates (FSO, 2019).[15]

The cantonal universities have varying combinations of faculties and institutes in law and social sciences, mathematics and natural sciences, humanities, economics and medicine. Some of the universities have a specific profile and focus on particular fields: for example, the University of St. Gallen is one of Europe's leading universities for business administration and economics. Unlike the two FITs, the cantonal universities do not offer programmes in engineering sciences.

Universities of applied sciences
Almost 78 500 students were enrolled at the seven public universities of applied sciences (UASs) and at the private Kalaidos UAS in 2019 (FSO, 2019). The UASs were set up in the 1990s through mergers of professional education institutions. An eighth public UAS was created on 1 January 2020.[16]

The universities of applied sciences have a strong regional character and are important cooperation partners for local SMEs. More

[11] The following institutions also form part of the higher education landscape: Universitäre Fernstudien Schweiz, Graduate Institute of International and Development Studies (IHEID) (both officially entitled to receive federal funding under the HEdA), Swiss Federal Institute for Vocational Education and Training (SFIVET) and the Swiss Federal Institute of Sport Magglingen (SFISM).

[12] Five cantonal universities (Basel, Bern, Geneva, Lausanne, Zurich) plus the ETH Zurich and EPFL have featured for several years in the top 200 of a number of international higher education rankings (Shanghai, QS, Times and Leiden).

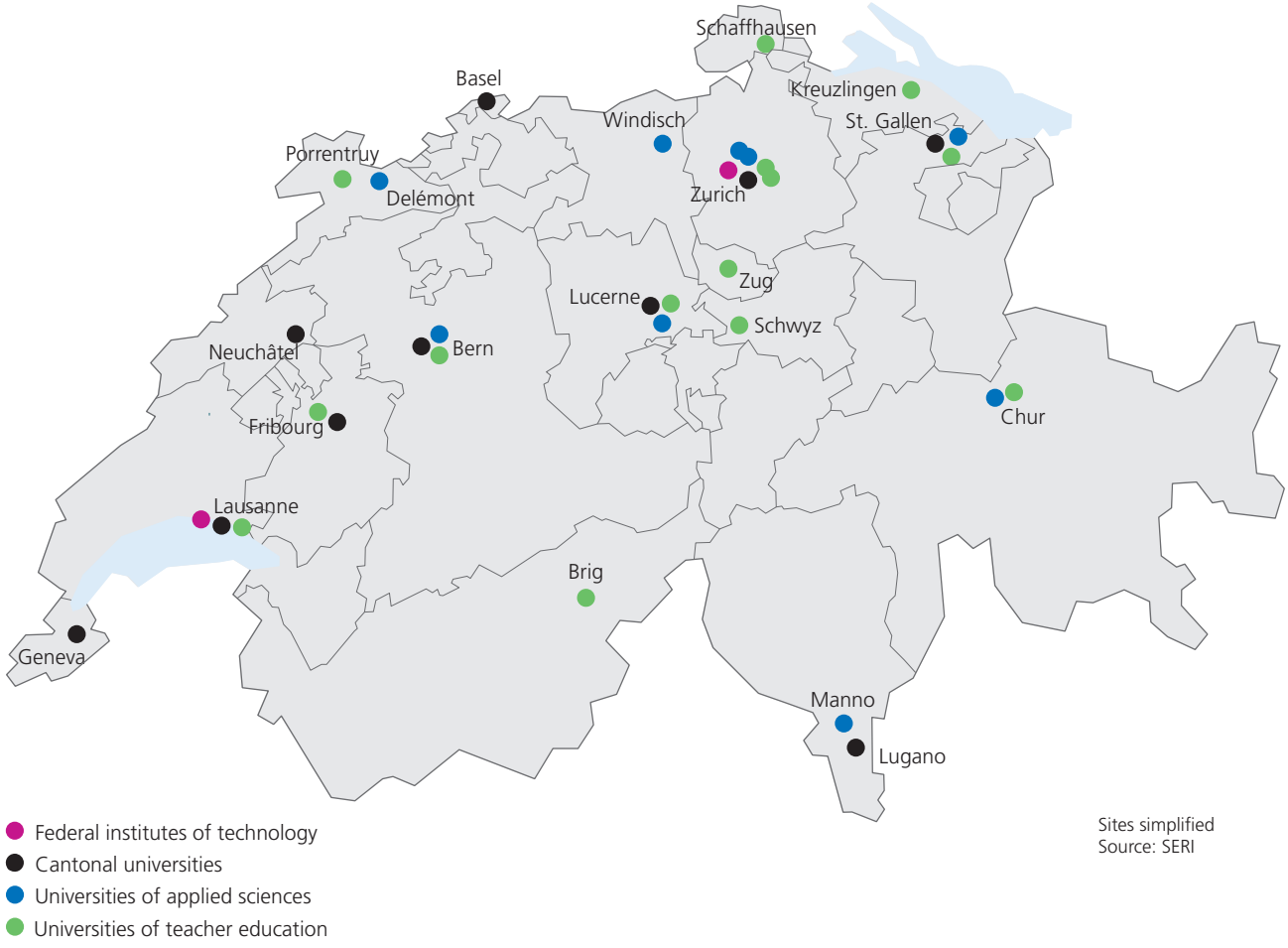
[13] The ETH Zurich was founded in 1855; the Federal Institute of Technology Lausanne (EPFL) was created in 1969 when the Confederation took over the Ecole polytechnique de l'Université de Lausanne (EPUL). The four research institutes (PSI, WSL, Empa and Eawag) were set up over the years. In 1991 the ETH Act was passed; this applies to the entire ETH Domain.

[14] University of Bern, University of Basel, University of Fribourg, University of Geneva, University of Lausanne, University of Lucerne, University of Neuchâtel, University of St. Gallen, Università della Svizzera italiana, University of Zurich.

[15] The University of Basel is by far the oldest university in Switzerland; it was founded in 1460.

[16] Bern University of Applied Sciences (BFH), University of Applied Sciences and Arts Northwestern Switzerland (FHNW), University of Applied Sciences of Eastern Switzerland (FHO), University of Applied Sciences of the Grisons (FHGR), Lucerne University of Applied Sciences and Arts, University of Applied Sciences and Arts Western Switzerland (HES-SO), University of Applied Sciences and Arts of Southern Switzerland (SUPSI) and The Zürcher Fachhochschule (ZFH). The former HTW Chur, formerly part of the FHO, became an independent UAS from the beginning of 2020 and is now known as the University of Applied Sciences of the Grisons (UAS Grisons).

Figure A 2.1: Swiss higher education landscape



than half of the projects promoted by Innosuisse (see Section 5) are conducted with research partners from the UASs.

The UASs offer bachelor's and master's degrees tailored to the needs of the labour market. They make a major contribution to the application of knowledge in marketable innovations. The practice-oriented bachelor's degree is the usual qualification obtained at a UAS. These universities offer a wide range of degree courses and each establishment offers a different combination of subjects: technology and information technology, architecture, construction and planning, chemistry and life sciences, agriculture and forestry, economics and services, design, health, social work, music, drama and other arts, applied psychology, applied linguistics and sport.

Universities of teacher education

Around 21 000 students were enrolled at the universities of teacher education (UTEs) in 2019 (FSO, 2019). There are 14 UTEs in Switzerland; four further teacher training institutions that are integrated into another type of university; and two federal teacher training institutions.[17] The UTEs train teachers and other educational specialists at all levels. They conduct educational and school research and occupational research and development, and provide services in this field for schools and other educational institutions.

[17] UAS BEJUNE (HEP-BEJUNE); UAS Vaud (HEP Vaud); UAS Fribourg (HEP / PH FR); UAS Valais (HEPVS / PHVS); University of Applied Sciences in Special Needs Education, Zurich (HfH); UTE Bern (PHBern); UTE Graubünden (PHGR); UTE Lucerne (PHLU); UTE Schaffhausen (PHSH); UTE Schwyz (PHSZ); UTE St. Gallen (PHSG); UTE Thurgau (PHTG); UTE Zug (PH Zug); UTE Zurich (PH Zürich).

