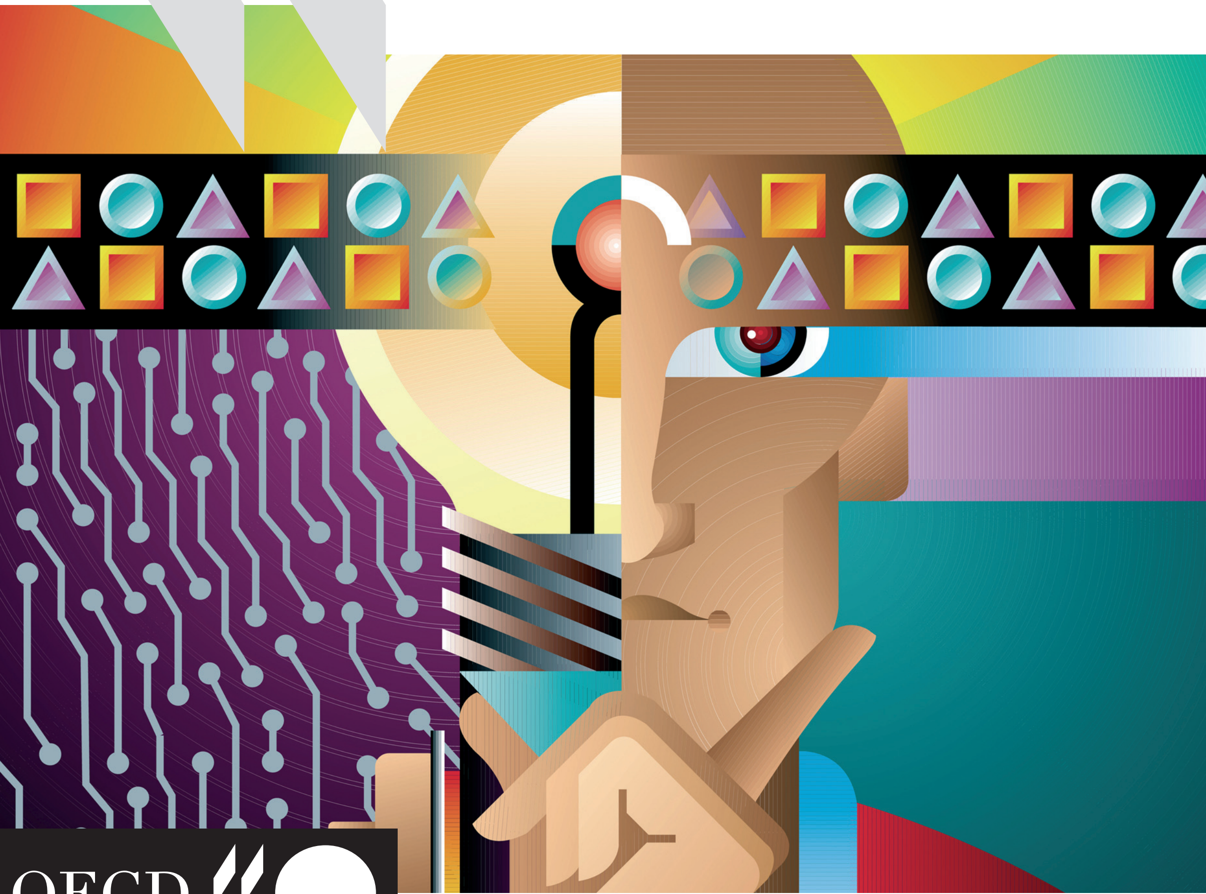
OECD Reviews of Innovation Policy

SWITZERLAND



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SUISSE

Foreword

This review of Switzerland's innovation policy is the first in a new series of OECD country reviews of innovation policy. It was requested by the Swiss authorities, represented by the Office of Professional Education and Technology (BBT), and was carried out by the OECD Directorate for Science, Technology and Industry (DSTI) under the auspices of the OECD Committee for Scientific and Technological Policy (CSTP).

The report complements the *OECD Economic Survey of Switzerland 2006*, which contains a chapter entitled "Innovation: Areas of Improvement", by exploring issues raised therein in greater detail, and by addressing additional topics that could not be covered in the *Economic Survey*.

This review draws on a background report prepared by the Swiss Institute of Business Cycle Research (KOF) at the Swiss Federal Institute of Technology (ETH) in Zurich (Arvanitis and Wörter, 2005) and on the results of a series of interviews with major stakeholders of Switzerland's innovation system by the OECD review team. The review was drafted by Gernot Hutschenreiter (Science and Technology Policy Division, DSTI, OECD) and Michael Stampfer (consultant to the OECD; Managing Director of the Vienna Science and Technology Fund) with the assistance of Michaela Glanz and under the supervision of Jean Guinet (Science and Technology Policy Division, DSTI, OECD).

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OVERALL ASSESSMENT AND RECOMMENDATIONS

Switzerland enjoys one of the highest levels of gross domestic product per capita in the OECD area. Yet, growth of per capita income has been among the lowest in OECD countries for an extended period of time. Sluggish growth has largely reflected weak productivity gains. In the absence of a significant pick-up in productivity, trend output growth can be expected to decline further owing to population ageing. Reviving growth through increased productivity is Switzerland's main economic policy challenge in the longer term. Further improving the country's high innovation performance will play a key role in boosting productivity.

Framework conditions for innovation

- Many framework conditions for research and innovation are good, including a reliable legal framework, a sophisticated financial system, a well-educated labour force, generally favourable taxation, etc. Openness of labour markets *vis-à-vis* the European Union facilitates balancing demand and supply for highly qualified human resources for science and technology (HRST).
- The lack of competition and market segmentation reduce incentives to innovate in some sectors (*e.g.* construction).
- Barriers to entrepreneurship are still rather high. These include difficulties in financing new innovative businesses, regulatory burden and opacity, and a punitive bankruptcy law. Double taxation of dividends makes equity financing expensive compared to internal funds and bank loans. Together, the bankruptcy law and the high cost of equity financing impair the creation and growth of small innovative firms. In fact, venture capital is in small supply and, moreover, directed at long-established firms and low-risk projects rather than at younger, highly innovative firms.

Achievements and challenges

Switzerland performs very well in terms of nearly all available indicators of science, technology and innovation, often holding with a leading international position. However, the stagnation in some indicators point to a deterioration of Switzerland's relative position *vis-à-vis* a number of countries, especially some small European economies that have moved ahead at a fast pace in recent years.

Strengths

- *Strong industrial research and innovation.* Switzerland has a strong and varied industrial research base. It comprises both large, R&D-intensive multinational enterprises which are at the forefront of industrial research and a large number of innovative small and medium-sized enterprises (SMEs) with strong positions in global market niches.
- *A high-quality research-oriented university sector and a well-developed research infrastructure.* Industrial research benefits from an excellent university-based public research sector, including the world-renowned federal institutes of technology in Zurich and Lausanne, and a number of very active cantonal universities as well as the some of the newly established universities of applied sciences (UAS). These institutions contribute effectively to Switzerland's high performance in innovation.
- *A strong services sector.* This sector, which includes a highly developed financial industry, plays an increasing role in the Swiss economy and innovation system. Its contribution to innovation in other sectors as well as its own innovativeness will therefore be of key importance for Switzerland's future economic performance.
- *Orientation towards high quality.* A pervasive orientation towards high-quality products and services throughout the Swiss economy contributes to high standards, performance and reputation.

Challenges

- *International competition.* The process of globalisation has led to fiercer competition and new sources of competition, even in niche markets where many Swiss small and medium-sized enterprises (SMEs) are leading actors. There is stronger international competition for the location of activities, including R&D, across the whole range of increasingly global value chains.

- *Insufficient innovation capabilities in parts of the economy.* Although most large and smaller Swiss firms show impressive innovative capabilities, there are pockets in the economy which are less advanced: enterprises in sheltered sectors which face too few incentives to innovate and some SMEs with an insufficient capacity to innovate. The issue is especially acute at the intersection of these two sets of firms.
- *A comprehensive reform of the higher education system is moving in the right direction but is not yet complete.* Universities of applied sciences have not always found their place in the innovation system. This will require further specialisation and consolidation. In addition, despite some progress, the education system does not sufficiently allow for student mobility, and the participation of women in higher education and science remains low by internationals standards.
- *Effective management of co-operative arrangements with the European Union (EU).* The European Research Area and related programmes have become vital for the Swiss innovation system. However, as a non-EU-member country, Switzerland faces particular challenges. There is room for improving the management of an increasingly dense and comprehensive web of agreements.

Assessment of current policy settings and instruments

Coping effectively with these new challenges may require addressing the following issues:

- *Vulnerability of public funding of research and innovation.* Public funding increases were sluggish during the period of slow economic growth. Although the government prioritised R&D spending for the period 2004-07, planned increases have been partly crowded out by other types of expenditure.
- *A piecemeal rather than systemic approach to science, technology and innovation policy,* which reflects the current balance of power among actors more than society's long-term needs.

This is apparent in:

- An imbalance in public funding according to the type of research (basic versus more applied research).
- The predominance of academics in governance and advisory bodies.
- The still minor role of the UAS in the Swiss research and innovation system.

The consequences of these features are amplified by the current practice of directing nearly all public funding instruments towards the academic partner in science-industry co-operation. Ruling out direct public support to industry has certainly avoided wasteful subsidisation of market actors. However, too rigid an application of this principle may hinder the government's ability to respond efficiently to new challenges, particularly when this involves addressing actors that have had little incentive and/or ability to draw on the research system.

Recommendations

To improve innovation performance, the government should both meet the needs of all actors more comprehensively and efficiently, and help some actors to better articulate their needs. This involves the following priority tasks.

Improving framework conditions for innovation

As pointed out by the *OECD Economic Survey of Switzerland 2006*, creating even more innovation-friendly framework conditions would entail notably:

- Pursuing efforts to increase competition and reduce market segmentation, by revising the domestic market law, eliminating administrative and technical barriers to EU imports and negotiating the same access for Swiss products to the EU market.
- Removing administrative, regulatory and financial barriers to entrepreneurship by streamlining authorisation procedures, reforming the bankruptcy law, and improving the tax, institutional and legal framework for venture capital.
- Improving the supply of human resources in science and technology by pursuing the reform of the university system, including the specialisation and the development of quality assessments of universities, increasing women's interest in sciences and engineering, and providing students from non-EU countries graduating in Switzerland more time to find a job in Switzerland.

Improving the governance of the innovation system

- Give high priority to public funding for science, technology and innovation in order to maintain Switzerland's world-class research and innovative performance. Take measures to safeguard public spending priorities more effectively, especially in an environment of fiscal consolidation and mandatory increases in other types of expenditure.
- Ensure that increased contributions to international co-operation in science and technology, notably to European programmes, do not crowd out funding of national programmes which address the specific needs of Switzerland.
- Maintain the *Message concerning the Promotion of Education, Research and Technology* (*ERT Message*) as a multi-annual planning instrument but ensure that it takes a more forward-looking approach to the needs of the Swiss innovation system.
- Make the Swiss Science and Technology Council (SWTR) more representative of the variety of stakeholders in the innovation system, notably from industry and include a larger number of members from abroad. Make better use of existing providers of strategic intelligence such as the Centre for Science and Technology Studies (CEST).
- Foster the Swiss National Science Foundation (SNF) and the Innovation Promotion Agency's (CTI) own strategic capabilities, and make good use of their experience as funding agencies when formulating overall science, technology and innovation policy strategies.
- Promote more interchange between the public sector, industry and academia regarding career patterns and mobility of researchers for co-operative research.
- Improve priority setting through a more systematic dialogue among key actors, making a more systematic use of advanced tools (technology foresight exercises, technology monitoring or road mapping and evaluations of programmes, institutions and policies). Revisit the role of TA Suisse in this context.

Improving support to university-based research

- Raise the budgets of the SNF at least to the levels envisaged in the ERT Message 2004-2007, and offer growth perspectives beyond 2007.
- Complement current SNF funding by well-endowed science prizes.
- Continue with the SNF Junior Professors initiative but ensure that junior professors are well integrated into the universities and that the scheme helps their subsequent academic careers.
- Make more use of foreign reviewers and peers in evaluations of researchers, projects and programmes.
- Promote further consolidation and specialisation of the UAS sector, including by better linking the development of UAS to regional and trans-regional clusters of economic activity, in co-operation with the cantonal authorities.
- Grant the UAS enough autonomy to enable them to develop relations with the business sector and to compete with established universities in certain areas.
- Allow, when appropriate, the UAS to offer master's degree studies both in order to increase their capabilities in the area of R&D and to improve their responsiveness to the needs of the business sector.

Promoting innovation within firms

- Raise CTI's budget at least to the levels foreseen in the ERT Message 2004-2007 and offer a growth perspective beyond 2007.
- Rebalance the portfolio of instruments towards more demand-oriented measures while keeping this portfolio as lean as possible.
- Consider launching a CTI funding programme for small firms aimed at a "first engineer" or "meaningful in-house innovation" projects. Undertake a study to prove the rationale and more precisely determine scope, size and instruments, possibly including direct funding, of such a programme.
- Consider launching a "centres of competence" programme[1] to catalyse relations with a broader set of actors in the innovation system. Such a programme should be implemented co-operatively by SNF and CTI.
- Give preference to strengthening technology transfer institutions that are already strong rather than creating additional ones.
- Take measures to make science, technology and innovation policy more responsive to the needs of the service sector, including the financial industry. First, support more research in the higher education sector to improve understanding of innovation in services. Second, consider promoting co-operative research involving public and private actors through the centres of competence approach referred to above.

1. Centres of competence, as understood here, are set up for a certain period of time to run a multi-annual research programme established and co-funded by one or several universities or public research institutes and a number of business enterprises with some support from government. This concept differs from that of the competence centres currently operating in Switzerland.

Chapter 1

INTRODUCTION

Switzerland is a very prosperous country. However, growth of per capita income has been weak in recent years, well below the OECD average. Achieving a higher trend output growth path is Switzerland's most important longer-term economic policy challenge. A persistent lack of dynamism is essentially linked to an underlying weakness in productivity growth. For this reason, boosting productivity is of key importance for the future development of the Swiss economy and to maintain Switzerland's high standard of living. Without a significant rise in productivity, trend output growth is likely to weaken further as a result of population ageing.

Productivity growth can be stimulated in several ways. In the longer term, building upon and further improving Switzerland's innovation performance will be of key importance. A leading position in innovation cannot be taken for granted. While Switzerland still performs very well in terms of nearly all available indicators of science, technology and innovation, some have weakened during the period of slow economic growth. Evidence suggests that the unfavourable business cycle is only part of the explanation (OECD, 2006*a*).

Since the early 1990s, Switzerland has been losing ground relative to other countries, including comparable small European economies. The ongoing globalisation of R&D poses new challenges: competition for the best international locations of R&D centres has been increasing among the most advanced countries, and new competitors entering markets for skill-intensive and, specifically, R&D-intensive products and services are confronting producers well-established in such markets. For a country with high labour costs, strong performance in innovation is crucial to maintain competitiveness.

Switzerland is endowed with valuable assets which allow the country to respond well and seize new opportunities, not least because of its advanced and sophisticated universities and industrial research. At the same time, there is scope for improvement. For instance, all aspects of framework conditions are not conducive to innovation, some parts of the innovation system are more developed than others, and the governance of science, technology and innovation policy would benefit from some adjustment.

Given Switzerland's underlying strengths, this will mainly involve fine tuning and, to some extent, rebalancing a very successful innovation system. Switzerland may also gain from adapting its approach to innovation policy. The experience of OECD countries shows that science, technology and innovation policy can play an important role in fostering innovation performance and economic growth. International good practices provide insights that can be useful in deriving policy responses geared to Switzerland's traditions and new requirements.

Chapter 2

MAPPING SWITZERLAND'S INNOVATION SYSTEM

2.1 Introduction

Switzerland is in many respects a most successful country. Building on more than 150 years of peaceful development, the Swiss Confederation is one of the safest and most prosperous places in the world. It has strong performers in a number of industrial and technological areas, such as pharmaceuticals, biotechnology, medical technology, machinery and equipment, food, and the financial industries. Endowed with few natural resources, Switzerland started early to rely on education, engineering skills and innovation for its economic and social development. Companies such as ABB, Nestlé, Novartis and Roche have their home base in Switzerland, and many smaller enterprises have an excellent reputation and large export shares in various high and medium technologies. Within the education sector, the universities of Zurich, Basel and Geneva, and the two federal institutes of technology of Zurich (ETHZ) and Lausanne (EPFL) have a long-standing tradition of excellence with respect to their scientific output and the achievements of their graduates.

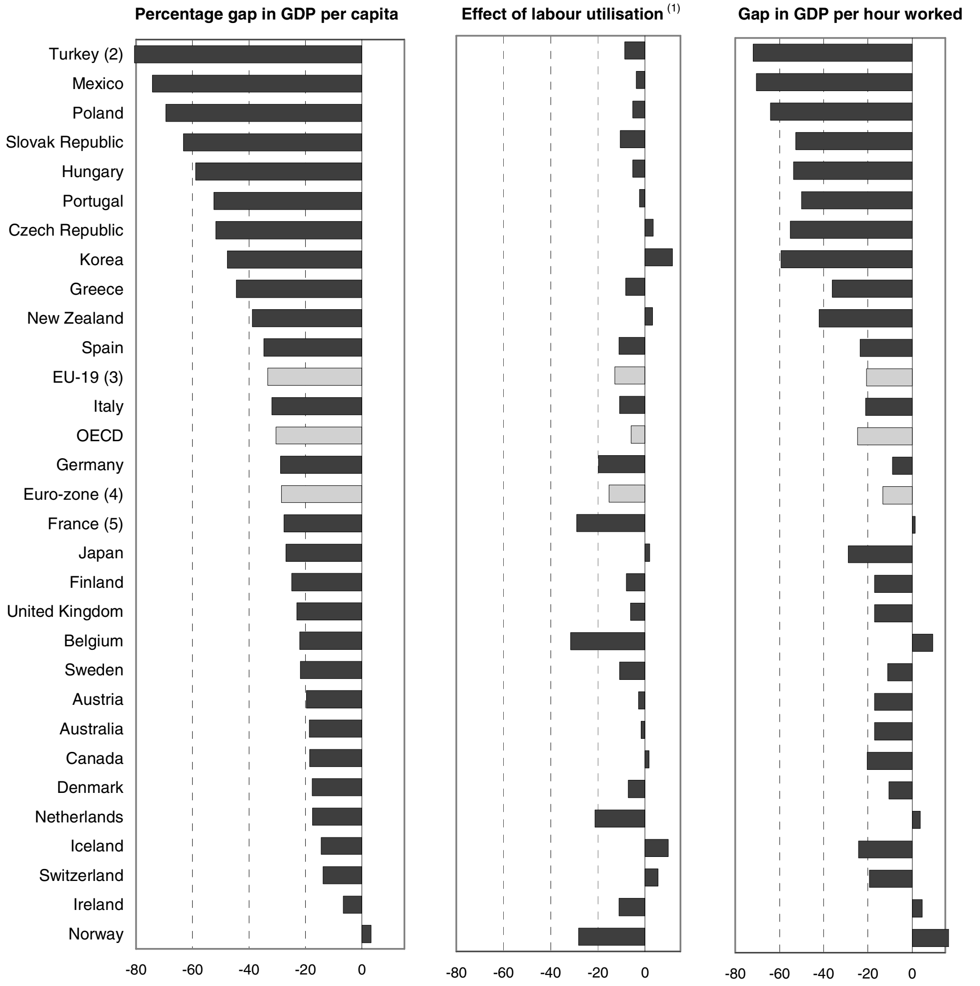
Switzerland has achieved a top international position in a number of the indicators widely used to measure the performance of innovation systems. It ranks very high in patents, publications and citations, as well as in innovation by business firms. Nevertheless, its relative position has weakened somewhat over the past decade. While remaining at a high level, many input and output indicators have tended to stagnate, and other economies both in Europe and worldwide are catching up, some rapidly. This has gone hand in hand with a slowdown in Switzerland's economic growth, which was almost flat in the 1990s. The low-growth trap has not yet been overcome and will be addressed in Sections 2.4 and 2.5.

While the performance levels of the economy in general and in the innovation system in particular remain high, the overall lack of dynamism has become a matter of concern for policy makers. The extended phase of slow growth was accompanied by rising public sector debt and federal budget deficits in eight of the eleven years between 1993 and 2003 (Swiss Federal Chancellery, 2005). Increases in public sector debt and deficits are not excessive in the European context, but they have an impact on policy making, including innovation policy, by making it difficult to allocate additional resources in areas that are very important for future productivity and growth, such as education and research.

The following section provides basic information about Switzerland's macroeconomic performance over the past 15 years and key data on the Swiss innovation system. This information is complemented by a brief presentation of the institutional landscape in science, technology and innovation in order to provide an overview of the architecture of the Swiss innovation system, its main components and their mutual relationships. No details, judgements or conclusions are given at this stage. Next, drawing on the background report prepared for this review (Arvanitis and Wörter, 2005) as well as other sources, the chapter takes a first look at actors in the public sector. Which are the governing institutions and who is in charge of public funding of different activities in the area of science and innovation? Who are the main performers and – taking an innovation system perspective – what does the overall architecture look like? The following section then describes the structure and main elements of public and private spending in this area, ranging from science and research to technological and some non-technological innovation activities. A large share of industry input and concentration of public sector spending on the higher education sector are two salient features of the Swiss innovation system. A final section focuses on innovation output data to show that Switzerland has a rather small but effective higher education and (publicly funded) science sector, which attracts many qualified people from abroad.

Figure 2.1. Income and productivity levels, 2005

Percentage point differences with respect to the United States



1. Based on total hours worked per capita.
2. GDP for Turkey is based on the 1968 System of National Accounts.
3. EU member countries that are also member countries of the OECD.
4. Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.
5. Includes overseas departments.

Source: OECD (2006*b*).

2.2 Macroeconomic performance

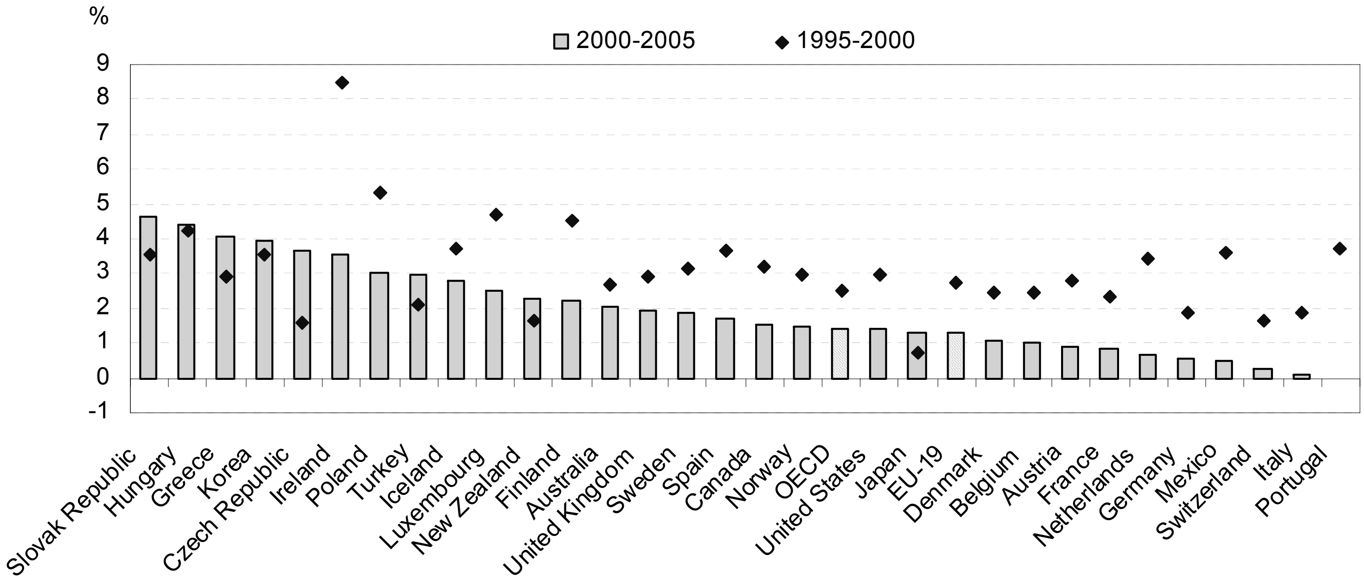
Switzerland is very prosperous: it ranks third among OECD countries in terms of GDP per capita at current exchange rates and fifth in terms of current purchasing power (2004). Gaps in income and productivity levels *vis-à-vis* the United States are comparatively small (Figure 2.1). Lagging labour productivity (in terms of GDP per hour worked) – partly compensated by a high level of labour utilisation – accounts for the gap in GDP per capita.

Although income and productivity levels remain high by international standards, Switzerland's growth performance has weakened since the early 1990s. In fact, GDP per capita contracted in the first half of the 1990s, and from 1995 to 2005 its growth was among the slowest of OECD countries (Figure 2.2). The *OECD Economic Survey of Switzerland* states that in terms of GDP, the growth differential with the three largest euro area countries has been approximately three-quarters of a percentage point a year since 1990, close to 1 percentage point with Austria and the Nordic countries, and 2 percentage points with the United States (OECD, 2006*a*). With a number of adjustments to deal with various distortions, the performance gap is reduced but Switzerland's growth performance still remains one of the weakest in the OECD area.

Labour productivity growth, in terms of change in GDP per employee in the business sector, was virtually nil in the first half of the 1990s, and again close to flat in the last decade (Figures 2.3 and 2.4). The *OECD Economic Survey of Switzerland* concludes that the main reasons for sluggish productivity growth are a lack of competition in sheltered sectors, inefficient product market regulations and high costs of services delivered by the public sector or financed by compulsory contributions.

Figure 2.2. Growth in GDP per capita, 1995-2000 and 2000-2005

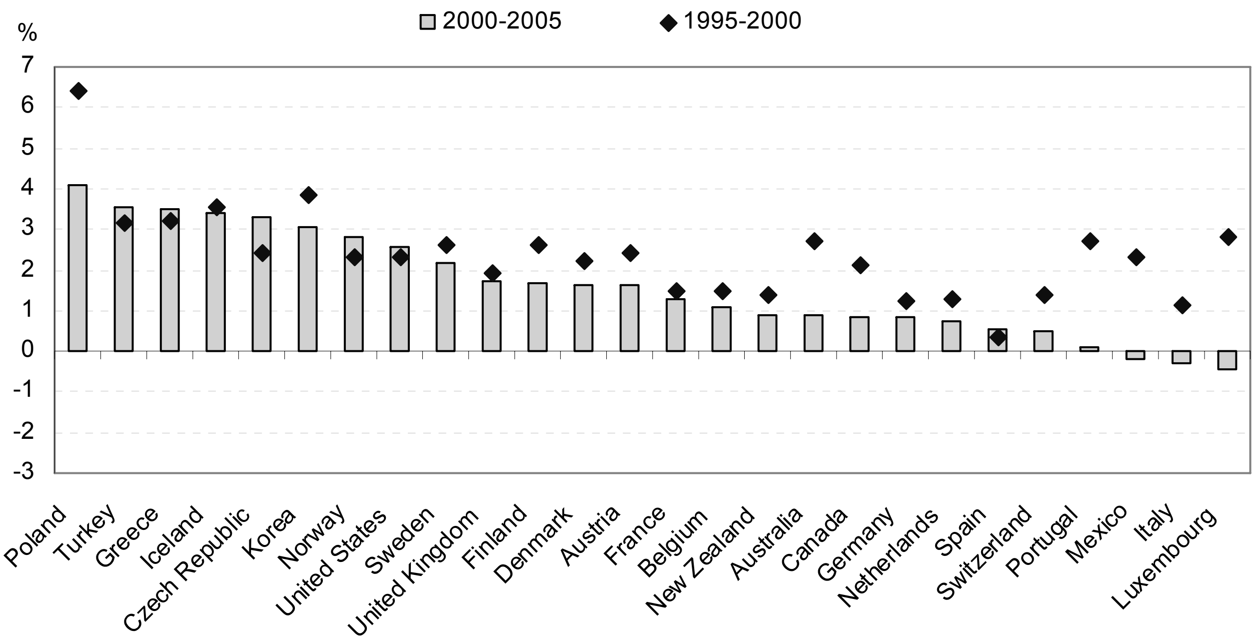
Total economy, percentage change at annual rate



Source: OECD (2006*b*).

Figure 2.3. Growth in GDP per employee, 2000-2005 compared with 1995-2000

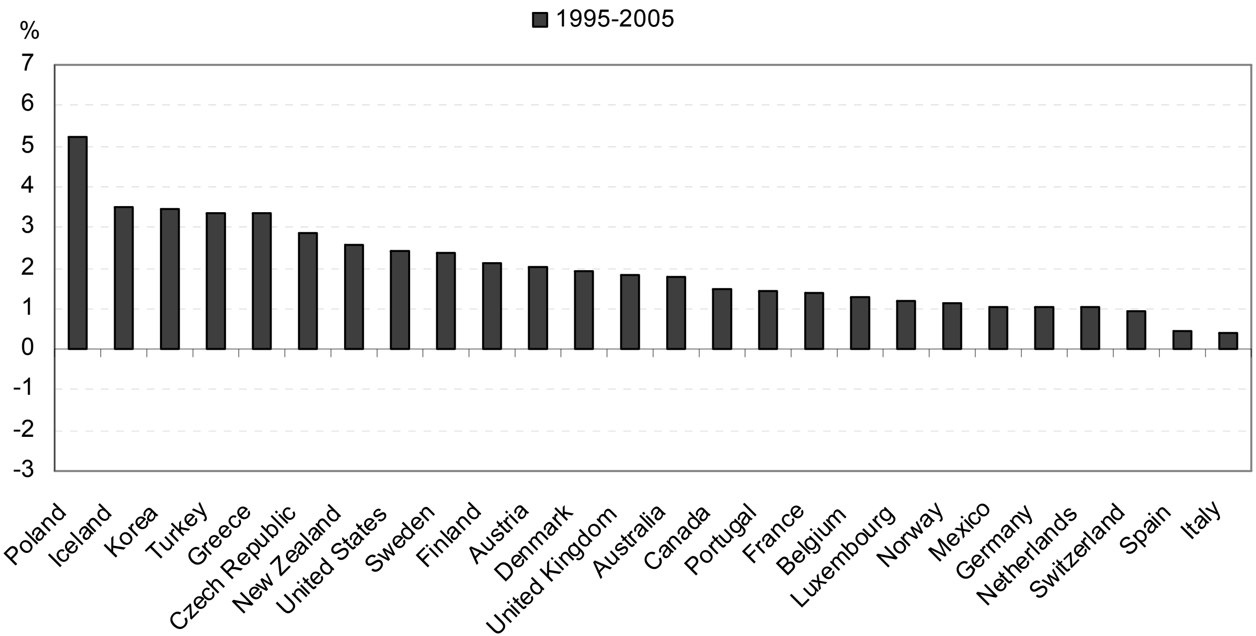
Business sector, average annual growth rate



Source: OECD (2006*b*).