The UTE Northwestern Switzerland (PHFHNW) and Dipartimento formazione e apprendimento DFA (SUPSI-DFA) are each affiliated to a university of applied sciences.

These two institutions are affiliated to a university: Zentrum für Lehrerinnen und Lehrerbildung (ZELF) (University of Fribourg); Institut Universitaire de Formation des Enseignants (IUFE) (University of Geneva). The universities of Zurich, Lucerne and St. Gallen and the ETH Zurich also have teacher training programmes.

The role of VPET in innovation

Vocational and professional education and training (VPET) is not an innovation player in a strict sense. But because of its importance for innovation, it is nonetheless mentioned here.

Two thirds of young people in Switzerland begin their professional career by doing an apprenticeship (at upper secondary level). Annually, 69 000 people complete an apprenticeship and 26 700 obtain a qualification in (tertiary-level) professional education and training, providing a pool of highly skilled workers and professionals for the private sector and public authorities. These people play just as much of an important role as university graduates in boosting businesses' competitiveness and innovative strength.

The Swiss VPET system is strongly linked to the needs of the labour market. The professional organisations define and update the content of courses, ensuring that they continue to meet the precise needs of the workplace and generate the innovative skills companies require. Those following the VPET path obtain a flexible and broad theoretical education and practical training, and this increases their ability and willingness to be involved in and drive forward the innovative process.

There are many opportunities in the VPET system to obtain higher qualifications or to switch direction, a mark of diversity that is also a major asset to innovation in Switzerland.

To summarise, the Swiss VPET system trains a broad spectrum of skilled workers and managers with wide-ranging skills, and so plays an important role in innovation.

2.3 Research institutions of national importance

There are around thirty research institutions of national importance, and these make a major contribution to generating scientific added value in all specialist areas and disciplines. They complement the research activities and research infrastructures at universities and in the ETH Domain. These facilities are both publicly and privately funded, with federal funding being subsidiary in character. Three types of institution may receive federal funding (RIPA Art. 15 para. 3):

- research infrastructures such as the Swiss Centre of Expertise in the Social Sciences (FORS) in Lausanne which collect, process, analyse and make available scientific information and documentation as a basis for further research.
- research institutions such as the Swiss Institute for Allergies and Asthma Research (SIAF) in Davos which focus on a highly specialised topic and generally work closely with cantonal universities or institutions in the ETH Domain.
- centres of technological excellence such as the Centre suisse d'électronique et de microtechnique (CSEM) in Neuchâtel which focus in particular on knowledge and technology transfer. They cooperate with institutions in the ETH Domain, the cantonal universities and the UASs; they also engage in innovation projects with the private sector.

2.4 Federal Administration

Specialist skills and knowledge are required to deal with public sector tasks and complex political processes. Federal Government Research is one area in which this acquired. This is research conducted by the federal entities themselves or by universities and private companies on behalf of the Federal Administration (see Section 5.4).

3 State responsibilities

State institutions at all three political levels – Confederation, cantons and communes – are responsible for ensuring that there is fertile ground for both private and publicly funded players in research and innovation. They guarantee the quality of education and training at all levels, make available the public infrastructure and create a stable political and legal environment.

3.1 Confederation

At federal level, the State Secretariat of Education, Research and Innovation (SERI), which is part of the Federal Department of Economic Affairs, Education and Research (EAER), is, as its name suggests, the principal body responsible for the ERI sector and for the implementation of related legislation. The Research and Innovation Promotion Act (RIPA) regulates competitive research funding and international cooperation in R&I.

The Higher Education Act (HEdA) states that the Confederation along with the cantons is responsible for ensuring the coordination, quality and competitiveness of higher education, under the umbrella of the Swiss Conference of Higher Education Institutions. The HEdA also states that the Confederation is responsible for co-funding cantonal universities and universities of applied sciences, but not universities of teacher education.

The Confederation is also responsible for the ETH Domain, whose governing body is the ETH Board (see also Section 2.2).[18]

The federal R&I funding bodies are the Swiss National Science Foundation (SNSF), Innosuisse and the Swiss Academies of Arts and Sciences (see Section 5). The Swiss Science Council (SSC) advises the government on R&I policy. Some other units in the EAER also deal with research and innovation, for example Agroscope, the federal centre of expertise for agricultural research.

Other departments besides the EAER also promote or commission research and innovation, for example as Federal Government Research (see Sections 2.4 and 5.4).[19]

[18] The Federal Act on the Federal Institutes of Technology (ETH Act, Art. 4) states that the ETH Domain reports to the EAER.

[19] The Federal Institute of Intellectual Property (IPI) and various commissions also play an important role in research and innovation. For example, the non-parliamentary Federal Energy Research Commission (CORE) plays a coordinating role in energy research policy.

Dispatch on the Promotion of Education, Research and Innovation

Every four years the Federal Council presents a dispatch on the Promotion of Education, Research and Innovation (ERI Dispatch) to Parliament, in which it draws an assessment of the current funding period and sets out the objectives and measures for the one to come. The ERI Dispatch contains the federal ERI budget for the coming legislative period and any amendments to the law optimising the legal basis. The funding decisions include all national federal measures in VPET, higher education and continuing education, and for the promotion or research and innovation.[20]

3.2 Cantons, cities and communes

Apart from the cases in which the Confederation is specifically mentioned in the Federal Constitution, it is the cantons that are responsible for the education system. They bear the main financial burden of education, research and innovation.

The cantons are responsible for the cantonal universities, the universities of applied sciences and the universities of teacher education. They provide core funding which covers a large proportion of the research activities at the cantonal universities. Some of their costs are met via inter-cantonal funding agreements. The cantonal universities, UASs and UTEs are largely autonomous: they plan, regulate and manage their own affairs under cantonal laws based on the Constitution and on the HEdA.

The Swiss Conference of Cantonal Ministers of Education (EDK) and the Conference of Cantonal Directors of Economic Affairs (VDK) play an inter-cantonal coordinating role in the field of research and innovation and at its interfaces with other sectors.

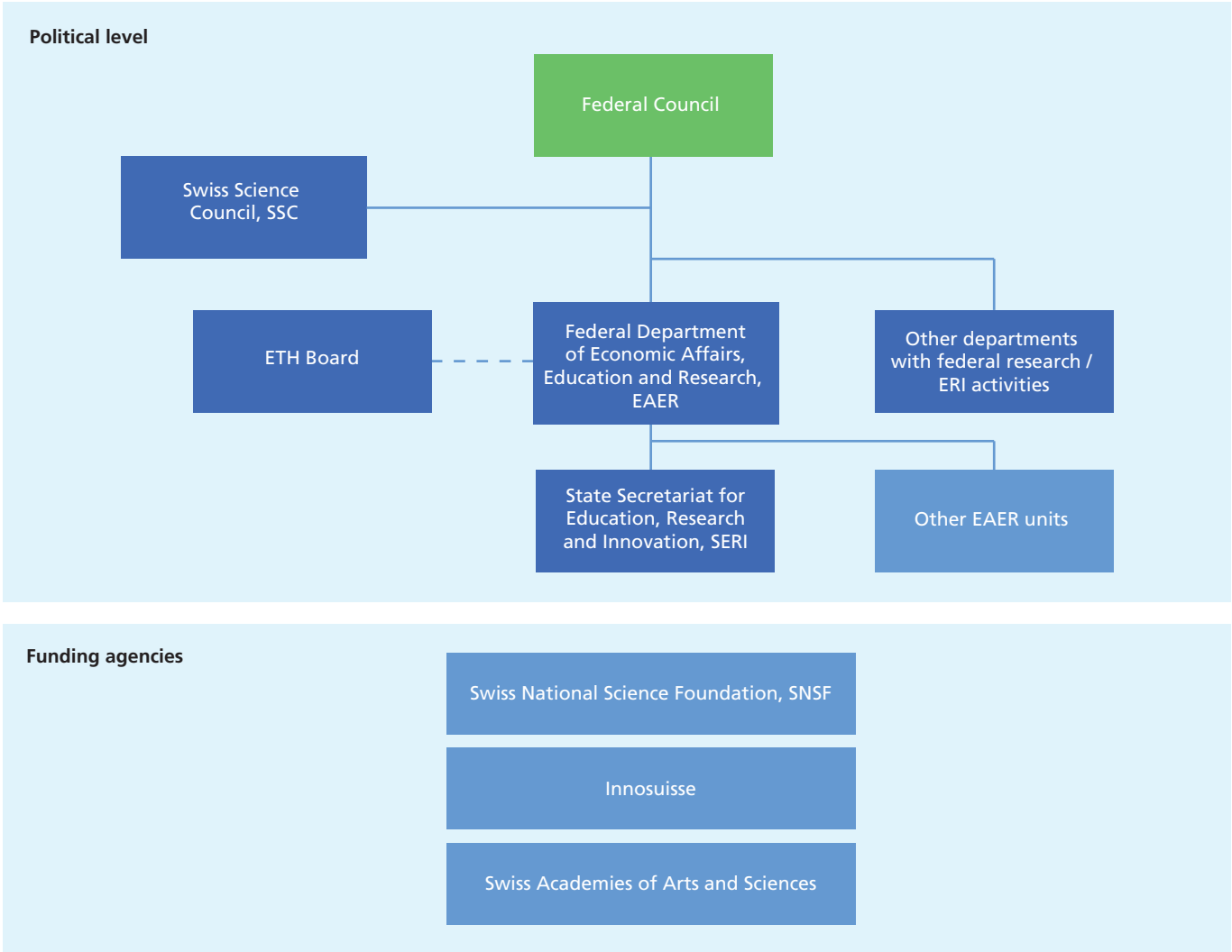
The cities and communes are also involved in innovation promotion, for example in setting up and running technology and innovation parks.

Joint federal-cantonal bodies

There are three joint bodies in which the Confederation and the cantons ensure the coordination, quality and competitiveness of the higher education sector: the Swiss Conference of Higher Education Institutions (SHK), the Swiss Conference of Rectors of Higher Education (swissuniversities) and the Swiss Accreditation Council.

[20] Separate funding decisions (form still undetermined) will be made regarding Switzerland's participation in the EU Framework Programme for Research and Innovation (2021–2027) and in the EU education programmes (2021–2027).

Figure A 3.1: Federal institutions responsible for research and innovation



Source: SERI

Federal statutory basis[21]

Federal Constitution
The Federal Constitution (Art. 64 FC) states that the Confederation shall promote scientific research and innovation.
It also states (Art. 63a FC) that the Confederation and cantons are jointly responsible for the coordination of and guarantee of quality in higher education. The Confederation is responsible for the federal institutes of technology and supports the cantonal universities financially. It encourages the provision of a diverse and accessible range of courses in vocational and professional education and training (Art. 63 FC).

Federal Act on the Promotion of Research and Innovation
The Federal Act on the Promotion of Research and Innovation (RIPA) is a framework law on the tasks and organisation of federal R&I promotion. RIPA regulates the tasks, procedures and responsibilities of the funding agencies legally established in RIPA – the Swiss National Science Foundation, Innosuisse and the Swiss Academies of Arts and Sciences – and of international cooperation in science. Moreover, it sets out the subsidiary participation of the Confederation in research institutions of national importance and the planning, coordination and quality assurance of federal research policy. It also contains the basis for funding of the Swiss Innovation Park.

[21] FC: SR 101; RIPA: SR 420.1; HEdA: SR 414.20; ETH Act: SR 414.110; VPETA: SR 412.10

Federal Act on the Funding and Coordination of the Higher Education Sector (HEdA)
The Higher Education Act states that the Confederation and the cantons are responsible for the coordination, quality and competitiveness of the higher education sector. The HEdA provides a basis for the establishment of joint federal and cantonal bodies, quality assurance and accreditation, uniform funding of the universities and other institutions in the higher education sector and the distribution of tasks in particularly cost-intensive fields. The provisions on funding in the HEdA apply only to the cantonal universities and the UASs, not to the FITs and UTEs. However, the latter, like the former, may receive project-linked funding.

Federal Act on the Federal Institutes of Technology
The Federal Act on the Federal Institutes of Technology (ETH Act) regulates the tasks and organisation of the ETH Domain (for institutions in the ETH Domain see Section 2.2).

Federal Act on Vocational and Professional Education and Training
The Federal Act on Vocational and Professional Education and Training (VPET Act) provides a basis for the success of the Swiss innovation system. As a driver of modernisation in the VPET system, it keeps abreast of the rapid changes in the labour market, and allows for differentiated and flexible paths in the education system. The VPET Act also provides the legal basis for the Swiss Federal Institute for Vocational Education and Training (SFIVET) and defines the Confederation's financial participation in VPET.

Legal basis for the cantons
The HEdA provides the legal basis for coordination in the Swiss higher education sector at federal level. The legal framework for the cantons' role, meanwhile, is set out in the Intercantonal Agreement of 20 June 2013 on Cooperation in Higher Education.[22] All of the cantons are party to this agreement.

Each canton hosting its own university has a cantonal law pertaining to it. The cantonal laws on universities of applied sciences provide the basis for the running of a UAS; generally, these laws address cooperation with other cantons and the Confederation. There are also cantonal laws relating to the universities of teacher education.

The Federal Vocational and Professional Education and Training Act (VPETA) assigns the cantons the task of ensuring adequate possibilities for vocational education and training, professional education and training, vocational continuing education and career and study guidance. The cantonal VPET laws provide implementing legislation to meet this task.

Innovation promotion as part of cantonal economic development is generally based on specific laws in the individual cantons.

[22] www.edk.ch/dyn/11662.php

4 Finances

4.1 Finance flows

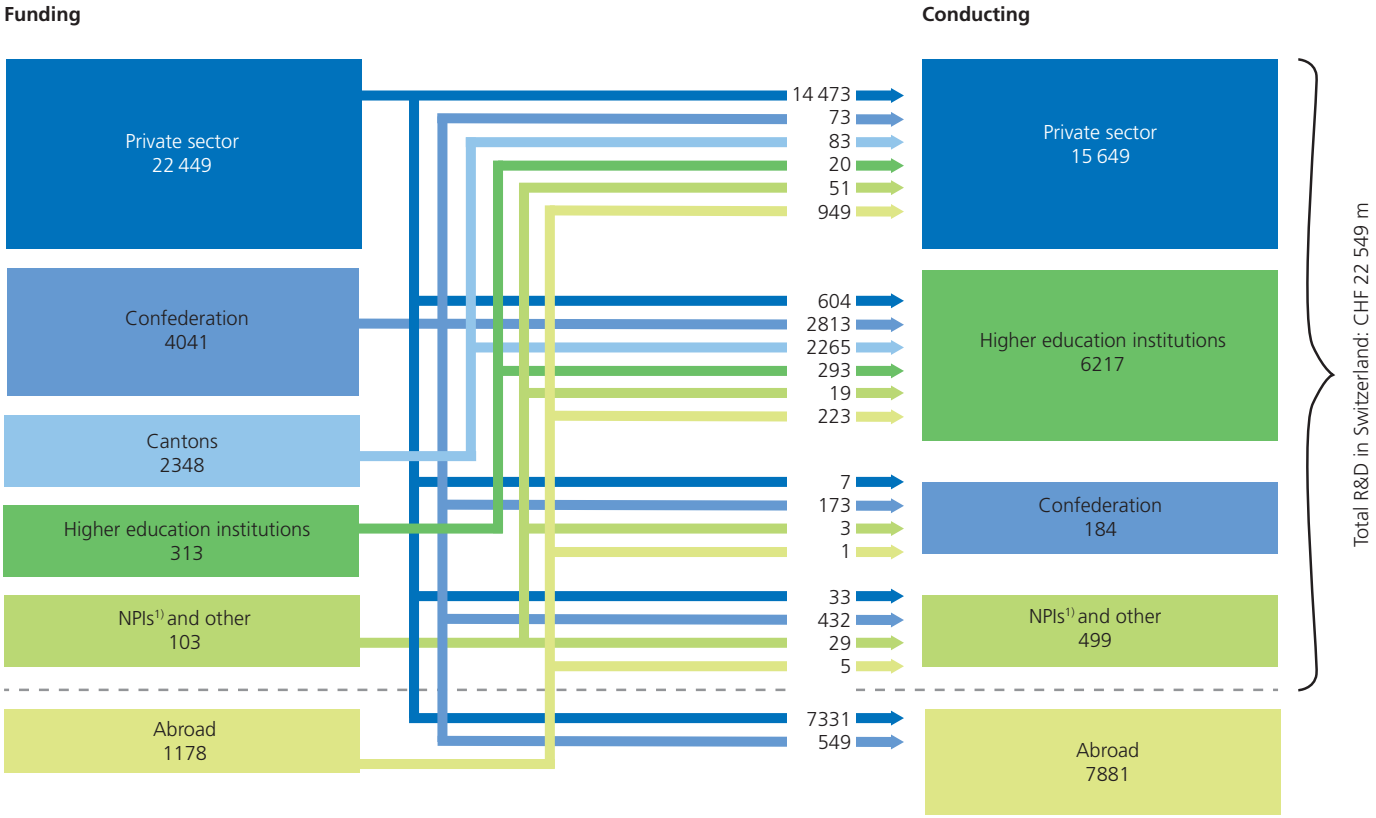
The private sector, public sector, universities and entities abroad all conduct and fund R&D activities.