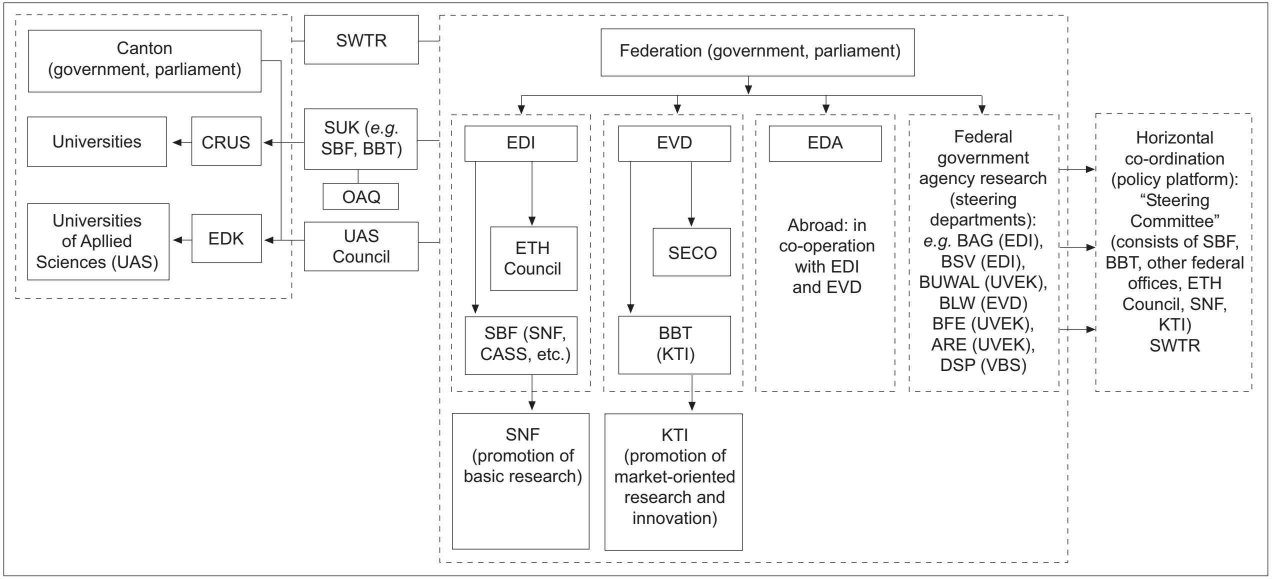
Figure 2.4. Growth in GDP per employee, 1995-2005

Business sector, average annual growth rate



Source: OECD (2006*b*).

Figure 2.5. Governance structure: the most important Swiss institutions for science and technology policy



ARE: Federal Office for Spatial Development, **BAG**: Federal Office for Public Health, **BBT**: Federal Office for Professional Education and Technology, **SBF**: State Secretariat for Education and Research, **BFE**: Federal Office of Energy, **BLW**: Federal Office for Agriculture, **BUWAL**: Agency for Environment, Forests and Landscape, **BSV**: Federal Social Insurance Office, **CASS**: Council of the Swiss Scientific Academies, **CRUS**: Rectors' Conference of the Swiss Universities, **DSP**: Directorate for Security Policy, **EDA**: Federal Department of Foreign Affairs, **EDI**: Federal Department of Home Affairs, **EDK**: Swiss Conference of Cantonal Ministers of Education,, **ETH**: Federal Institutes of Technology, **EVD**: Federal Department of Economic Affairs, **CTI**: Innovation Promotion Agency, **OAQ**: Centre of Accreditation and Quality Assurance of the Swiss Universities, **SECO:** State Secretariat for Economic Affairs, **SNF**: Swiss National Science Foundation, **SUK**: Swiss University Conference, **SWTR**: Swiss Science and Technology Council, **UVEK**: Federal Department of Environment, Transport, Energy and Communications, **VBS**: Federal Department of Defence, Civil Protection and Sports. *Source:* Arvanitis and Wörter (2005).

2.3 Public institutions and actors

The institutional setting appears broadly similar to that of many other OECD countries: two ministries (*départements*) are responsible for science, technology and innovation policy making and strategy. Within the ministries, a number of sub-units and organisations have specific tasks, and a policy steering committee acts as co-ordinating body. Both the Confederation and the regions – the *cantons* – have competencies and funds for higher education and thus for academic research. An advisory council serves as a strategic steering body. There are two separate and independent funding organisations, one of which is responsible for the funding of science and the other for the funding of more applied research. A number of governing and co-ordinating bodies are clustered around the higher education sector, which has three parts: the federal institutes of technology (the so-called ETH domain, which also includes some public research centres), the universities, and the universities of applied sciences (UAS). Industry also has a number of strong sectors: pharmaceuticals, chemistry, electrical engineering, machinery and banking. The institutions and their interplay within the innovation system are discussed in more detail later in the report. The public and private research performers are also described in individual chapters.

Viewed in greater detail (Figure 2.5), the institutional arrangement is as follows. The federal government is responsible for the legal framework, the bulk of public funding and the main directions of innovation policy. The two departments in charge are the Federal Department of Home Affairs (EDI) and the Federal Department of Economic Affairs (EVD). EDI has most of the responsibility for higher education and basic research, and EVD is the main actor in promoting applied research, entrepreneurship and science-industry co-operation. EVD also steers one part of the higher education sector, the technically oriented UAS, which are also currently upgrading their capabilities in the fields of health, social studies and the arts. Switzerland has a very small federal administration, owing to a tradition of lean government based on the principle of subsidiarity, by which anything that can be decided or administered at the community level is as a general rule to be decided or administered there. Other decisions are taken at the level of the 26 cantons. For a country of 7.3 million inhabitants this implies a rather high degree of decentralisation. Only in exceptional cases, where regional policy making is clearly insufficient, is the federal level in charge. The federal government has only eight departments including the Federal Chancellery; this explains why higher education is under the Ministry of the

Interior.[2] Lean government also means rather small ministries with comparatively small staff. In the Swiss parliament, each chamber has a parliamentary commission covering science, education and innovation topics. Representatives of the administrative offices concerned are consulted on a regular basis and on a wide range of relevant issues.

EDI has a number of federal offices and other institutional subdivisions. For innovation policy, the main actor is the State Secretariat for Education and Research (SBF), which only officially began operations in 2005. SBF is the result of the merger of two agencies, the former Swiss Science Agency and the former Federal Office for Education and Science. Its state secretariat status formally gives it influence over federal innovation policy. SBF represents the federal state in the areas of education and research in a number of national and international committees. Its annual budget is about CHF 1.7 billion (2005). At the international level, it supervises and finances Swiss membership in multinational organisations such as ESA, CERN or EU Framework Programmes. At the national level, it works towards a coherent research and innovation policy. SBF is in charge of all aspects of Swiss science policy, except for certain regulatory issues directly administered by the ETH Council (see below). Furthermore it (co-)funds the cantonal universities, more than 20 research centres, the Swiss Academies of Science and some research funding institutions, most notably the Swiss National Science Foundation (SNF). Another important actor within the EDI's domain is the ETH Council, the governing body of the two technical universities in Zurich (ETHZ) and Lausanne (EPFL) and four research institutes, the Paul Scherrer Institute (PSI, a kind of national laboratory), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Testing and Research (EMPA) and the Swiss Federal Institute for Environmental Science and Technology (EAWAG). The Council is chosen by the federal government and consists of nine members, including top management in the ETH sector. It steers and designs ETH policy. With an annual budget of about CHF 1.8 billion, it is the second big financial player in EDI.

The innovation policy agenda of EVD is vested with the State Secretariat for Economic Affairs (SECO) and the Federal Office for Professional Education and Technology (BBT). SECO acts as the Confederation's competence centre for all core issues relating to economic policy. Within the State Secretariat, a Promotion Activities Directorate deals with SME policy,

2. In Finland, the Ministry of the Interior enters innovation policy *via* regional policy and co-ordinates a number of other ministries in the large centres of expertise programme.

regional policy and tourism, fields in which innovation is important. BBT steers the Commission for Technology and Innovation (CTI), the Swiss innovation promotion agency with an annual budget of about CHF 100 million. BBT is also responsible for the federal share of the UAS system with a budget of about CHF 270 million. The EVD's role in higher education policy is the result of the evolution of vocational and upper secondary training for mostly technical professions, for which it was responsible, towards the UAS sector. BBT now manages the consolidation of this sector and its better integration with the tertiary education sector.

Representatives from SBF, BBT, SNF, CTI, the ETH Council and other federal offices form the so-called Steering Committee for horizontal co-ordination of innovation policy. This committee acts as the most important information exchange platform in this policy field.

External policy advice is provided by the Swiss Science and Technology Council (SWTR). The SWTR was initially designed as an advisory body for science policy, but its mandate was broadened in 2000 to include all matters relating to science, education and technology policy. It mainly consists of Swiss scientists – a point addressed below – and its tasks are to deliver statements and reports and to organise evaluations. The SWTR governs two important providers of strategic intelligence, TA Suisse for technology assessment and CEST (Centre for Science and Technology Studies) for strategic studies and data compilation.

The two major funding institutions have a long history: KTI – the Commission for Technology and Innovation – was founded in 1943 as a commission for the promotion of scientific research in a beleaguered economy[3] and received its present name in 1996. SNF was founded in 1952 as a private non-profit foundation following an initiative of Bern University professor Alexander von Muralt. These two funding agencies have distinct roles and different missions in the innovation system and both fund university-based research.

CTI tries to improve links between science and industry and co-finances market-oriented research, provided that the industrial partners contribute to the project. According to Swiss innovation policy, business firms cannot be funded directly by a federal agency. With an annual budget of about CHF 100 million (KTI, 2004), the agency is the smaller of the two funding institutions and has weaker legal safeguards. A number of programmes

3. Therefore the legal framework was called *Krisenbekämpfungsgesetz* (literally translated, "law concerning the combat of crisis").

address certain technology fields, such as nanotechnologies or medical technologies, certain types of actors such as the UAS, or certain stages in the lifecycle of firms, such as the start-up phase. At first glance it works on a mix of bottom-up and top-down elements. CTI relies on a "militia type" body of experts for project appraisal.

SNF has a strong federal mandate and a high degree of autonomy. Its main governing bodies are the Foundation Council and the National Research Council.[4] It is by far the most important instrument for project-based and programme-based science funding. It supports investigator-driven research in all disciplines, with excellence as its main criterion. It funds first and foremost individual, bottom-up grants for researchers, along with scholarships and various programmes ranging from bottom-up networks to top-down priority-setting activities or other human resource activities. Its budget, about CHF 400 million a year, comes from the federal government.

The cantons have their own administrative structures for economic and education policy. There are relatively few specific funding instruments at the cantonal level. Corporate tax arrangements are one important policy instrument, and cluster structures supported by regional actors are another. Cantons have strong structures in the area of higher education policy, as they have primary responsibility for education policy at all levels.

Co-ordination of higher education issues is a matter of concern in Switzerland; this is reflected in the operation of the university rectors' conference (CRUS) and its UAS counterpart, the conference of the UAS for steering and co-operation within sectors. The ETH Council has similar functions for the ETH sector but also covers governance issues. The Swiss University Conference (SUK) brings together cantonal and federal representatives to issue directives concerning the recognition of previous studies and qualifications which become binding through cantonal agreements. It is responsible for the recognition of academic bodies. SUK can also award project-specific grants and makes periodic assessments of certain network-oriented funding instruments, the development of individual university profiles and the balanced distribution of tasks among universities. The role of the UAS Council is to balance cantonal and federal interests in its area of competence. The important task of inter-cantonal co-ordination is carried out by the Swiss Conference of Cantonal Ministers of Education (EDK). Linked to SUK, the Accreditation and Quality Assurance Body (OAQ) promotes quality of teaching and studies at Swiss universities. Finally,

4. Their functions are described in Chapter 6. They should not be confused with the Swiss Science and Technology Council.

reform of the university sector is a main activity of the Swiss Science and Technology Council.

An appraisal of the institutions and more detailed descriptions of key actors and systemic aspects are given in Chapters 5-7. The foregoing short description of the most important public policy actors reveals certain features of the Swiss system:

- There is a strong reliance on the science sector, *i.e.* on universities, and a rather limited number of policy actors and instruments for promoting industrial innovation in a broad sense.
- There is no dominant actor. The arena is rather small, with the notable exception of the governance of higher education.

Before undertaking a more in-depth analysis, it is useful to consider some basic data on the position of Switzerland in terms of inputs into the innovation system as well as innovation output and performance.

2.4 Innovation inputs

Switzerland has been traditionally viewed as having comparatively high research intensity (defined as the share of gross expenditure on research and development [GERD] in GDP), of the order of 2.9%.[5] Among OECD countries, only Sweden, Finland and Japan are more R&D-intensive, and Korea and Iceland have now reached about the same level. Switzerland has historically had a high level of GERD. GERD did not increase significantly in the second half of the 1990s, and in the 1990s compound annual growth rates of GERD at constant prices were far below the OECD or EU average, but have picked up in recent years. The evolution of GDP itself, which is still at a high level, has shown a tendency towards low growth. Among OECD countries, Switzerland had the lowest rate of growth of GDP in the period 1995-2004.

The relative stagnation in Switzerland's R&D intensity contrasts with other countries' more dynamic past performance and ambitions, which have led some of them to set explicit R&D intensity targets (Table 2.1).

5. Compared to more than 2.7% in the second half of the 1980s.

Table 2.1. Targets for R&D spending

Country/economy	Target	Date	Most recent
Austria	2.5% GDP	2005	2.3% GDP (2005)
Canada	Top 5 in OECD	2010	1.99% (2004) (12th)
China	2.5% GDP	2020	1.23% (2004)
Denmark	3% GDP	2010	2.5 % (2004)
Finland	4% GDP	2011	3.5% (2006)
Germany	3.0% GDP	2010	2.5% GDP (2004)
Greece	1.5% GDP	2010	0.6% GDP (2004)
Hungary	OECD avg.	2006	0.9 (2004)
Ireland	2.5% GNP	2010	1.2% GDP (2004)
Korea	Double public investment	2007	2.9% GDP (2004)
Luxembourg	3.0% GDP	2010	1.8% GDP (2004)
Netherlands	3.0% GDP	2010	1.8% GDP (2004)
Norway	3.0% GDP	2010	1.6% GDP (2004)
Poland	2.2%-3.0% GDP	2010	0.6% GDP (2004)
Portugal	Double public investment in R&D to 1% of GDP and triple business R&D	2010	0.8% GDP (2003)
Russia	2.0% GDP	2010	1.15 % GDP (2004)
Spain	2.0% GDP	2010	1.1% GDP (2004)
Chinese Taipei	3% GDP	2006	2.56% (2004)
United Kingdom	2.5% GDP	2014	1.9% GDP (2003)

Source: OECD (2006*b*) and OECD Main Science and Technology Indicators (MSTI).

Between 2000 and 2003, Switzerland's R&D expenditure amounted on average to about CHF 10.7 billion annually. A little less than three-quarters, CHF 7.9 billion, was private R&D expenditure, mainly by industry. The remaining CHF 2.8 billion was public spending (Table 2.2). Of this, roughly three-quarters is federal expenditure and one-quarter cantonal.