Figure A 4.1 provides an overview of the finance flows between individual sectors in 2017. It shows all the R&D finance flows in Switzerland and the funds coming from or going abroad. The left-hand side of the graphic shows the funding sources for Swiss R&D and funds from abroad, the right-hand side the four sectors in which R&D is conducted in Switzerland and the amount spent on R&D conducted abroad.

In 2017, CHF 22.5 billion was invested in R&D in Switzerland – about 3.4% of GDP. This puts Switzerland among the top group of OECD countries (FSO, 2017). The lion's share was invested by the private sector, which funds and conducts around two thirds of R&D activities.

In the private sector, businesses fund and conduct almost all the R&D activities themselves. The ETH Domain, the cantonal universities and the universities of applied sciences are the main receivers of funding. They are primarily funded by the Confederation and the cantons.

Figure A 4.1: Entities engaged in funding and conducting R&D in Switzerland by sector, in CHF million, 2017 (not including branches of Swiss companies abroad)



[1] Non-profit institutions
Source: FSO

The private sector and the Confederation also fund R&D activities abroad, and entities abroad fund R&D projects in Switzerland.

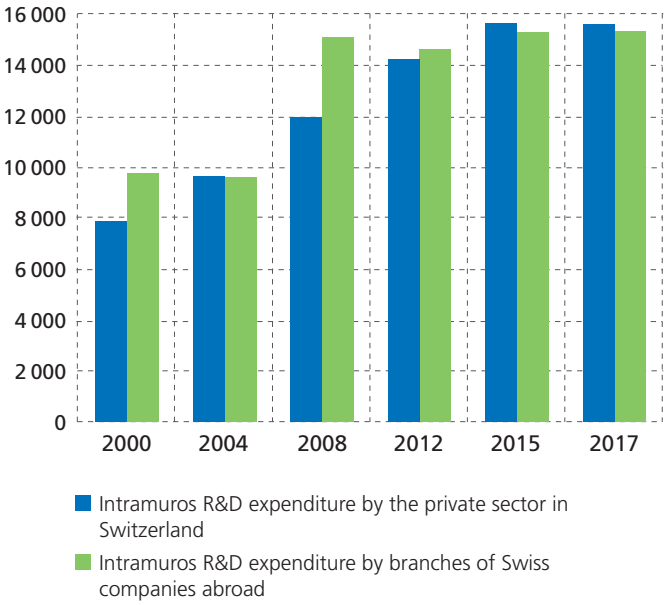
Other entities (non-profit institutions, foundations etc.) play a comparatively minor role both in funding and in conducting R&D in Switzerland.

4.2 R&D expenditure by branches of Swiss companies abroad

The private-sector companies that invest heavily in R&D tend to operate internationally. This can be seen from the expenditure on research by branches of Swiss companies abroad (Figure A 4.2), accounted for by just a small number of internationally active corporations.

In 2017 R&D expenditure by branches of Swiss companies abroad amounted to CHF 15.3 billion,[23] just slightly less than the CHF 15.6 billion spent by the private sector on R&D in Switzerland in the same year.

Figure A 4.2: Development of intramuros R&D expenditure by the private sector in Switzerland and by company branches abroad, in CHF million



Intramuros R&D expenditure is expenditure on R&D activities conducted by companies on their own premises: 'within their own walls'.
Source: FSO, Adapted by SERI

5 National, regional and cantonal promotion

The Confederation is primarily responsible for public-sector R&I funding. Its main instruments are the Swiss National Science Foundation (SNSF) for the funding of basic research, and Innosuisse for the promotion of science-based innovation. A further player is the association of Swiss Academies of Arts and Sciences, which foster cooperation in and between the science disciplines and promote the place of science in society.

Main principles of R&I funding
- Public R&I funding functions according to bottom-up principle – on the individual initiative of researchers and businesses.
- Project applications receive public funding on a competitive basis.
- In an international comparison, Switzerland is not strong on the top-down setting of areas and programmes that are eligible for funding.
- Generally, no funding is awarded directly to private businesses.

5.1 Swiss National Science Foundation

Founded in 1952, the Swiss National Science Foundation (SNSF) is the main institution funding scientific research and promoting young academics.[24] In order to ensure that research remains independent, the SNSF is set up as a private foundation. SERI concludes four-year performance agreements with the SNSF in accordance with the budget set by Parliament. All scientific disciplines have access to SNSF funding.

The SNSF has CHF 1.2 billion at its disposal annually, which it awards in a competitive process. Several thousand project applications are assessed in a peer-reviewed process. The SNSF's National Research Council, comprising around 100 academics from Swiss higher education institutions, selects applications on the basis of expert reports from 90 evaluation bodies with over 700 members.

The SNSF has a broad range of funding instruments (Figure A 5.1). The principal instrument is project funding, which accounts for around half of all approved funding. Here the researchers select the topic and nature of their projects; the SNSF thus provides the necessary freedom for innovative ideas.

[23] The data collected between 2008 and 2017 was probably affected by strong currency fluctuations, whose impact cannot be quantified.

[24] The report on Germany's research, innovation and technological performance compiled by the German Commission of Experts for Research and Innovation (EFI) contains a comparison between the German funding body DFG and the main research funding organisations of the United Kingdom, the Netherlands, Switzerland and the US, in which Switzerland – the SNSF – does very favourably (EFI, 2019).

Other funding instruments are the National Centres of Competence in Research (NCCRs) and the National Research Programmes (NRPs):

– The NCCRs are a federal funding instrument and are conducted by the SNSF on behalf of the Confederation. Running for a period of ten years, they contribute to improving the structuring of the Swiss research landscape by acting as centres of expertise in major fields such as robotics, quantum science, neuroscience and migration.
– The NRPs are a federal instrument to promote scientific research into urgent issues of national importance. Designed to address and solve specific problems, they are application-oriented and transdisciplinary. Knowledge and technology transfer is a primary element in the NRPs. Topics are set by the Federal Council in a selection process open to all academic fields; the SNSF is responsible for implementing them. For example, research projects run from 2020 in NRP 77 'Digital Transformation'.

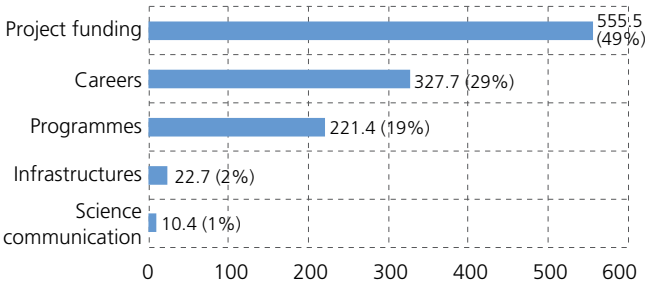
A further key focus of the SNSF is promoting the careers of young scientists and academics via a range of instruments and across all disciplines. The SNSF supports the careers of young, highly qualified researchers from their doctorate thesis through to their position as lecturer/assistant professor, for example by providing grants for working abroad or for projects conducted independently.

Funding is also apportioned to infrastructures. The SNSF funds high quality and innovative apparatus under the R'Equip scheme, and publication projects in the humanities. Furthermore, it fosters communication on scientific issues among researchers and between researchers and the general public.

The SNSF also has many instruments to promote international cooperation e.g. under federal bilateral programmes. These facilitate cooperation between research groups in different countries.

Figure A 5.1 shows the funds approved in 2018 by the SNSF by funding category.[25]

Figure A 5.1: Funding awarded by SNSF funding category, in CHF million, 2018



Total without overhead: CHF 1137.6 million
Total with overhead: CHF 1248.3 million
Source: SNSF

5.2 Innosuisse

Innosuisse, the Swiss Innovation Agency, supports science-based innovation in the interests of the economy and society. Until the end of 2017 it was known as the Commission for Technology and Innovation CTI. Support for knowledge and technology transfer has existed in this form since 1944. Whereas the CTI was an executive commission with decision-making powers, Innosuisse is now an institution under public law with its own budget. The Innosuisse Board, which reports to the Federal Council, is the agency's strategic body, the management team its operational body.

Innosuisse has an annual funding budget of around CHF 200 million. The Innovation Council, its specialist body, selects project applications and provides advice on scientific and innovation issues during the course of projects, with support from a range of experts.

Innosuisse's key activity is funding projects in all scientific disciplines and areas of innovation. Its focus lies on applied research into the development of new products, processes and services for the economy and society and on the valorisation of the research findings on the market.

Innosuisse's main funding instrument focuses on innovation projects run jointly by research institutions and implementation partners from the private sector. The projects thus contribute directly to KTT. To qualify for funding, projects must demonstrate innovation potential and scientific content, as well as promise to produce marketable results. Funding is awarded exclusively to research institutions, largely in the form of salaries for those working on the projects. The private-sector implementation partners provide matching funds in the form of own funds (working hours, apparatus etc.) and are usually required to make a cash contribution of at least 10% of the project costs. No direct payments are made to companies in research and innovation promotion in Switzerland in general and by Innosuisse in particular.

Innosuisse also promotes innovation projects which do not have an implementation partner, for feasibility studies, prototypes and pilot facilities. In addition, its 'innovation cheques' provide SMEs with the funding necessary to conduct small-scale preliminary studies with research partners.

Innosuisse also funds science-based start-ups, which are offered coaching tailored to their individual needs and help in developing their international market presence in the form of trade fair appearances and internationalisation camps. Awareness-raising and training modules are also offered for people from the higher education sector who are interested in setting up a business. Furthermore, it has SME-specific measures such as the National

[25] The term 'overhead' refers to indirect research costs (e.g. for rent, power, administration).

Thematic Networks (NTN), thematic specialist events, innovation mentoring and the Enterprise Europe Network (EEN),[26] which serve to foster KTT.

Innosuisse also funds and steers the eight Swiss Competence Centres for Energy Research (SCCERs), as part of the 'Coordinated Energy Research in Switzerland (2013–2020)' action plan. The centres focus on research into efficient and renewable energies in a range of action areas.

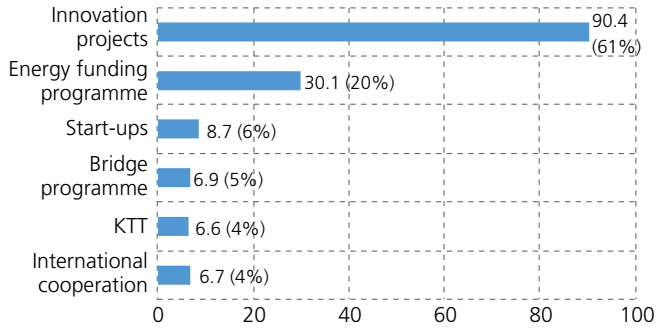
Furthermore, the agency promotes international cooperation in the private sector in order to boost companies' competitiveness in global value creation chains. To this end, it participates in several international initiatives and fosters contacts with innovation funding agencies and other partner organisations around the world.

Figure A 5.2 shows the funds awarded by Innosuisse in 2018 by funding category.

Cooperation between the SNSF and Innosuisse

The SNSF's funding activities focus on the acquisition of scientific knowledge. The focus of Innosuisse funding, meanwhile, is on innovation with the goal of market implementation. Both institutions thus have a clear profile with their own focus and complement each other perfectly. This results in numerous areas of cooperation, such as the Bridge programme, which is supported by both organisations and is aimed at projects at the interface between basic research and science-based innovation.

Figure A 5.2: Funding awarded by Innosuisse by funding category, in CHF million, 2018



Total (incl. overhead of CHF 11.6 million): CHF 149.4 million
Bridge programme: Innosuisse share
Source: Innosuisse, Adapted by SERI

[26] The purpose of the ENN is to support cooperation, KTT and strategic partnerships for SMEs. It has 600 member organisations offering support in over sixty countries worldwide. Switzerland participates in the EEN and contributes financially to it.

5.3 Swiss Academies of Arts and Sciences

The Swiss Academies of Arts and Sciences promote dialogue with the public and advise politicians, the administration and the public on scientific and societal issues. They represent the arts and sciences and make an important contribution to transdisciplinary networking. On behalf of the Confederation they design stimulus and coordination initiatives, which they implement jointly with other ERI players.[27] They promote Switzerland's representation in international specialist organisations and academies, thereby promoting Switzerland as a science location.

Anchored in the scientific community, the Academies network has access to the expertise and excellence of some 110 000 people. It uses this expertise to address overarching issues such as the science culture and infrastructure planning, to provide specialist advice on policy issues, and to promote scientific understanding in society. The Academies are funded by the federal government via a service level agreement to the tune of around CHF 43 million annually.

The association comprises 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). The competence centres TA-SWISS (Foundation for Technology Assessment) and Science et Cité (which promotes dialogue between the sciences and the public) are also part of the association.

5.4 Federal Government Research

The federal government initiates what is known as Federal Government Research, because the findings are used in executing federal tasks (see Section 2.4). Federal Government Research involves both basic and applied research as well as market-oriented development in fields such as engineering, in pilot and demonstration facilities.

The Confederation runs a number of its own research institutes, in which it also conducts R&D. These include Agroscope, affiliated to the Federal Office for Agriculture, and the Spiez Laboratory, affiliated to the Federal Office for Civil Protection. The federal government also conducts its own research programmes in conjunction with higher education institutions, the SNSF, the Academies and Innosuisse.

Furthermore, the Confederation awards grants to third parties and commissions research, which primarily involves expert reports and assessments or accompanying research for evaluating the impact of policy measures.

[27] E.g. the programme to promote STEM (Science, Technology, Engineering and Mathematics) and the Swiss Personalised Health Network (SPHN).

Over 30 federal agencies are involved in Federal Government Research. SERI coordinates these in eleven policy areas selected by the Federal Council. In 2018 the federal government invested around CHF 308 million in Federal Government Research.

5.5 Regional, cantonal and communal promotion

The individual regions of a country often have varying degrees of competition and innovative power. In Switzerland as abroad, the regions are playing an increasingly significant role in innovation funding (OECD, 2011).

The Confederation's New Regional Policy, anchored in the State Secretariat for Economic Affairs SECO, was introduced in 2008 to address this situation. The policy supports rural areas and cantons with mountainous regions by funding local entrepreneurship and innovation in order to boost competitiveness. The aim of these regional innovation systems (RISs) is to improve coordination between existing funding mechanisms (e.g. clusters, innovation coaching, events, cooperation projects between economic branches) to the benefit of local SMEs, and to tailor these mechanisms to regional circumstances (SECO, 2018). Regional potential can be better exploited as a result, and a boost given to innovation dynamics in the regions. The cantons have a large degree of flexibility in the design of these RIS programmes, and so there is considerable variation between them.