Table 2.2. Public R&D expenditures, annual average 2000-03

Estimations in CHF millions

	Cantonal research	Federal research	Total	Cantonal (%)	Federal (%)	Total (%)
Universities/ETH (without universities of applied sciences and projects with co-operation)						
Cantonal universities	765	191	956	80	20	34
ETH	-	923	923	-	100	33
Promotion of national basic research						
SNF	-	365	365	-	100	13
Scientific academies, institutions in art. 6 and 16 of the Federal Law on Research	-	80	80	-	100	3
International promotion of research						
EU research programmes and COST	-	168	168	-	100	6
International co-operation	-	100	100	-	100	4
ESA	-	122	122	-	100	4
Innovation promotion (CTI)						
CTI and Top Nano	-	91	91	-	100	3
Total public funding R&D	**765**	**2 040**	**2 805**			**100**
Private R&D			**7 913**			
Total R&D			**10 718**			

Notes: Support for secondary and tertiary education ("*Ausbildungshilfen*") is not considered. Figures for federal expenditures are taken from the public account (*Staatsrechnung*) 2000/01 and from the budget 2002/03. The data are approximations Public expenditures for research at universities and ETHs were calculated based on data from the Statistical Office (*BFS, 2002*). Based on the distribution of activities at universities and ETHs (teaching versus R&D activities) in 2000, averages (weighted by employment) were derived for a university or ETH, respectively. The weight refers to scientific personnel only. The proportion of research is 46% for universities and 53% for ETHs. Public expenditures of cantons and the federal government on education and research were weighted by these figures. Public expenditures for universities of applied sciences and project co-operation are not considered. However, the federal government provided CHF 8 million for applied R&D at UAS for 2003. Not considered are public expenditures for government agencies' research which are determined by separate budget negotiations in the Federal Parliament. For the period 2004-07 around CHF 615 million is planned for government agencies' research (see *Schweizerisches Bundesrat, 2002*).

Source: Arvanitis and Wörter (2005) based on Schweizerisches Bundesamt (2002), authors' calculations.

Table 2.3. Evolution of R&D expenditure, selected countries

	R&D expenditure as a percentage of GDP, 2004	Average annual growth rate of R&D expenditure, 1996-2004	Business R&D expenditure as a percentage of value added in industry, 2004	Average annual growth rate of BERD, 1996-2004	Percentage share of business R&D expenditure by size classes 2001				Average annual growth rate of GBAORD, 1995-2005
					< 50 employees	50 – 250 employees	> 250 employees	Total	
Switzerland	**2.94**	**2.8**	**3.21**	**3.4**	**10.6**	**19.6**	**69.8**	**100**	**-0.3**
Netherlands	1.78	1.3	1.54	2.5	5.9	13.2	80.9	100	1.0
Sweden	3.95	4.9	4.64	4.8	n.a.	13.1	n.a.	100	5.4
Finland	3.51	8.0	3.67	8.7	10.0	12.6	77.4	100	2.2
Denmark	2.48	5.8	2.73	7.3	12.7	17.8	69.5	100	0.2
Austria	2.24	6.7	1.99	9.0	5.5	12.3	82.2	100	1.7
Ireland	1.20	6.5	1.07	5.3	20.5	28.7	50.8	100	10.1
Germany	2.49	3.1	2.51	3.9	5.8	9.3	84.9	100	-0.2
France	2.16	1.9	2.04	2.1	4.2	9.2	86.6	100	2.8
Italy	1.11	3.3	0.76	1.8	5.9	59.6	34.5	100	5.1
United Kingdom	1.88	2.9	1.70	2.3	14.4	20.5	65.1	100	2.4
United States	2.68	3.9	2.69	3.6	5.9	8.2	85.9	100	7.2
Japan	3.13	2.4	3.13	3.1	n.a.	7.0	n.a.	100	5.9
EU15	*1.90*	*3.5*	*1.76*	*3.7*	*7.4*	*17.0*	*75.6*	*100*	*1.0*
OECD	*2.26*	*3.7*	*2.17*	*3.7*	*5.3*	*11.4*	*83.3*	*100*	*3.5*

Column 1: Italy, Sweden, United Kingdom, EU15: 2003. *Column 2:* based on year 2000 PPP USD. Italy, United Kingdom, EU15: 1996-2003; Sweden: 1995-2003. *Column 3:* Sweden: 2003, Austria: 2002. *Column 4:* BERD: business enterprise expenditure on R&D, based on year 2000 PPP USD; Sweden: 1995-2003; Austria: 1993-2002. *Columns 5, 6 and 7:* Switzerland, Netherlands, Italy, France, United States: 2000; Germany, Denmark: 1999; Austria: 1998. *Column 9:* GBAORD: government budget appropriations or outlays for R&D, based on year 2000 PPP USD, Switzerland: 1996-2002; Finland: 1997-2005; Denmark: 2001-2005; Ireland: 1995-2004; Italy: 1995-2001; Germany, France: 1997-2004; United Kingdom, Japan: 1995-2003; United States: 2000-2005; EU15: 2002-2003; OECD: 2000-2003. *Source*: OECD Main Science and Technology Indicators, 2006/1, OECD (2005*c*), Arvanitis and Wörter (2005).

In terms of international comparisons, overall growth of GERD and business enterprise expenditure on R&D (BERD) has been below average. Table 2.3 shows that for 1996-2002 Switzerland experienced a stagnation in government expenditure on R&D (GBAORD). The latter has picked up in recent years. Contrary to the catching-up hypothesis, Sweden and Finland both had higher research intensities *and* experienced significantly higher growth in GERD and BERD than Switzerland, and, to a lesser extent, the same is true of the United States. Other small European countries such as Denmark, Austria and Ireland also increased their investment in R&D at a much faster pace.

Public funding of R&D is average by international standards, at about 0.65% of GDP; cuts in the 1990s primarily affected public research. Public R&D expenditure is strongly focused on the university sector (Arvanitis and Wörter, 2005, p. 20). In terms of spending for research (annual averages for 2000-03) the ETH sector and the cantonal universities each get roughly one-third of the overall research budget. While the ETH sector is entirely financed by the federal government, four-fifths of the funds for cantonal universities are provided by the cantons. Another 13% is allocated to the Swiss National Science Foundation for project- and programme-based science funding, and another 3% goes to various scientific institutions, including academies. Participation in EU Framework Programmes, international co-operation and the European Space Agency (ESA) receive another 14%, and the remaining 3% go to CTI for funding mostly university-based applied research. These figures (which exclude some public-sector research agencies and commissioned research) show that about 80% of public spending is for a block composed of the ETH sector, universities and SNF. If the four ETH research institutes are omitted,[6] the universities and SNF still account for more than 70%.[7] Considering that Swiss universities also benefit from CTI funding and indirectly receive a good share of the money for international programmes and infrastructure, 80% to 90% of the core public R&D budgets seem to go to the university sector (see also Lepori, 2005*a*, p. 11).

6. See Section 2.2; these are pure research institutions and do no teaching.

7. The ETH sector budget of about CHF 1.8 billion is composed as follows: ETHZ: CHF 940 million, EPFL: 430 million, PSI: 220 million, EMPA: 83 million, EAWAG and WSL: 47 million each, *i.e.* the two federal institutes of technology together get more than three-quarters.

Project and programme funding are important vectors in an innovation system, contribute to the quality of research and indicate specific directions. An overview of project funding (Lepori, 2005*a*, p. 13) shows a variety of sources for 2002 (*i.e.* before the SBF merger mentioned above), with most of the funds allocated to the higher education sector. SNF is the single most important funding institution in Switzerland and uses a broad variety of instruments. The three most important of these are funding for bottom-up projects (65-75%), academic competence centres (10-15%), and personnel grants (10-15%) (see Section 5.5). CTI is much smaller but also has a variety of instruments. One of the most interesting features of the Swiss innovation system is EU Framework Programme funding. Switzerland is now a full member of the Framework Programme and contributes an annual lump sum of more than CHF 200 million. In a move away from Swiss tradition, any firm can directly profit from participation in an EU project.[8] International project or programme funding also includes COST and EUREKA, or the international R&D programme Intelligent Manufacturing Systems (IMS). A last chunk of money comes from research programmes and contracts made directly by ministries. Commissioned research can be tracked by a dedicated database (ARAMIS) managed by the State Secretariat for Education and Research on which the Swiss Federal Statistical Office bases its surveys. For 2002, CHF 82 million were devoted to such projects. The regional and local authorities are reported to have spent at least another CHF 49 million for contract research (Lepori, 2005*a*, pp. 23 *ff*).

The Swiss Federal Statistical Office (OFS) has recently updated data on federal input into the research system, excluding block funding for universities, the ETH sector and other research institutions (BFS, 2005*b*). A residual of about CHF 1.4 billion is split roughly as follows: CHF 420 million for SNF, CHF 280 million for international programmes and organisations, another CHF 130 million for ESA, CHF 100 million for CTI. In addition, a total of CHF 220 million was spent in 2004 for commissioned research and in-house research of the federal departments, one-third of which went to the agricultural sector, the largest single spending block. Over the years the funds allocated to commissioned research have declined steeply, while those for SNF, etc., have increased. The bundle of public R&D expenditure shrank in the second half of the 1990s, but began to rise as of 2000. According to the ERT Message 2004-2007, future budgets are expected to rise. This upward trend is to some extent endangered by general budget cuts.

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8. This issue is taken up later in the review.

Business sector R&D expenditure grew rather slowly, at an average annual rate of 2.4% in the second half of the 1990s (up to 2001); this was considerably below the averages for the European Union (4.4%) and the OECD area (5.3%). However, more dynamic development has been observed in recent years. Switzerland still ranks fourth among OECD countries in terms of BERD as a share of GDP (2004). R&D intensity in both large and small firms contributes to maintaining this position. Moreover, about 70% of GERD is financed by industry, one of the highest shares among OECD countries. Other European countries, some starting from significantly lower levels, are shifting their overall funding patterns in this direction: in Finland, Denmark, Sweden and Austria, BERD has grown faster than GERD. Compared to Switzerland, BERD has been increasing at a considerably faster pace and has been accompanied by a considerable rise in public spending on R&D. The share of BERD performed by large firms (500 employees or more) was about 70% in 2003, well below the shares in Sweden, the United States, France and Germany, but similar to those in the Netherlands, Finland and Canada (OECD, 2004, p. 30).

While Swiss business firms' domestic R&D investment have shown little dynamism, they invest heavily abroad. For the period 1996-2000 alone, business enterprise spending abroad rose by 76% (Schweizerischer Bundesrat, 2002, p. 2418). In 1989, CHF 6 billion was spent in Switzerland and about CHF 5.5 billion abroad. In 2000, instead, industry R&D spending at home was about CHF 8 billion, but expenditure abroad reached CHF 9 billion. Swiss firms follow markets, people and research capabilities at universities or research institutes.

Only a few OECD member countries collect data on the R&D activities of their multinationals abroad. Among them, Switzerland is the only country where R&D expenditure of its affiliates abroad represents more than the R&D expenditure of all firms located domestically (Figure 2.6). More than 70% of this expenditure concerns two sectors, pharmaceuticals and electronics. Half of these R&D laboratories are located in Europe and most of the others in the United States (OECD, 2005*e*).

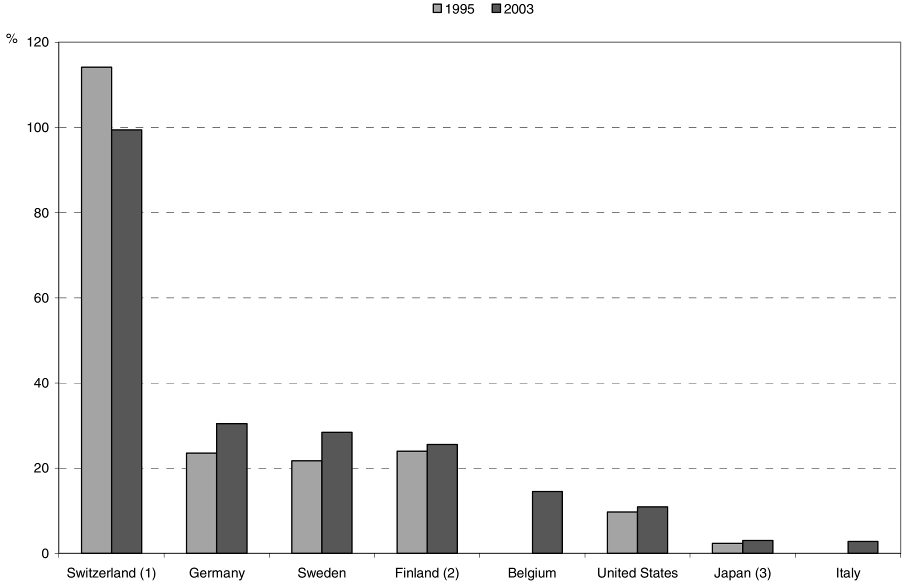
Basic research seems to be a relatively more important part of the research portfolio than in other countries.[9] With basic research accounting for 28% of GERD, Switzerland even surpasses the United States in this respect. The ratio of basic research to GDP is 0.72% (2000), the highest recorded among OECD countries. The main reason is university-based basic

9. International comparisons based on these data are not entirely reliable.

research. In addition, industry reports spending 10% of its R&D budget on (in-house) basic research.

Switzerland has little room and few resources for a "third sector". While other countries have large national laboratories – such as the CNRS in France, the TNO in the Netherlands or the Fraunhofer Gesellschaft in Germany – Swiss spending patterns are simpler and more straightforward. With a ratio of higher education R&D to GDP of 0.67%, Switzerland is among the leading OECD countries, together with Sweden, Finland and Canada. However, Switzerland has by far the lowest recorded share of government R&D in GDP. The most important recipient is the ETH research institute sector with an annual budget of about CHF 400 million.

Figure 2.6. Business sector R&D expenditure by affiliates abroad as a percentage of domestic R&D expenditure in selected OECD countries, 2003



1. 1996 and 2004.
2. 1993 and 1998.
3. 1997 and 2002.

Source: OECD, AFA database.

Against this background it is not surprising that cross-funding between the public and the private sector is only average or below average. The government funds only 1.5% (2004) of business sector R&D, one of the lowest shares – together with Japan – among OECD countries. Lepori (2005, p. 11) indicates that 3% of overall public funding goes to the private sector and that the two biggest recipients may be ESA and the EU Framework Programmes. On the other hand, the share of industry funding of university research tends to be higher. About 9% of the overall higher education R&D expenditure (HERD) is financed by industry (2004), more than the OECD and EU15 averages.

Besides adequate funding of R&D, knowledge-based economies need a sufficient supply of qualified R&D personnel. In 2003, 44% of the Swiss labour force worked in science and technology, and about half had an educational background in S&T. About one-quarter of the Swiss labour force has S&T training. This share is one of the highest among OECD countries, but at 1.04%, the average annual growth rate for 1999-2002 is low. Once more the picture is one of low growth at a rather high level (BFS, 2005*c*; OECD, 2004).