The cantons make an important contribution to research and innovation promotion via their funding of the cantonal universities, universities of applied sciences and universities of teacher education. Most cantons also have their own innovation and business promotion, in part supported by regional policy mechanisms. This takes the form of support for new businesses, coaching or the funding of regional networks or clusters in close cooperation with businesses. The cantons have their own economic development agencies individually or in association with other cantons. These agencies inform businesses about the advantages of setting up in the given canton, and they draw up concrete offers for interested parties, maintain contacts with investors and put businesses in contact with them, and are responsible for client care. Some cantons offer tax advantages, or promote regional development via their educational institutions.[28]

Like other financial institutions, the cantonal banks and regional banks offer financial help for start-ups. They frequently put up prize money for competitions and awards for particularly innovative businesses. Some of the cantonal banks also provide help for start-ups in the form of advice and business model templates.

The cities and communes also promote innovation in the form of business start-up centres or technology parks. These are primarily funded by the private sector – as is the Zurich Technopark – but sometimes in partnership with the public purse. A real estate company provides the buildings, and the operating company invites innovation-oriented businesses to use the premises, while providing them with the necessary services.

5.6 Foundations

There also a large number of foundations that fund research and innovation. In 2018 around 13 000 charitable foundations in Switzerland enriched the cultural, social and economic life of the country. Around 20% of these are active in the field of education and research (Eckhardt et al., 2019). Examples are the Gebert Rüf Foundation,[29] Cancer Research Switzerland[30] and the Hasler Foundation.[31]

Since the foundations fund a wide range of R&I undertakings and apply varying funding criteria, they play an important role in bringing diversity to R&I funding.

6 International cooperation

Switzerland engages in international cooperation in order to consolidate and further strengthen its position as one of the world's most competitive centres in terms of ERI. International F&I funding mechanisms complement national instruments and give Swiss players access to international networks.[32]

6.1 EU Framework Programmes for Research and Innovation

The European Union's Framework Programmes for Research and Innovation (FPs) are of particular importance in Switzerland's international cooperation activities. The 8th programme generation, Horizon 2020, runs from 2014 to 2020 and the 9th, Horizon Europe, from 2021 to 2027.

[28] Examples of cantonal business promotion agencies or regional networks: the Hightech Aargau initiative, the Agenzia per l'innovazione regionale del Cantone Ticino and platinn in western Switzerland.

[29] The Gebert Rüf Foundation funds innovation that benefits the Swiss economy and society. It supports application-oriented science projects undertaken by young people at Swiss higher education institutions.

[30] Cancer Research Switzerland funds all areas of cancer research (basic research and clinical, epidemiological and psychosocial research) and with a particular focus on support research with close patient involvement.

[31] The Hasler Foundation was set up to fund information and communication technologies (ICT) to promote know-how and expertise in Switzerland.

[32] In 2018 the Federal Council updated its International Strategy in Education, Research and Innovation (Federal Council, 2018).

Switzerland's status in the FPs has varied over the years:

1987–2003: FPs 1–6	Third country
2004–2013: FPs 6 and 7	Full association
2014–2016: Horizon 2020 (FP 8)	Partial association
2017–2020: Horizon 2020 (FP 8)	Full association

At the current time (late 2019) it is still not known what form Switzerland's participation in Horizon Europe will take.

F&I researchers' participation in the FPs creates many benefits for Switzerland. Researchers from Switzerland cooperate in international projects with colleagues in Europe and around the world. The positive scientific, technological and economic impacts of Switzerland's participation are particularly significant (SERI, 2019). The success rate of project applications with Swiss participation is excellent in a European comparison, although for the first time Swiss participation in the FPs declined slightly at times during Horizon 2020 as a result of only partial association.[33] A definitive assessment of the benefits of participation can only be made once Horizon 2020 has concluded (SERI, 2018).

Advisory services for Swiss researchers participating in EU programmes

Euresearch is mandated by SERI to inform and advise research and innovation players in Switzerland who are interested in participating in an FP project. The Euresearch network has advisory points at ten higher education institution locations and is headquartered in Bern.
The Confederation helps to fund SwissCore (Swiss Contact Office for European Research, Innovation and Education, funded jointly by SERI, the SNSF and Innosuisse). The liaison office for Swiss researchers and students, located in Brussels, helps Swiss ERI players to network locally.

6.2 EU education and mobility programmes

Switzerland's cooperation with the EU in the field of education has been an established element of the Confederation's international promotion policy for over 20 years. Participation in the EU's multi-annual education programmes – either on a project basis or in the form of association – creates opportunities for mobility and cooperation between Swiss and EU educational institutions and individuals.

The present EU education programme Erasmus+ runs from 2014 to 2020. Switzerland currently participates with third-country status. In 2019 almost 12,700 persons from Switzerland and Europe were able to spend time abroad and thus enrich their educational experience under the programme. In Switzerland, the foundation Movetia, funded by the Confederation and the cantons, organises educational exchanges and mobility. The federal government is currently in discussions with the European Commission over Switzerland's possible association to the Erasmus+ successor programme (2021–2027).

6.3 Programmes, infrastructures and initiatives for international research and innovation cooperation

Switzerland does not only take part in the EU Framework Programmes, it is also a member of and partner in other international R&I programmes, infrastructures and initiatives. These give Swiss R&I players access to major international networks and thus to cost-intensive research facilities for conducting experiments and to a broad range of knowledge.

For example, Switzerland is a founder member of the European Space Agency (ESA). Thanks to its participation in the ESA programmes, Swiss R&I players have access to scientific data and can compete at an international level for research project funding and for contracts. Since ESA was founded in 1975, an effective, innovative Swiss space-related ecosystem has developed based on top quality research and value creation.

Switzerland also participates in CERN, the research facility for basic physical research and the world's largest research centre for particle physics. Set up in 1964 in Geneva and with locations in Switzerland and France, CERN is one of the world's largest international research infrastructures. It plays a major role in the Swiss research and innovation landscape.

Switzerland also participates in EUREKA, an international initiative promoting innovation cooperation for SMEs in particular.

A non-exhaustive list of Swiss participation in international programmes, infrastructures and initiatives can be found in the annex to this part of the report (pp. 48–49).

6.4 Bilateral research and innovation cooperation and the swissnex network

The Confederation funds bilateral programmes for research and innovation cooperation with selected countries such as China, India, Russia, South Africa, Japan, South Korea and Brazil. These programmes aim to promote the diversification of international partnerships and provide instruments for cooperation in order to facilitate the emergence of new partnerships of excellence with scientifically promising countries or regions. They also support Swiss ERI players in their autonomous internationalisation efforts.

[33] Indicated by the relative reduction in Swiss participation compared to other countries, the marked decline in Swiss coordination, and the reduction in EU funding to Swiss research institutes as a proportion of the total funding for projects under Horizon 2020.

Figure A 6.1: swissnex network

Source: SERI

The swissnex network is a further government-based instrument for promoting international cooperation. It fosters international networking of Swiss higher education institutions, scientists and research-related companies. The network includes around 20 science counsellors based at Swiss embassies around the world and at the five swissnex locations in Bangalore, Boston, Rio de Janeiro, San Francisco and Shanghai.

7 Knowledge and technology transfer

Successful innovation relies to an ever greater extent on cooperation among companies and between companies and universities. Businesses make use of the skills and services of their respective partners to boost their own innovation potential.

Knowledge and technology transfer (KTT) involves the exchange, provision and transfer of information, skills and R&D findings between universities and research institutions on the one hand and between companies and publicly funded players on the other. The aim is to initiate and improve innovation processes and thereby promote innovation. There is a focus on gaining economic benefit from existing and jointly created knowledge.

The ETH Domain and higher education institutions are also required to provide services and KTT. Since they traditionally focus on teaching and research, KTT is carried out primarily via the graduates who go to work in the private sector. Other forms of KTT include research cooperations and consulting.

KTT also takes place via Switzerland's participation in international F&I cooperation programmes (e.g. the FPs), infrastructures (e.g. CERN) and initiatives (e.g. EUREKA) (see Section 6.3 and annex to Part A). With Switzerland's participation in the European Space Agency, the Confederation also pursues a KTT policy, from institutional R&D programmes to commercial markets. KTT in space technology is also promoted via a range of complementary national measures.

Of equal importance is the transfer of knowledge from the fields of health, social affairs and arts as well as from the humanities and social sciences. This takes the form of advice, situation analysis and solutions with innovative perspectives for the social field.

7.1 Technology transfer offices

Technology transfer offices and KTT offices in publicly financed research and education institutions provide researchers with skilled partners for R&D projects both within and outside their institutions. These offices identify and evaluate research findings with economic potential, define a valorisation strategy with the researchers (e.g. how best to obtain patents and licences) and work with researchers and industry to implement this strategy.
In Switzerland there are three main types of KTT office:

- The office is an administrative unit fully integrated into a higher education institution and is centrally managed. This is the case in the majority of cantonal universities and at the FITs; for example, the KTT office ETH Transfer at the ETH Zurich.
- The office is integrated into a higher education institution but most of its activities are decentralised, taking place in departments and faculties with KTT tasks outsourced. This organisational model is the one preferred by the universities of applied sciences.
- Several universities pool their KTT activities, perhaps jointly owning an externally run KTT office which promotes transfer processes on their behalf. This is the approach adopted by the universities of Zurich, Bern and Basel in cooperation with the company Unitectra AG.

7.2 Public-private partnerships and centres of technological excellence

Public-private partnerships (PPPs) between higher education and the private sector create enormous potential for KTT. This is the case, for example, with Empa, a research institution in the ETH Domain, which transforms its research findings into marketable innovations in cooperation with industry partners and via spin-offs. Private and public co-financed research institutes (e.g. Disney Lab Zurich and Nestlé Institute of Health Sciences) and privately funded university chairs play an important role in KTT. In addition, institutions such as the European Space Agency (ESA) are increasingly implementing programmes as PPPs, with Swiss companies involved.

The centres of technological excellence (Art. 15 RIPA) are conceived of as PPPs and as transferers of knowledge. These are autonomous research institutions of national importance outside of the university sector which work with higher education institutions and the private sector. Examples of such centres include the Centre Suisse d'Electronique et de Microtechnique (CSEM) in Neuchâtel, the Geneva Biotech Campus and Inspire AG, based in Zurich and St. Gallen, whose focus is mechatronic production systems and manufacturing techniques.

Swiss Technology Transfer Association

The Swiss Technology Transfer Association (swiTT) brings together persons who are primarily engaged in technology transfer in their professional lives and who deal with cooperation between public and private research institutes, hospitals and other not-for-profit research institutions. The association connects KTT between the research institutes and the private sector. Members and other persons involved in KTT in the Academies and private sector benefit from the specialist support and continuing education opportunities and from a wide range of services.

7.3 Swiss Innovation Park

The Swiss Innovation Park is a public-private partnership of national importance run by the Confederation and cantons, the science community and the private sector. Under the umbrella brand 'Swiss Innovation', the park currently comprises five principal site operators: Switzerland Innovation Park (SIP) Basel Area, SIP Biel / Bienne, SIP innovaare, SIP Network West Swiss Federal Institute of Technology Lausanne and SIP Zurich. Several smaller sites are affiliated to these main ones.

The activities focus on enabling R&D cooperations between businesses, the higher education sector and research partners; on attracting companies and research groups; R&D investments by private investors; KTT and creating attractive conditions for start-ups.

The Innovation Park was launched around five years ago, and a positive assessment can already be made: all five sites are up and running, and the brand Switzerland Innovation is well established. Considerable progress has been made in creating jobs and in attracting businesses and investments. New premises are being added, thus making the Park even more attractive to new players in R&D.

The Park is funded by the cantons and private investors. The Confederation's involvement is restricted to providing guarantees for ring-fenced and fixed-term loans for the various site operators, primarily for the construction of research infrastructures. The Confederation can also lease federally owned land with building rights to the site operators (under Art. 33 RIPA).

The Innovation Park adds considerably to Switzerland's attractiveness as a location for research and innovation.

Figure A 7.1: Swiss Innovation Park sites

Source: Switzerland Innovation

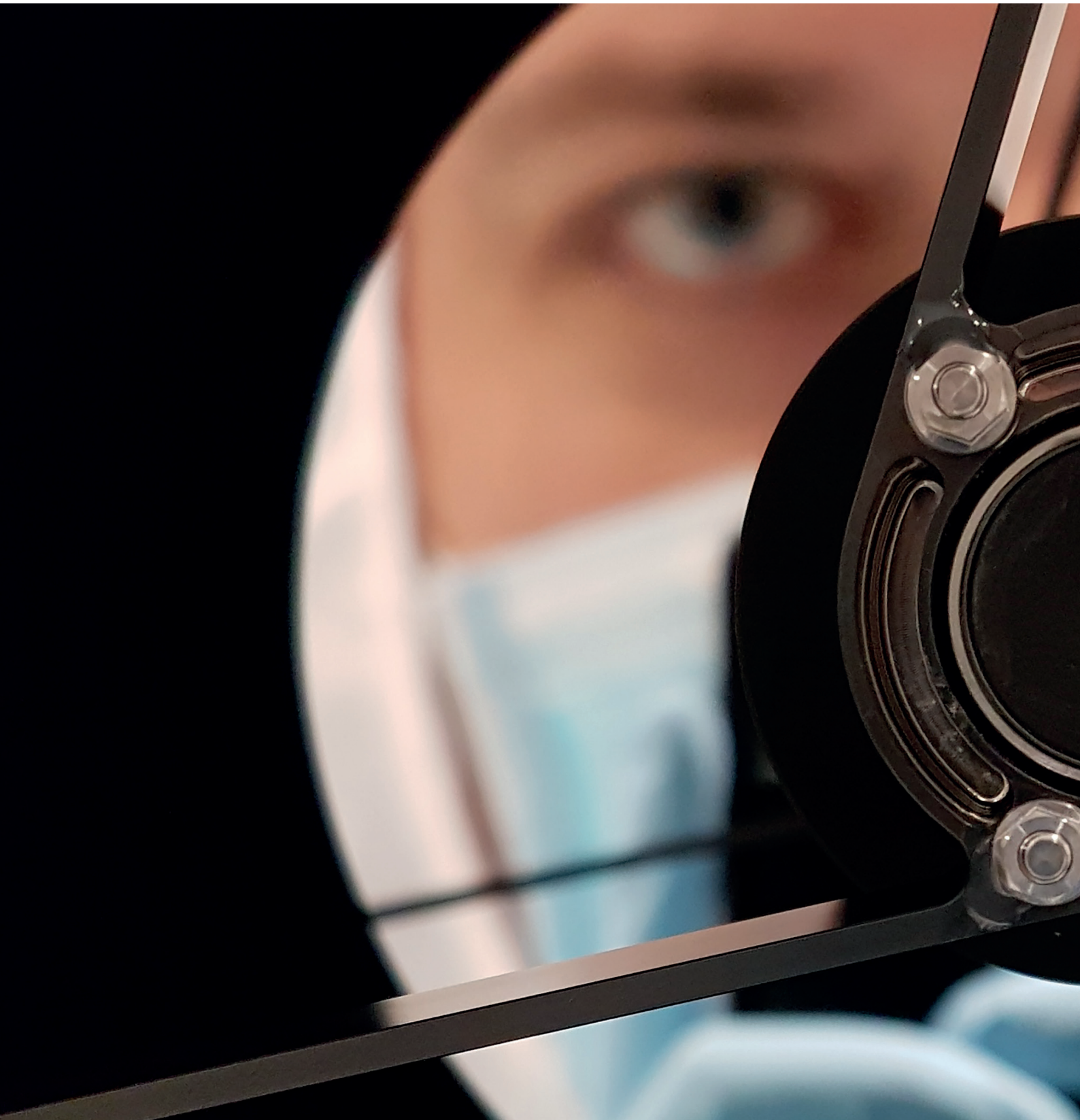
Annex to Part A

Programmes, infrastructures and initiatives for international research and innovation cooperation

An overview of the examples found in Section 6.3 and of examples of Swiss participation in international research and innovation programmes, infrastructures and initiatives can be found in the non-exhaustive list below.