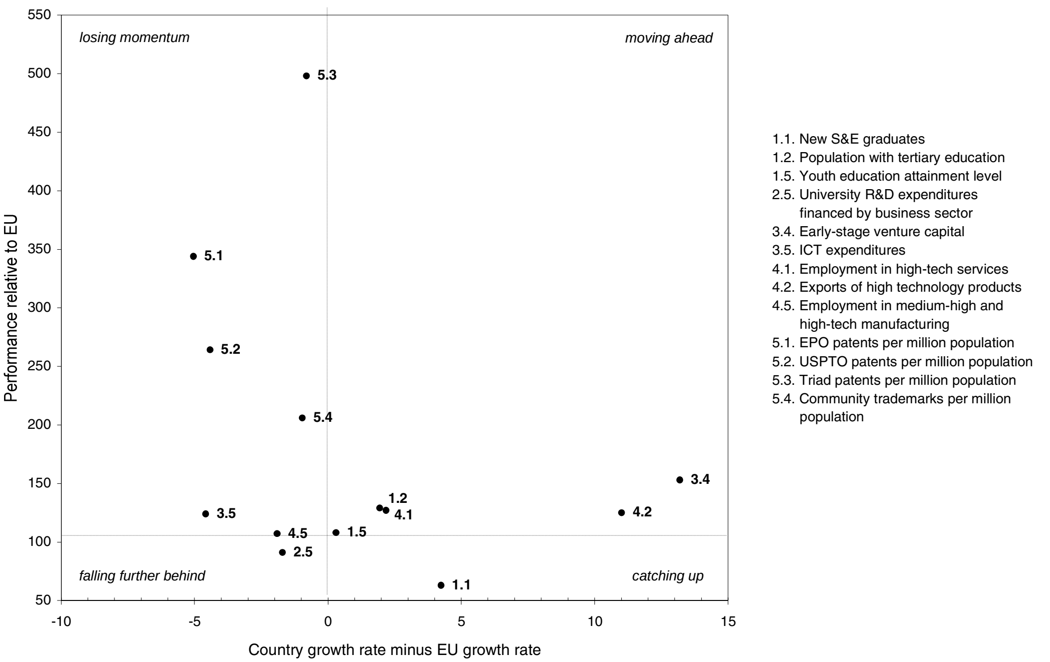
2.5 Innovation output and performance

The output and performance of an innovation system can be observed at different levels. A very important "output" is highly skilled people, *i.e.* young graduates at the start of their professional careers. Publications and their impact show the quality of the science sector. On the technological and industrial side, patents are a robust but not always sufficient output indicator. More broadly, the pace and intensity of industrial innovation can be measured by a mix of input and output indicators: the number or share of new products and processes, the number and quality of collaborative efforts, or the share of innovative products in turnover are indicators typically included in innovation surveys.

Overall, Switzerland ranks high in terms of most of these indicators (Figure 2.7). Scientific output is world class in many respects, while graduation rates and the number of students in relation to population size are average or below average. At the same time, investment per student is high and the qualifications of graduates seem good. Overall, Switzerland is a net importer of talent. The Swiss Innovation Survey (Arvanitis *et al.*, 2004) and reports to the European Trend Chart project (European Commission, 2003*a*, 2004*a*, 2005*b*) show very good performance in patents, a high rate of innovation among both small and large firms, and high value added in high-technology manufacturing. However, in eight out of 12 indicators Switzerland is reported to be losing momentum compared to the EU25 averages, notably for patents with the European Patent Office (EPO) and the US Patent & Trademark Office (USPTO), where Switzerland's position is still very strong. Its position in terms of levels of performance is also still very good, but many countries are catching up, some of them rapidly. One reason for the weakening Swiss position in patenting may be insufficient development of business sector R&D. Only in areas such as lifelong learning, tertiary education and employment in high-technology services is Switzerland moving ahead.

Figure 2.7. Switzerland's innovation performance

EIS 2005 innovation performance of Switzerland



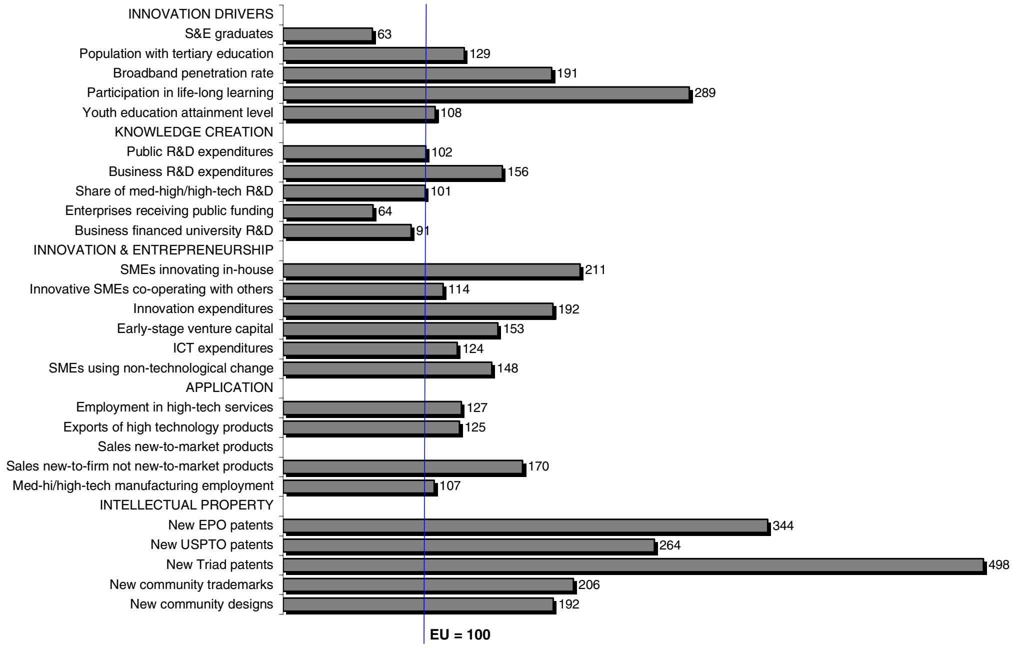
Source: European Commission (2005*c*).

The tertiary education sector is small and expensive. On average, Switzerland spends the equivalent of 67% of GDP per capita per student, whereas the EU25 average is just 37% (BFS, 2005*a*). In 2004, 1 057 graduates left the Swiss university sector at the bachelor level, 9 816 at the diploma level, 287 at the master's level and 2 768 at doctoral level (BFS, 2005). In 2001, 15.0% of all graduates were in science and 14.1% in engineering, with both figures above the OECD, EU25 and EU15 averages

(OECD, 2004). In 2000 the share of PhDs as a percentage of the population at the typical graduation age was higher in Switzerland (2.6%) than in Sweden (2.5%), Germany (2.0%) or Finland (1.9%). In terms of science and engineering alone, Sweden had a slightly higher percentage of doctorates (1.2% compared to 1.1% in Switzerland). Further, the share of business researchers increased by 6.5%, far above the average for the OECD (3.6%) or the EU (2.9%) (Arvanitis and Wörter, 2005).

Figure 2.7. Switzerland's innovation performance *(continued)*

EIS 2005 innovation performance of Switzerland relative to EU average



Source: European Commission (2005*c*).

In 2003, 32.2% of all graduates at the doctorate level graduated in medicine and pharmacology and 29.9% in science; the shares were 12.2% in the social sciences and humanities and 12.8% in the technical sciences. The Swiss system of doctoral education is also very attractive for foreign students, and more than 38% of all doctorates in 2004 were awarded to foreigners. The share was highest in economics (53.7%), followed by the technical sciences (51.2%) and science (50%) (BFS, 2005). Because Switzerland receives a rather high share of its "student talent" from abroad, immigration, labour market regulations including work permits are key issues.

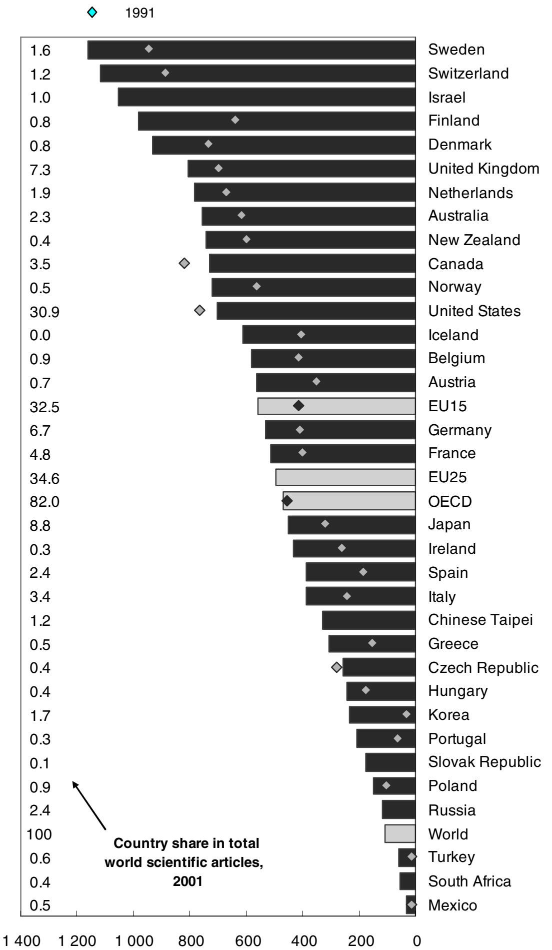
Switzerland's scientific output and "impact" are very high by international standards (Figure 2.8). Swiss researchers publish a great deal in good journals and rank at the top in citation indices. An international comparison of 31 countries (King, 2004) shows that Switzerland has a (rising) world share of 1.84% in scientific publications, 2.95% in citations (1997-2001), and an even higher share in the top 1% of citations. Switzerland is the world leader in terms of citations per paper.[10] This comparative study sees Switzerland as part of a group of very competitive smaller European countries: "Thus, taking Belgium, Denmark, Finland, the Netherlands, Sweden and Switzerland together, with a total population of 53 million, in 1997-2001 this group generated 12.7% of the most cited papers, putting them in the same bracket as the United Kingdom (12.8%) and Germany (10.4%). Since the combined GDP of these countries is marginally (6%) smaller than that of the United Kingdom, their combined science citation intensity is higher" (King, 2004, p. 316). OECD data confirm Switzerland's leading position. The number of published articles per million inhabitants is highest in Sweden, followed by Switzerland. Finland, Denmark, the United Kingdom and the Netherlands follow at a considerable distance.

At the same time the Swiss research portfolio is highly specialised. In 2001, clinical medicine accounted for 32.7% of Swiss publications, biomedical research for 16.1%, physics for 13.4% and chemistry for 12.8%; while engineering and technology accounted for only 6.6%. For 1986-2002, the higher education sector (universities, ETHs and UAS) produced more than two-thirds of all scientific publications, other research organisations accounted for 21%, and the business sector for 9%. The share of scientific publications from industry is higher in pharmacology (50%) and in immunology and food sciences (more than 25% each) (Arvanitis and Wörter, 2005; Lepori, 2003; OECD, 2004).

10. Impact in this context means how often publications are cited. King also draws a comparison between scientific wealth (citation intensity) and material wealth, establishing a clear link between the two.

Figure 2.8. Scientific and engineering publications by economy, 1991 and 2001

Published articles per million inhabitants



Source: OECD (2004) based on National Science Board (2004).
Population data from OECD MSTI database, June 2004.

Patenting provides another measure of the performance of innovation systems. In 2001, Switzerland had 110.9 triadic patent families[11] per million inhabitants, far ahead of Sweden (92.3), Japan (92.2), Finland (83.0) and Germany (69.4), and three times more than the EU15 average (36.2). Switzerland still leads, but the absolute number of patents is stagnating and its position is weakening with respect to the EU15; in 1990 Swiss patents were 7.9% of total EU15 triadic patents, declining to 6.4% in 1995 and to 5.9% in 2001. The picture is similar for patents registered with the EPO. Over 1990-95 Swiss patent registrations were as much as 6.0% of total EU15 registrations with the EPO but they dropped to 5.3% for 1996-2001. In ICT and biotechnology, two fields with high potential, Switzerland is losing momentum. Swiss patents accounted for 4.6% of EU15 patent registrations in ICT in 1990-95 but only 4.1% in 1995-2001. The figures for biotechnology are similar: in 1990-95 5.1% of EU15 patent registrations with the EPO were Swiss, but in 1996-2001 only 4.5% were (OECD, 2004).

In 2002, Switzerland had a slightly positive technology balance of payments, behind Denmark, Sweden and Finland but comparable to the Netherlands and Austria. In 2001, the technology balance of payments amounted to 30.4% of Swiss GERD (OECD, 2004).

The share of high-technology exports as a percentage of total exports of manufacturing goods increased from 18.4% in 1998 to 22.9% in 2002, *i.e.* above the OECD average (20.5%), and is in the range of Finland and the Netherlands. There is a rather high level of specialisation in pharmaceutical products, scientific instruments, chemical products and non-electrical machinery. In contrast, the Swiss position is comparatively weak in technology-intensive product groups such as aircraft and aerospace, computers or electronics.

In terms of innovation indicators (such as the share of firms introducing product and/or process innovations, share of firms with R&D activities, patent applications and new-to-the-market products), the Swiss manufacturing sector saw a marked decrease in innovation performance between 1991-93 and the late 1990s. Since then its performance has stabilised. The situation has been similar in the services sector, although the tendency to scale down innovative activities was somewhat less pronounced than in manufacturing. Swiss firms still maintain their top ranking in innovation

11. Triadic patent families are defined as a set of patents taken at the European Patent Office (EPO), the Japanese Patent Office (JPO) and the US Patent & Trademark Office (USPTO) that share one or more priorities (see OECD, 2005*c*, p. 68).

performance, but the lead over countries such as Sweden, Finland and Germany is narrowing.

In terms of public/private partnerships (P/PPs), the position of Swiss science and research institutions is good. The propensity of Swiss firms with R&D activities to engage in co-operative R&D with universities is 27.4%, a figure comparable to that of other advanced European countries. In 2000-02, only Sweden (31.8%) and, in particular, Finland (50.6%) had higher shares of firms co-operating on innovative activities. In Switzerland, publications, patents, prototypes and new products are more likely to be the result of joint projects between universities and firms than between business enterprises (Arvanitis and Wörter, 2005).

In summary, in terms of nearly all indicators measuring knowledge and innovation output, Switzerland still performs well by international standards and in a number of respects it leads. At the same time, its relative position *vis-à-vis* other countries, including some EU15 members, has weakened.

Chapter 3

THE SWISS INNOVATION SYSTEM: STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS

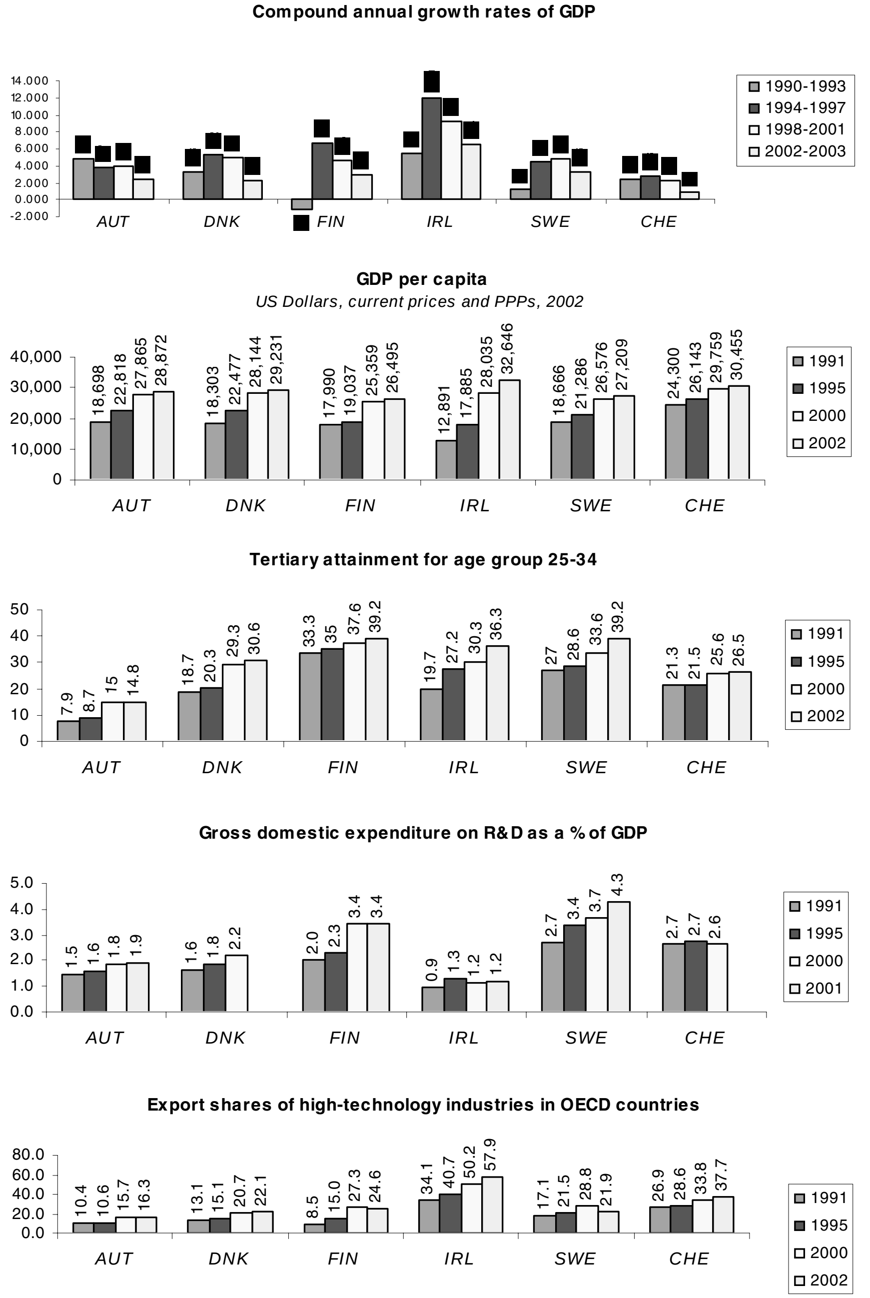
3.1 Challenges for the Swiss innovation system

As a highly developed, small, open economy, Switzerland faces a number of challenges – as well as opportunities – many of which have an international dimension.

3.1.1 Challenges related to a changing economic environment

- Slow economic growth over an extended period – as in Switzerland over the past 15 years – poses a challenge to the innovation system. Loss of momentum and scaled-down innovative activities may have long-lasting effects on innovative performance (OECD, 2006*a*).
- While the catching up of lagging countries can be considered a predictable – although by no means automatic – process, various countries have had better performance than Switzerland in the recent past. Within Europe, countries such as Finland, Sweden, Denmark, Ireland and Austria have been more dynamic in several respects. On the one hand, their GDP has grown much faster in both absolute and per capita terms; on the other, they have increased the input into their innovation systems more rapidly. These countries show different patterns and trajectories: some started in the early 1990s at a comparatively low level in terms of economic and innovation performance (with Ireland and, to some extent, Finland suffering from severe economic crises); some were economically prosperous, despite low innovation input (Austria); still others started with a high income level and a well-endowed research system but went through an economic crisis (Sweden). From the early 1990s onwards all of these countries – not to mention newly industrialised economies such as Korea, Singapore or Chinese Taipei – had better economic performance and more dynamic development than Switzerland in terms of most innovation indicators (Figures 3.1 and 3.2).

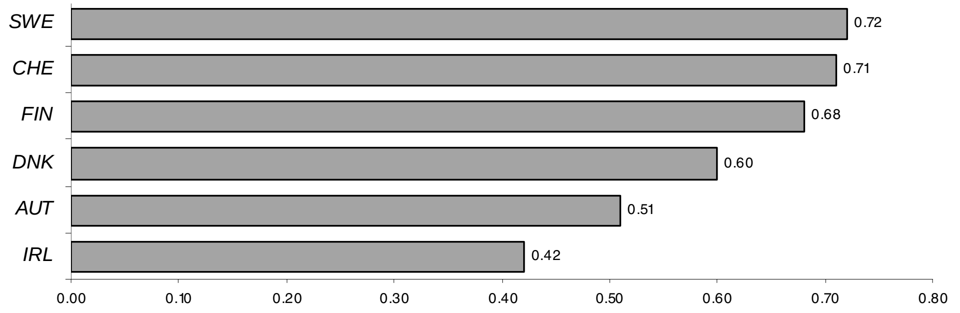
Figure 3.1. Performance of six small European economies



Note: Data for gross domestic expenditure on R&D as a percentage of GDP are for 1999 instead of 2000 for Denmark and Sweden, and for 1996 instead of 1995 for Switzerland. *Source:* OECD (2005*c*).

Figure 3.2. Overall innovation performance of six small European economies

Summary innovation index, 2005



Source: European Commission (2005*c*).

- Globalisation poses formidable challenges and offers opportunities to all advanced countries as well as others. The rapid growth of emerging economies, such as China and India, provides new market opportunities, rapidly changes the international division of labour and leads to the entry of new competitors in a variety of (high-technology) markets in which they may enjoy considerable cost advantages. Some emerging economies are rapidly developing their knowledge base. Even if they are generally still far below Swiss standards, massive public and private investment in selected areas is expected to have an impact on their technological competitiveness. Overall, Switzerland seems to cope quite well with these challenges and opportunities. Nevertheless there remains scope for improvement by drawing on the country's innovative capabilities and advantages in science and technology. Some industries may find themselves in a more contested position. However, the history of the Swiss watch industry, its decline and re-emergence, shows that Switzerland can mobilise a high degree of ingenuity and adaptability.

- Emerging fields such as biotechnology and structural adjustment in traditional sectors pose formidable policy challenges. Most countries have abandoned direct industrial policy interventions and concentrate on framework conditions and on supporting processes of adjustment and change. Switzerland has not favoured policies targeting "national champions". Although framework conditions are good in general, there is again scope for improvement. Moreover, there is some evidence that individuals are less ready to operate in risky contexts (unlike the engineers/entrepreneurs that spurred Swiss manufacturing innovation a century ago), and some evidence of a lack of "intrapreneurship" within firms.

- Switzerland is surrounded by the European Union and its internal market. The latter offers a number of growth opportunities to its member states, including the rapidly developing markets of the ten new members and at least two accession countries. Comparisons between Sweden, Finland and Austria, which became members in 1995, and Switzerland show that the former have had better economic performance (Pointner, 2005; for a comparison of Austria and Switzerland, see Breuss, 2005). Switzerland has entered into a dense network of bilateral contracts in order to participate in the common market[12] while maintaining what are perceived as specific Swiss advantages.

3.1.2 Challenges related to innovation and human resources

- Human resources are at the centre of innovation systems, owing to rapid technological change and to the complexity of societal challenges. Skills must be provided at various levels, and higher education deserves special attention. Switzerland has a good education system with a strong focus on vocational and upper secondary professional schools. Early selection implies restricted access to the *Gymnasien* (the upper secondary schools that are the main route to university studies) but choices are also affected by culture: careers based on vocational training or upper secondary professional schools are highly valued and well paid. The university sector is well financed but rather small, and the number of graduates is low by international standards (OECD, 2003*b*). The authorities are aware of this challenge and have undertaken a number of reforms. A second important aspect of human resources is the openness of borders, including generous working permit regulations and attractive living conditions. Switzerland is a net importer of a highly educated workforce and gives long-term rights to reside without granting Swiss citizenship.

12. These bilateral contracts enlarge the 1972 free trade agreement in the areas of freedom of individual movement, technical trade barriers, public procurement, air and land transport, agriculture and last but not least research. The goal of these contracts was a far-reaching equal legal status for individuals and firms from the EU and from Switzerland (Pointner, 2005, p. 105). In two referendums (the last in autumn 2005) Switzerland opted for open labour markets.

- The organisational structure of universities and the higher education sector in general plays a crucial role in meeting the demand for well-educated graduates and fuelling the innovation system. Many OECD countries, specifically those in which governments have strong direct involvement in higher education, are currently reforming their university sectors. The goals are often the same: greater autonomy, use of management principles, better indicators, building on strengths, the bachelor-master-PhD structure. Switzerland has a growing but still relatively small university sector. As in many continental systems, public governance is strong, and there are few private actors such as business schools. For its size, the Swiss system is very complex, owing to an intricate balance of powers between the federal and the cantonal level and – deriving from this balance – the three types of universities, with their differing legislation, logic and entry points. As the *OECD Tertiary Education Review* (2003*b*) shows, selection takes place at 14 years of age with the choice of upper secondary school. Horizontal barriers between universities appear quite high. Swiss policy makers give great attention to finding solutions to these issues and the Bologna Process[13] seems to be the instrument of choice.

- A further challenge for all innovation systems, and specifically for universities as producers of knowledge, is the quest for "more relevant" scientific research.[14]

13. The Bologna Process is a multilateral initiative of about 40 mostly European countries aimed at structuring their higher education systems along common principles to make them more open for trans-national study programmes. The process has been in operation for a decade, with its most significant feature the three-stage bachelor-master-PhD curriculum.

14. Following an influential book of the 1990s (Stokes, 1997), the call for "more relevant" scientific research comes under the heading of "Pasteur's quadrant". Citing Pasteur as a scientist who achieved both better scientific insight and better solutions with application potential, Stokes criticises both the traditional continental European university model characterised by single professors who hold a chair for a narrow field and have life-long governance of a rather small department, and the US science policy of the second half of the 20th century. The first is criticised for being too rigid and specialised, the latter for relying too much on pure, curiosity-driven research, the results of which are believed somehow to "trickle down" and sooner or later lead to industrial applications. Besides Pasteur, two of the remaining three quadrants of the matrix are occupied by Niels Bohr (great scientific insight/no application or problem orientation) and Thomas Edison (no scientific insight/great use or problem orientation). The fourth quadrant remains void for good reason.

- Many European countries fear an erosion of their national research base as “their” large firms increasingly invest in R&D facilities located in the United States and, increasingly, in Asia. Firms are not necessarily motivated solely by lower costs; they may also seek proximity to key markets and to strong academic partners for co-operation and graduates or they may wish to avoid restrictive domestic regulations in areas such as biotechnology. Switzerland appears to be affected by these developments, but not to an extent that would put its research and innovative capacity at risk.
- The innovative capacity of firms is a key driver of long-term economic growth and prosperity. Most countries provide various types of support to business enterprises to improve their innovation capacity. Swiss firms seem to perform satisfactorily in terms of the share of new products and processes (Arvanitis *et al*., 2004; European Commission, 2005). How well they translate innovative performance into growth is a different issue. To provide favourable conditions for firms’ growth and help them realise their potential deserves the attention of policy makers.

3.1.3 Challenges related to governance

- Each OECD member country has its distinct balance of power between federal, regional and local governments or administrations. Countries offer a wide range of constitutional structures, with different implications for economic policy and the innovation system. Large administrations and pronounced multi-level systems can pose serious challenges, as can underdeveloped government functions or excessive centralisation. Switzerland has a three-tier system based on bottom-up principles. This has numerous advantages, but there is a looming danger of overco-ordination, pork barrel funding and policy “blind spots”. A plethora of co-operative policy bodies (Sieber, 2003) may lead to governance by the lowest common denominator. “Magic formulas” for political representation, cantonal influence and proportional participation of the different language areas could also affect the set-up of the innovation system, in terms of whom to hire and where and how to invest (see Chapter 2; an overview of the history and burden of excessive federalism, mainly concerning fiscal misallocations and obstacles to implementation of reforms, is contained in OECD, 2002*b*)

3.2 A SWOT analysis of the Swiss innovation system

The following analysis of the Swiss innovation system addresses its strengths, weaknesses, opportunities and threats by referring to the challenges outlined above and applying a systems perspective (Table 3.1). This analysis is designed to contribute to a better understanding of the elements of the system, *i.e.* the three "strings" of the so-called "triple helix" and their interrelations, and to derive some recommendations (see Chapters 5 to 7).

Table 3.1. Swiss strengths, weaknesses, opportunities and threats

Strengths	Opportunities
• Strong industry (large and small firms), good framework conditions • Many sectors of Swiss industry (and services) strong in innovation, high level of industrial research • Very good university sector • Strong research infrastructure • Strong academic output (people, publications, etc.) and impact • Strong application-oriented professional education • High-quality approach in all sectors • Language skills and ability to master intercultural settings	• Building on scientific strengths • Active internationalisation, new market opportunities • Attractiveness as a workplace for foreign experts • Clustering within Switzerland and in trans-border co-operations
Weaknesses	**Threats**
• Slow economic growth • Lack of entrepreneurship and of competition in a number of sectors • Lack of "demand orientation" in the innovation system • Some innovation system actors underdeveloped, policy learning difficult • Innovation issues not strongly represented in the political arena • Small numbers of higher education graduates; education system not permeable enough	• Decline in innovative performance after extended period of stagnation • Exposure of SMEs to new international competition • Public sector deficits plus rising social security costs crowding out fresh money for innovation. • Consensus-based policy making getting too strong in innovation policy • Competition between national and EU innovation funding

3.2.1 Strengths

- *Strong industry (large and small firms), good framework conditions.* Switzerland has a strong industrial base. However, its scope is limited in terms of its technology portfolio (although still broad for a small country), and a number of traditional strengths have been declining. The presence of export-oriented manufacturing and service networks helps traditional sectors to meet the challenges ahead. Switzerland is generally reported to have conducive framework conditions in terms of its labour laws, working time, company laws and intellectual property protection. One shortcoming which has a negative impact on innovative performance is barriers to competition in some sheltered sectors of the economy. For industry data, see Section 6.2.

- *Many sectors of the Swiss economy, including some important service industries, are strong in innovation, with a high level of industrial research.* The Swiss Innovation Survey (Arvanitis *et al.*, 2004) provides ample evidence in this respect. Not only is the pharmaceutical industry a constant innovator, fields such as precision machinery, medical technology or micro-technology are strong as well. For more detail, see Section 6.2.

- *Very good university sector.* Swiss universities have a strong international reputation. ETH Zurich and the University of Zurich are among the world's top 60 universities. EPF Lausanne is growing and focusing on its key strengths. For data see Section 2.4, and for more detailed information regarding universities, see Section 5.1.

- *Strong research infrastructure.* The research infrastructure, predominantly located at universities, is modern and of high quality. An example is ETH Zurich with its Imaging Centre or the Centre for Micro and Nano Sciences. See Chapter 5.

- *Strong academic output and impact.* This includes graduates, publications and other output from the academic sector. Most indicators are stagnating, but at a very high level. Overall, education is considered good at all levels, including universities and UAS as well as vocational training. See Section 2.4 and Chapter 6.

- *Strong application-oriented professional education.* Strong application-oriented basic professional education and advanced vocational training (tertiary level B) and vocational training at university level, mainly at UAS (tertiary level A) contribute to the sustainable development of Switzerland's innovative performance and to the diffusion of new knowledge.

- *Language skills and ability to master intercultural settings.* With its intercultural and multilingual setting and its favourable position in lifelong learning, Switzerland is in an advantageous position.

3.2.2 Weaknesses

- *Slow economic growth*. For long-term developments, see Chapter 2.
- *Lack of competition and entrepreneurship in a number of sectors*. Innovation is stifled in sheltered sectors. Cartels are reported to be strong in some areas (OECD, 2002*b*). As in other European countries, there seems to be a lack of entrepreneurship in various sectors. For industry, see Chapter 6.
- *Lack of a "demand orientation" in innovation policy*. Owing to the absence of direct public support for innovation in the business sector, innovation policy instruments are predominantly oriented towards the "supply" of applied academic research, *e.g.* through the establishment, maintenance and networking of transfer institutions, UAS networks, etc. Helping small firms define and solve problems requires sending out university professors. For a view on such policies from a systems perspective, see Chapters 5 and 7. A broad range of public support mechanisms for private sector R&D are being used by (or within) the EU, but they are largely not used in Swiss innovation policy (European Commission, 2003*c*).
- *Some innovation system actors are insufficiently developed; policy learning is difficult*. There could be a case to strengthen the position and independence of CTI and to broaden its portfolio. Other resources with greater potential include the policy advisory bodies and the federal administration, where a number of competencies could be further developed (*e.g.* distributed strategic intelligence). See Chapters 5 and 7.
- *Innovation issues are not strongly represented in the political arena.* Parliament appears to have few resources for policy analysis. See Section 4.2.
- *Small number of higher education graduates; education system not sufficiently permeable.* Switzerland is catching up, but although a lot of money is being spent, the system produces relatively few graduates. Mobility within the education system is not yet high enough; broad access to higher education remains a difficult issue (OECD, 2003*b*). See Section 2.4 and Chapter 6.