Name	Function
International research and innovation programme	
FP, European Union Framework Programme for Research and Innovation, Brussels (Belgium)	Main EU instrument for implementing its science and technology policy. The 8th programme generation Horizon 2020 lasts from 2014 to 2020, the next generation Horizon Europe from 2021 to 2027.
Partnership instruments co-funded under Horizon 2020: – European Public-Public Partnerships (P2P) e.g. Active Assisted Living (AAL), European & Developing Countries Clinical Trials Partnership (EDCTP), Eurostars, European Metrology Programme for Innovation and Research (EMPIR); – European Joint Undertakings (JU) e.g. Innovative Medicines Initiative (IMI), Bio-Based Industries (BBI), Electronic Components and Systems for European Leadership (ECSEL).	
EURATOM, European Atomic Energy Community, Fusion research programme, Brussels (Belgium)	Coordinates national research activities relating to the peaceful use of nuclear energy in an international context.
EMBC, European Molecular Biology Conference, Heidelberg (Germany)	Promotes research in molecular biology in Europe and supports training and exchange of information between European researchers.
International research infrastructures	
CERN, European Laboratory for Particle Physics, Geneva (Switzerland)	Ensures the exclusively peaceful cooperation of European states in the field of nuclear and particle physics and promotes high-energy physics research with its accelerator facilities.
EMBL, European Molecular Biology Laboratory, Heidelberg (Germany)	Promotes European cooperation in basic research in molecular biology, provides the necessary infrastructure and participates in the development of cutting-edge instruments for biology.
ESO, European Southern Observatory, Garching (Germany) and various locations in Chile	Constructs and operates astronomical observatories in the southern hemisphere and promotes European cooperation in the field of astronomical research.
ESRF, European Synchrotron Radiation Facility, Grenoble (France)	Provides X-rays with high energy, intensity and accuracy, necessary for structural analysis in solid state physics, molecular biology, materials science, for diagnosis and therapy in medicine, and for special experiments in radiobiology, fundamental physics and physical chemistry. ESRF is complementary to the Swiss Light Source (PSI).

Name	Function
International research infrastructures	
ITER Organization, Cadarache (France); Fusion for Energy, Barcelona (Spain)	ITER is building the world's largest experimental nuclear fusion reactor to generate energy by means of nuclear fusion. Switzerland participates indirectly in ITER, via representation by the EU. However, it is a full member of the European undertaking Fusion for Energy, which manages and supplies the European contribution to ITER. ITER is complementary to the Swiss Plasma Center installations (Swiss Federal Institute of Technology Lausanne).
European XFEL, European X-Ray Free-Electron Laser Facility, Hamburg (Germany)	Creates short X-ray laser flashes with very high luminosity. This allows, for example, the recording of atomic details of viruses, of the molecular composition of cells, of elements of the nanocosmos and of physio-chemical and biological reactions. European XFEL is complementary to SwissFEL (PSI).
ILL, Institut Max von Laue – Paul Langevin, Grenoble (France)	Provides a high-performance neutron source for research and studies in material science, solid state physics, chemistry, crystallography, molecular biology, nuclear physics and fundamental physics. The ILL is complementary to the Swiss Neutron Spallation Source (PSI).
ESS, European Spallation Source ERIC, Lund (Sweden)	This European research infrastructure is building the world's most powerful neutron source. Switzerland has participated in the construction of the ESS and will also be involved in operating the facility. ESS is complementary to the Swiss Neutron Spallation Source (PSI).
Space	
ESA, European Space Agency, Paris (France)	Promotes cooperation between European countries in space research and technology for scientific purposes and for applications such as navigation systems and weather satellites.
International R&I initiatives	
COST, European Cooperation in Science and Technology, Brussels (Belgium)	Brings together researchers from research institutions, higher education and the private sector and gives them the opportunity to take part in European research networks and in a wide range of R&D activities. COST is complementary to the FPs and EUREKA.
EUREKA, European cooperation in technological research initiative, Brussels (Belgium)	Instrument to promote Europe's competitiveness. Operating on the bottom-up principle, it promotes market-oriented research, and development and knowledge transfer. Businesses, research centres and higher education institutions in countries around the world cooperate in bringing innovative products, processes and services onto the market. The initiative is particularly important to SMEs, which make up half of the partners. EUREKA is complementary to the FPs and COST.



ANNEX

Switzerland is active in space research and a founding member of the European Space Agency ESA. Thanks to this participation, key skills can be strengthened in Swiss research institutions and industry and new ones developed. A good example of this is the CHEOPS mission launched in 2019. CHEOPS is a space telescope on a satellite platform, developed and assembled by the University of Bern in close cooperation with the University of Geneva. The mission is the first to be jointly headed by Switzerland and ESA. Its aim is to obtain new insights into planets outside our solar system, known as exoplanets. This will help us to discover whether other planets could be habitable. Image: University of Bern

Annex 1 – Bibliography

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Annex 2 – Abbreviations

aR&D	Applied research and development
BFH	Bern University of Applied Sciences
CERN	European Organization for Nuclear Research
EAER	Federal Department of Economic Affairs, Education and Research
Eawag	Swiss Federal Institute of Aquatic Science and Technology
EDK	Swiss Conference of Cantonal Directors of Education
EFI	Commission of Experts for Research and Innovation
Empa	Swiss Institute for Materials Science and Technology
EPFL	Swiss Federal Institute of Technology Lausanne
ERI	Education, Research and Innovation
ERI Dispatch	dispatch on the Promotion of Education, Research and Innovation
ESA	European Space Agency
ETH Zurich	Swiss Federal Institute of Technology Zurich
EU	European Union
FC	Federal Constitution
FHGR	University of Applied Sciences of the Grisons
FHNW	University of Applied Sciences and Arts Northwestern Switzerland
FHO	University of Applied Sciences of Eastern Switzerland
FIT	Federal institute of technology
FP	European Union Framework Programme for Research and Innovation
FSO	Federal Statistical Office
GDP	Gross domestic product
HEdA	Higher Education Act
HES-SO	University of Applied Sciences and Arts Western Switzerland
ICT	Information and communication technology
Innosuisse	Swiss Innovation Agency
IHEID	Graduate Institute of International and Development Studies
KTT	Knowledge and technology transfer
MEM	Mechanical and Electrical Engineering Industries
NCCR	National Centres of Competence in Research
NRP	National Research Programmes
OASI	Old Age and Survivors' Insurance
PPP	Public Private Partnership
PSI	Paul Scherrer Institute
R&D	Research and development
R&I	Research and innovation
RIPA	Research and Innovation Promotion Act
SAHS	Swiss Academy of Humanities and Social Sciences
SAMS	Swiss Academy of Medical Sciences
SATW	Swiss Academy of Engineering Sciences
SCNAT	Swiss Academy of Sciences
SECO	State Secretariat for Economic Affairs
SERI	State Secretariat for Education, Research and Innovation
SFIVET	Swiss Federal Institute for Vocational Education and Training
SHK	Swiss Conference of Higher Education Institutions
SIP	Swiss Innovation Park
SME	Small or medium-sized enterprise
SNSF	Swiss National Science Foundation
SSC	Swiss Science Council
SUPSI	University of Applied Sciences and Arts of Southern Switzerland
swissuniversities	Swiss Conference of Rectors of Higher Education
swiTT	Swiss Technology Transfer Association

TA-Swiss	Foundation for Technology Assessment
UAS	University of applied sciences
UAS Grisons	University of Applied Sciences of the Grisons
UTE	University of teacher education
VDK	Conference of Cantonal Directors of Economic Affairs
VET	Vocational education and training
VPET	Vocational and professional education and training
VPETA	Vocational and Professional Education and Training Act
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
ZFH	Zürcher Fachhochschule