3.2.3 Opportunities

- *Building on scientific strengths*. This core asset should be further strengthened. More than a third of Swiss PhD positions are filled by foreigners. See Chapter 5.
- Active *internationalisation, new market opportunities*. Qualified people can enter easily, but freedom of movement within Europe could in effect make recruiting from non-European countries such as China and India more difficult. There is lively discussion about internationalisation based on past experience. Switzerland is well equipped to act internationally.
- *Attractiveness as a workplace for foreign experts*. Switzerland has a very high share of non-nationals. Highly skilled specialists and low-skill workers have qualifications that complement the predominant skill pattern among nationals and therefore fulfil important roles in the Swiss innovation system.
- *Clustering within Switzerland and in trans-border co-operation*. There seems to be room for new collaborations within the Alpine region (500 km radius). Baden-Württemberg, Bavaria, northern Italy, western Austria, parts of France and Switzerland, regions well-endowed with technology, could gain from pooling strengths. See Chapter 6.

3.2.4 Threats

- *Decline in innovative performance after an extended period of stagnation*. Switzerland still has a powerful innovation system, yet declines in some indicators may indicate the need to take strategic decisions.
- *Exposure of SMEs to new international competition*. How to help innovative small and medium-sized firms maintain their position or expand into new markets in an increasingly globalised world is an issue for all industrialised countries. See Section 6.3.
- *Public sector deficits plus rising social security costs crowding out fresh money for innovation*. This was the case in the 1990s and even recently, part of the extra allocations in the federal multi-annual budgets (Schweizerischer Bundesrat, 2002) were withheld in an attempt to contain public deficits. Budget consolidation therefore tends to come at the expense of long-term investment, also in research and innovation. See Chapter 4.

- *Consensus-based policy making becoming too strong in innovation policy*. A tendency towards harmony, mainstreaming and "go slow" prevails too often. See Chapter 4.
- *Turf wars between national and EU innovation funding*. There is a danger of crowding out national funding when EU budgets are raised. Taking into account their specific roles, EU programmes and national initiatives should generally not to be treated as substitutes. See Chapter 4.

Chapter 4

GOVERNANCE AND PUBLIC POLICY

4.1 Introduction

A primary objective of this review is to provide an independent comparative assessment of the strengths and weaknesses of the Swiss innovation system in a changing global environment. For a description of major features of the innovation systems approach see Box 4.1.

Box 4.1. The innovation systems approach

The concept of innovation systems emerged in the 1980s owing to the increasing inadequacy of a purely linear model and a move towards systemic thinking and the need to draw policy makers' attention to systemic failures (Nelson, 1993; Rosenberg, 1982, 1994; Edquist, 1997; Lundvall, 1992, 2002). Since then, this broad conceptual framework for innovation policy has become the dominant paradigm for many OECD countries, leading *inter alia* to intense activities among OECD and EU countries in terms of comparative assessments and identification of good policy practices regarding public intervention in innovation systems. Important features of the innovation systems approach are noted below.

While individual (types of) actors are of key significance, linkages between them are equally important. A country's long-term, cumulative success in innovation cannot be achieved by actors operating in isolation. This does not imply that secrecy and in-house R&D are no longer important for firms, or that scientists should spend most of their time networking. In many cases, the resources required for innovation are not all available at a single place. Innovation processes have become more complex, and there is an influential strand of literature claiming that the nature of scientific work has changed ("Mode II", see Gibbons *et al*., 1994; Gibbons, 2001).

Though an innovation system has many facets, one key to success is the presence of innovative firms and their capacity to solve problems. This does not diminish the role and importance of other actors, in particular the science sector. In the innovation system approach the unit of analysis is often a network or a set of actors instead of a single actor. The linear model of science push and automatic market uptake has been replaced by more multi-actor, feedback-driven and collaborative settings.

Policy makers and policy analysis concentrate less on the bounded rationality of individual actors than on path dependencies. A system can be seen as the expression of its past. History and culture matter in order to understand what drives actors and to see what can be changed and under what conditions. Contexts must be understood and analysed and good governance principles should be a major issue in policy discussions. The concept of distributed strategic intelligence (see Kuhlmann, 2001*b*; Bührer and Kuhlmann, 2003; Smits and Kuhlmann, 2004) has been developed to come to terms with multi-actor arenas. The "arena model" states that there is no single dominating actor in an innovation system, which requires that all sets of actors need a common understanding and the capacity to formulate their strategies in a co-ordinated way. This is very demanding and cannot be simply ordered top-down.

In applying the national innovation systems approach, the Swedish innovation agency VINNOVA and Finnish innovation policy makers use the so-called "triple helix" metaphor. This stands for close interaction within the innovation system between public authorities, universities and other research institutions, and industry. Each actor has a distinct role but is also aware of the role and behaviour of the others. A variety of linkages of different kinds and qualities bridge the gaps. The helix image evokes the importance of co-operation, of expertise embedded in all three "strings", and of trust, as well as a process of co-evolution. In Finland (Romanainen, 2001) large funding programmes are designed as to fully reap the benefits of this approach; they include firms of all sizes, universities, research institutions and public sector institutions engaged in longer-term co-operation[15].

In the light of international experience, the set of public actors in Switzerland and their interrelations appear to be both simple and complex. As seen in Chapter 2.2, two ministries, a few intermediaries and two clear-cut funding agencies appear at the federal level. Public research is concentrated at a number of universities. Some activities typical of other countries – such as direct business funding or fiscal incentives for R&D – are not part of the Swiss policy toolkit. Complexity arises when entering the federal-cantonal interplay in higher education, which involves numerous councils, types of schools and regulations.

Based on the innovation systems concept, the set of actors (Section 2.2), and the challenges and SWOT analysis (Chapter 3), this chapter relates Swiss innovation policy to policy trends in the OECD area, discusses some important issues regarding the interplay between legislation, ministries and agencies and asks why so much energy is devoted to the Bologna Process, one of the main arenas where Swiss policy makers meet. In this regard, the roles of the Swiss Science and Technology Council and other advisory bodies are discussed to consider whether they can provide substantial input into the governance of the Swiss innovation system and whether they can be seen as a good representation of the "triple helix" approach. This leads to the more general question of priority setting – an area in which Switzerland displays an active policy record – and to issues of policy learning and evaluation. Once more, the "triple helix" and the "arena" metaphors are employed. Internationalisation matters and policy recommendations conclude the chapter, deferring discussion of all public policy instruments exclusively targeting either financing or operating higher education or the business sector to Chapters 6 and 7.

15. For the helix see also Lepori (2003).

Governance consists of a set of "hard" and "soft" measures to influence the behaviour of public and private actors. Beyond government and legislation, governance in innovation policy broadly defined (*e.g.* Lundvall, 2002) ranges from funding science and innovation to relevant regulations, policy advice and programmes, as well as to features deriving from cultural specificities. Governance always encompasses relations between actors and is not restricted to a single level. Multi-level governance involves relations between the levels of European, national and regional policy making, for example, or the relations between ministries, agencies and their customers (see Kuhlmann and Edler, 2003; Boekholt and Arnold, 2002; OECD, 2003*a*; or various contributions in Edler *et al.*, 2003). The role of government is understood in a comprehensive way, as encompassing both activist and hands-off policies, the elements actually in place at a certain time in a given country, as well as elements that may be missing.

The *OECD Science, Technology and Industry Outlook* (OECD, 2004, p. 47 *ff*) reports a number of recent developments and overall trends in OECD member countries' science, technology and innovation policy. All these developments belong to the sphere of "governance". A discussion of recent developments in Switzerland in light of these international trends and developments leads to the identification of a number of differences (as well as similarities) which provides a useful tool for reflecting upon the policies concerned (Table 4.1). The European Trend Chart project (European Commission, 2005*b*) has come forward with similar comparisons.

A fairly clear picture seems to emerge from this exercise. While there are operative planning and evaluation mechanisms in place, policy makers refrain from "grand designs" and rapid changes. A question to be considered here is whether there is too much reliance on the past and too little analysis of the current and future needs of the Swiss innovation system in a rapidly changing global environment. Some of the nodes in the governance network could become ineffective, and spending follows rather traditional patterns in terms both of quality and quantity. Compared to the EU and most of its member countries, which use a differentiated mix of direct public support mechanisms for private sector R&D in an attempt to systemically raise R&D intensity (European Commission, 2003*c*), the portfolio of instruments in Switzerland is restricted to "supply-side" measures, *i.e.* institutions, programmes and funding schemes primarily target the "knowledge-supplying" higher education sector. Funding flows all go in this direction. Non-interference in the operation of markets is a powerful guiding principle for public policies towards most sectors of the economy. Nevertheless, there is some demand for a stronger Swiss innovation policy (Hotz-Hart and Küchler, 2002).

From an innovation systems perspective, intermediary institutions, networks, linkages and the ability to understand the other players can be seen as crucial for the functioning of the system. Accordingly, the chapters devoted to the three "strings" of the "triple helix" – this one on public governance, Chapter 5 on the science system and Chapter 6 on the business enterprise sector – will include recommendations for new or better intermediaries, public/private partnerships or forums. However, intermediary institutions have no value apart from serving the three "strings". This implies that intermediaries are important and should prosper, but only in close relation with the major actors in the innovation system: the business sector as the main source of income and wealth, the science system as the main provider of knowledge, and the public sector responsible for the public good called governance. For this reason, this review does not contain a distinct chapter devoted to intermediaries.

The "triple helix" metaphor evokes a constellation in which all three partners in the innovation system – public authorities, universities and other research institutions, and industry – are well-integrated in policy and strategy formulation and engage in an ongoing dialogue. The current Swiss situation appears rather different. In Switzerland, the attention of policy makers – in accordance with the direction of funding – is relatively strongly focused towards the universities and other public performers of research. In addition, university professors come close to holding a monopoly position in public advisory bodies. In contrast, the dialogue between industry and public policy makers appears weak.

Swiss innovation policy is deeply rooted in the experience and thought of past decades. Lepori (2003) describes the evolution of the country's research policy from 1945, showing the early beginnings of a predominantly science-oriented policy; developing key technologies such as nuclear power produced rather mixed results in terms of performance. The early beginnings of the CTI did not lead to a "grand design", while SNF and universities prospered. The author shows the roots of the objections to public funding of industry and more applied research. The late 1980s saw key technology programmes as a significant policy innovation and in the 1990s the UAS sector emerged, followed by streamlining in the public sector. While the development of national instruments was slow, integration with swiftly changing EU policies in the area of research and technological development progressed rapidly. This may to some extent be indicative of a perceived insufficiency in the portfolio of instruments available at the national level.

Table 4.1. Trends in innovation policies

Feature in the innovation system	Comment (OECD trend and Swiss trend)	Swiss position[1]
1) Strategic planning for innovation	OECD: Priority setting, strategic plans become good practice. CHE: Federal multi-annual messages, linking budgets to priorities; no "grand design" beyond.	***
2) New governance structures for innovation policy	OECD: New laws and institutional structures, *e.g.* for better policy co-ordination, higher university autonomy, integrate research better into society and economy. CHE: Many small steps regarding technology transfer, reforms in the education system and other fields. Ongoing discussion about new interplay between departments and advisory bodies.	**
3) Increased public R&D expenditure	OECD: Despite budget constraints, public expenditure for R&D continues to grow. CHE: Due to budget constraints, public expenditures on R&D grew only moderately following long-lasting stagnation.	*
4) Transition to more project-based funding in public research institutions	OECD: Block grants are declining, while project and programme-based grants are growing. CHE: Change only at a moderate level, largely between commissioned research and agency funding.	*
5) Strengthening of policy initiatives to encourage industrial R&D and innovation	OECD: Direct public funding for business R&D decline moderately while tax incentives for R&D gain in importance, more support for innovation in SMEs, better IPR regimes. CHE: Mostly "supply-side" measures: technology transfer (though the CTI technology transfer programme also includes demand-side elements), IPR.	*
6) Increased attention to science-industry linkages	OECD: Better IPR legislation, more funding programmes to improve science-industry linkages. CHE: Again only "supply side": IPR; CTI funding for universities.	**
7) Growing concern about human resources for science and technology	OECD: Better career perspectives, public understanding, international mobility programmes, new education curricula. CHE: Challenge to enlarge higher education sector in general, obviously no problem to attract foreign S&E students/graduates/experts.	**
8) Greater attention to policy evaluation	OECD: In many countries formal evaluations of policy instruments have become compulsory. CHE: Implementing international good practice.	***

1. The number of stars indicates the relative position of Switzerland (stars do not indicate "good" or "bad"). *** = fully in international mainstream; ** = well in line; * = only a few/*ad hoc* activities in Switzerland; 0 = absence of such a policy (instrument).

Source: OECD (2004, p. 47 *ff*) for the categories.

4.2 Interplay among actors: legislation, departments, agencies, cantons

The overall system was outlined in Section 2.2, and attention now shifts to the interplay of actors. The so-called "arena model" concept, initially developed to describe Germany's highly decentralised innovation system (Kuhlmann, 2001*a*) is used as a reference. In an arena no overarching and dominant actor exerts control. Rather, a multitude of (public) actors have varying degrees of power and influence – sometimes depending on the context – and are continuously engaged in negotiations with different partners and competitors. Parts of the arena are populated by private actors (business firms), but these are left aside here as public governance is presently the centre of attention. While the Swiss "arena" basically follows typical practices, it seems to be a little smaller, with fewer agencies and programmes and a leaner policy portfolio in terms of instruments and target groups. Its procedures involve long negotiation processes rather than quick skirmishes. One part of the arena seems very crowded, an observation that will be addressed below.[16]

Parliament appears to have few resources for analysis and policy drafting. Science and innovation are not very well represented, and a few members of parliament (MPs) seem to have a strong network and influence in this policy field. The overall role of parliament in the governance system is important owing to the detailed planning process embodied in the so-called "Message concerning the promotion of Education, Research and Technology" (ERT Message). The relation between the legislature and ministries, *i.e.* the two federal departments in charge, is characterised by the preparation and issuing of these four-year budget and planning documents. The ERT Message is prepared every fourth year by the Swiss government and passed by the parliament. The ERT Message 2004-07 contains a budget allocation of more than CHF 17 billion for the period. This provides a growth perspective for most Swiss research funding and performing institutions. Nevertheless, in the wake of fiscal consolidation, budget increases have been reversed lately, leading *inter alia* to a 15% reduction for CTI, thus setting its budget back to the *status quo* of about CHF 100 million a year. The Message defines three overarching goals (Schweizerischer Bundesrat, 2002, p. 2368 *ff*):

16. For multi-level governance in a programme context see also Stampfer (2003).

- Renewal of Swiss higher education, with the ETH sector strengthening fields of excellence and creating graduate schools; the cantonal universities receiving more resources for the humanities and junior positions; and finally, the UAS strengthening their applied research capacities and gradually giving up the two-tier system of cantonal and federal UAS. Nationwide portfolio building and the Bologna Process provide the main links between the three types of universities.
- Strengthening research and innovation funding: SNF, CTI and technology transfer by higher education institutions are the three instruments of choice. SNF is to support the goals of quality higher education, and give more funding to the humanities, graduate schools or targeted research programmes. CTI basically continues to fund entrepreneurship, project-oriented, project-based research and international co-operation.
- Strengthening national and international co-operation.

The two ministries have a similar set-up; both are an umbrella for a state secretariat and a few agency-style operational units.

The *relation between the departments and agencies* is based on their legal status. SNF has a strong position because it is legally independent and is organised as a foundation. The only remaining governance instrument – apart from a (theoretically possible) new law on the organisation of research – is allocation of funds. As Swiss innovation policy making is based on multi-annual planning and budgeting documents, SNF can rely on a stable mid-term perspective. Its internal proceedings and leadership issues, including senior positions, are not subject to negotiations with the government. CTI instead can rely neither on a high degree of independence nor on firm legal safeguards. Moreover, at least from outside, it is difficult to fully understand and describe briefly the relationship between CTI and BBT. CTI's mid-term financial perspective can be compared to that of SNF. The 2002 evaluation of both agencies recommended a doubling of SNF and CTI funding (SWTR, 2002) in order to strengthen their main instruments. Although a strong budget increases were foreseen for both SNF and CTI (Schweizerischer Bundesrat, 2002, pp. 2426 and 2432), this has not happened, and the increase is threatened by budget cuts. Strengthening the position of CTI in the Swiss innovation system, in both financial and organisational terms should be considered. The ETH Council is another interesting institution that links EDI and the ETH sector: it acts as a board with a broad governance agenda which ranges from controlling and supervision to allocation. Complementing this vertical governance, its steering committee brings together representatives from departments and agencies for horizontal policy co-ordination.

Inter-agency relations: SNF and CTI, as the two main agencies, claim that they co-operate at the operational level.[17] There is a certain overlap between their portfolios as both primarily address university-based researchers. This is not a matter of concern as their agendas differ sufficiently. From this perspective it was reasonable not to follow suggestions made a few years ago to merge the two funding bodies. Moreover, there seems to be broad consensus about the relative positions of these agencies. Inter-agency co-operation has intensified over the years. Originally SNF and CTI met once a year, but now most SNF sections identify projects that may affect the economy and give them to CTI staff for comment. This appears satisfactory, although more could be done.[18] The increasingly blurred lines between basic science and applied research should encourage SNF and CTI to interact more intensively with respect to funding.[19]

The federal and the cantonal levels meet at one important level. Both are engaged in higher education policy. The numerous councils, conferences and steering bodies that link the federal and cantonal levels, the cantons, higher education institutions of the same type, and those of a different kind face many challenges. On the one hand, they are concerned with financial and regulatory affairs, from canton-wise student quota financing to recognition of diplomas. On the other hand, they are trying to develop a new, simplified system for which the Bologna reform process is a strong common denominator and catalyst. However, the cantons and the Confederation do not meet at the level of business promotion. The federal level takes a hands-off policy and therefore lacks instruments, while the cantons dispose of few forms of direct funding. Their main instruments seem to be provision of infrastructure and tax relief for firms willing to (re)locate.[20] A kind of back-

17. CASS, the association of the Swiss Academies of Sciences, is also listed as a funding organisation (Arvanitis and Wörter, 2005, p. 5). The ETH Council was previously responsible for funding for nanotechnologies, but this funding was transferred to CTI.

18. In Austria, for example, the equivalent to the SNF, the FWF (*Fonds zur Förderung der wissenschaftlichen Forschung*), has been included as organising body for scientific reviews in a large science-industry co-operation programme managed by another agency. Now, FWF and the innovation promotion agency FFG (*Forschungsförderungsgesellschaft*) run back-to-back programmes for "translational research" (linking oriented basic research to applied research) called "TRP" and "Bridge" with a joint steering committee.

19. As an example of joint action see the DORE programme for applied research at the cantonal UAS (social sciences and humanities). The ongoing DORE III is administered by SNF alone.

20. Compare numerous federal-state (*Bund – Bundesländer*) funding instruments, also in the area of economic policy, in Germany and Austria. Corporate tax policy is cantonal, while personal income tax is local.

stage, where cantons and the federal government also meet, concerns regional policy. Until the beginning of the 1970s Switzerland had no explicit regional policy, although the federal constitution includes a commitment to equity and protecting the economically threatened (and later, mountainous) regions. Today there is a broad range of laws and approaches, mainly dealing with financial equalisation. At the end of the 1990s, the focus of regional policy shifted from reducing disparities to promoting efficiency and increasing regions' competitiveness. New instruments beyond infrastructure support, such as the Regio Plus programme or InnoTour, were introduced. However, regional policy should be further developed in three directions: *i)* in addition to mountainous and economically disadvantaged areas, federal regional policy should cover all types of regions; *ii)* regional policy should focus on indirect support that benefits the entire region instead of supporting individual activities or sectors, and individual support measures such as tax concessions should be abolished; *iii)* sustainable rural development strategies should be based on natural and cultural endowments (see OECD, 2002*b*, p. 97 *ff*).

Finally, governance also shapes *the relation between agencies and their clients*. New funding programmes, their goals, target groups, signals and incentives are the outcome of overall policy goals. At the programme level, the following policy goals are important: encouraging science-industry co-operation (a number of CTI programmes), entrepreneurship (more CTI programmes); strengthening thematic strong points (a number of SNF and CTI programmes); building critical mass in scientific research (SNF NCCRs); furthering international co-operation (SNF outgoing grants, some CTI initiatives). This shows that programme goals are quite in line with the overall goals of the ERT Message. The comparatively small number of policy initiatives helps. Comparable countries nowadays operate a plethora of programmes for every problem identified.

4.3 The Bologna Process

The ability of a set of policy actors to react to bottlenecks and to display a system-oriented agenda seems to be crucial for innovation policy. There are nevertheless cases in which one topic becomes so important that many of the policy actors in an arena narrow their agenda for a certain period of time. This allows changes based on a broad consensus but may also draw attention away from other important issues. To a certain extent this seems to be the case for the reform of tertiary education in recent years and the introduction of the three-stage Bologna system. This reform includes streamlining, a better policy governance system and clearer profiles for Swiss higher education institutions (see Arvanitis and Wörter, 2005, p. 4).

A number of important co-ordinating bodies are engaged in: *i)* bringing the cantons together with the universities; *ii)* finding a financial equilibrium between the cantons with universities and those that have students but no universities; *iii)* shaping common policy principles for challenges like the Bologna Declaration and other goals such as quality assurance; and *iv)* organising co-ordination between the federal and the cantonal level. Comparable governance and co-ordination structures exist for the UAS sector and for the ETH domain, and universities and the UAS have their own platforms. Working groups are wrestling with the overall reform process, and issues of overall innovation policy need to be addressed. The institutions involved in the reform process include the two relevant departments, the governments of the cantons in which universities are located, the ETH Council, the Swiss University Conference (SUK),[21] the UAS Council, the OAQ for quality assurance and various other intergovernmental or inter-institutional conferences like EDK or CRUS. There is an active SNF-appointed project group. Finally, one of the main activities of SWTR is university reform. The reform process extends over a decade, is coupled with the ERT Messages and seems to be on the right track.

Clearly, a large number of bodies and activities are involved in or related to higher education reform, which is indeed an issue of key importance. On the other hand, too exclusive a focus may divert attention from other problems in the system, in particular the slowly deteriorating innovative capacity in the business enterprise sector.

4.4 Giving policy advice: SWTR and other councils

The Swiss Science and Technology Council is the central advisory body for the Swiss government, mainly for the Federal Council but also for the cantonal level. Currently it consists of 11 members, all but one of whom are Swiss scientists from various fields.[22] Up to 15 members may be named. SWTR has a secretariat and financial resources for its work. Moreover, with TA Suisse for technology assessment and CEST for strategic studies and data compilation, the council has two important providers of strategic intelligence. It has a considerable record in science policy advice. The "T" for technology was added in 2000, and the council's mandate was enlarged to

21. SUK was founded in 2001 on the basis of the new University Promotion Law (*Universitäts-förderungsgesetz*, UFG 2000). It is described as the first strategic federal and cantonal co-operation body in this policy field.

22. One person is from abroad. One Swiss member is a university professor with ample industrial background.

cover all matters relating to science, education and technology policy. At the same time its legal basis speaks of it as the "voice of science".

SWTR describes its function as follows: "The SWTR formulates general concepts for the Federal Council and suggests measures for their implementation. On its own initiative, or at the request of the Federal Council, the Federal Department of Economic Affairs or the Federal Department of Home Affairs, the SWTR takes a position on policy issues and problems relating to science, higher education and technology. The SWTR is also open to requests by other federal or cantonal authorities."[23] It provides statements and reports and organises evaluations. It works on the basis of a regulation of 2000, which in turn derives from Article 5a of the Swiss Research Law (*Forschungsgesetz,* FG). As regards its role in and impact on the Swiss innovation system, at least five observations can be made:

- First, SWTR has produced major documents and activities in recent years, the so-called "Nine Points (*Neun Punkte*) programme (SWTR, 2002*a*) and the well-planned SNF/CTI evaluation (SWTR, 2002*b*).[24] More and more of its publications focus on the regulation of higher education. At the same time, some stakeholders in the Swiss system point to a lack of visibility and clarity in terms of its role.
- Second, while on paper the SWTR's agenda is very broad, in recent years it seems to have concentrated on a few international issues and especially on matters regarding university reform, convergence of the different university sectors, and the broad introduction of the three-stage university system. As mentioned, all Swiss advisory and co-ordination bodies participate in the Bologna process.
- Third, the Council is composed of scientists, and ten out of the eleven members come from Swiss universities. The composition of the Council may to some degree influence its agenda.[25]
- A fourth issue regards the somewhat precarious standing of SWTR in the debates on Swiss institutional reform. A more active role might mean a stronger position in a changing framework. This would imply a broader agenda, coming from the Council itself.

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23. See *www.swtr.ch/swtr_en/aufgaben.htm*
24. It served as a blueprint for the Austrian evaluation of the two large research funding bodies FWF (SNF equivalent) and FFF (KTI equivalent but different instruments).
25. The Swiss paradigms and the recent history (2000-03) of SWTR seem to influence the choice of topics as well.

- Fifth, the SWTR's adjunct think tank CEST has a strong mandate based on SWTR's regulations.[26] Some CEST studies are of high quality and provide a good basis for policy making. Unfortunately, many actors – including SWTR – seem to have mixed feelings about CEST, and in recent years there have been misunderstandings, university criticism targeted at certain studies ("Champions League"), and an unclear governance relation between SWTR and CEST. SWTR seems unaware of its unusual position: few advisory councils in Europe have such resources. TA Suisse, the Council's second adjunct, has also achieved international renown for the quality of its work. CEST appears to be underused as a resource and its future is unclear. It is recommended to find a more effective role for CEST as a provider of strategic intelligence.

It appears doubtful whether the SWTR in its current form can provide the necessary advice and be a catalyst for change in the Swiss innovation policy system. A minimum requirement is a more balanced composition, with a good mix of Swiss and foreign members, and the inclusion of a number of members from industry.

One example of a successful high-level advisory body is the Finnish Science and Technology Policy Council (see Box 4.2), which reflects the "triple helix" approach and may serve as an interesting example. There are of course limits to the power of an advisory council. A "mixed" case in this respect is the Austrian Council for Research and Technology Development which was founded in 2000. It consists of eight members, seven national and one international expert. Four are nominated by the Minister of Education, Science and Culture and four by the Minister of Transport, Innovation and Technology. Half of the members represent science and research, while the other half represents economic/industrial interests. The Council acts as a small independent group that focuses mainly on advisory activities and as a network builder for the government. The government is obliged to discuss the recommendations of the Council according to a certain procedure but is not obliged to follow them. The Council became very influential as in 2001 the Ministry of Finance linked its allocation decisions for extra funding for research and technological development (RTD) – over EUR 1 billion in six years – to Council recommendations. This gave it great freedom for starting new initiatives and setting priorities, but at the same time shifted the balance

26. "Provides and examines the basis for an all-Swiss research, higher education and technology policy … performs analyses … in an international comparison … and evaluations."

from advice to decision making and raised some discussions of democratic legitimacy.

Box 4.2. The Science and Technology Policy Council of Finland

The Science and Technology Policy Council of Finland (STPC) was established in 1987 as "successor" of the Science Policy Council (established in 1963). It functions as a high-level political body for the formulation of Finnish science and technology policy guidelines and is the main inter-ministerial body co-ordinating and integrating science and technology activities. Its main tasks are to advise the government and the ministries, to prepare proposals and reviews for the Council of State and the ministries, to issue statements on the allocation of public funds to science and technology, and to act as an expert body for any questions relating to science and technology. Though it only participates in drafting science, technology and innovation policy and legislation by formulating guidelines and national strategies, as it formally only has advisory capacity, the STPC is mainly responsible for the strategic development of Finnish science, technology and innovation policy (SATW, 2004; Lemola, 2002; Seppälä, 2002).

The members of the STPC, which is chaired by the Prime Minister, are the Minister of Education and Science, the Minister of Trade and Industry, the Minister of Finance, and up to four other ministers. Further, the membership includes ten other members with a stake in science, technology and innovation policy, including representatives from the Academy of Finland, the National Technology Agency of Finland, universities and industry as well as employers' and employees' organisations. They are appointed by the Council of State for three years. This corporatist structure is based on the Finnish tradition of decision making and consensus building and ensures broad-based discussion among stakeholders and thus support for policies, which at least ensures their smooth implementation. The STPC functions as a forum for discussion where policy makers and main stakeholders develop a common political knowledge and future vision of the Finnish education and science, technology and innovation system. The STPC has two sub-committees with preparatory tasks: the science policy subcommittee, chaired by the Minister of Education and Science and the technology policy subcommittee, chaired by the Minister of Trade and Industry. In addition each of the Council's subcommittees draws on the knowledge and the advice of two experts (SATW, 2004).

The Council's strategic guidelines and issue statements are published as part of a science and technology policy review every three years. These policy papers analyse past developments, draw conclusions and make proposals for the future. For example, in its review of 1990, the STPC promoted the concept of a national innovation system, understood as a complete set of public and private factors influencing the development and utilisation of new knowledge and know-how. Following several OECD recommendations, the concept of a knowledge-based society was launched in 1996. In its review *Knowledge, Innovation and Internationalisation 2002*, the Council stresses the importance of the rapidly internationalising innovation framework and the pressures for structural and operational change in Finland. It urged the need for increased government R&D expenditures. Public funding is to increase faster than the estimated growth in GDP, which would mean an increase of EUR 300 million from 2002 to 2007. The money is to be allocated to promising Finnish research areas such as the life sciences, environmental technologies, ICT, health and to the knowledge-intensive services sector (European Commission, 2004*b*; Lemola, 2002).

Sources: SATW (2004); Berghell and Kiander (2003); Seppälä (2002); Lemola (2002); European Commission (2004*b*).

There is generally strong reliance on academic advice in the Swiss system. SNF is governed by academics. The CTI Commission and other bodies also show strong university representation. An interesting case is the powerful ETH Council, on which a number of academics have a dominant position, owing to participation by the institutions governed by this body. However, two of the nine members have an SME background (one of whom also has a background in politics), a third comes from a large pharmaceutical company and a fourth is named by the School Assemblies. This council thus has a better balance than others. The overall Swiss picture is completed by what seems to be a strong influence of academic groups in informal policy making. In terms of the "triple helix" metaphor this seems to indicate that: *i)* the distance between industry and the government is quite large; *ii)* advisory bodies cannot be described as balanced; *iii)* the balance between "militia" members and professionals in some settings should be closely reviewed. Such arrangements carry a risk of lock-in.

4.5 Priority setting, evaluation and policy learning

There is a considerable degree of thematic priority setting in science. The reform of higher education includes portfolio management, fostering strengths and profiles, and allocation of much university investment to a few selected fields. Both ETH Zurich and EPF Lausanne strongly focus on biosciences, with ETH Zurich and the University of Basel building the Systems X campus for systems biology in Basel. SNF funding includes national research programmes (NRP) based on socioeconomic priorities and a broad-based search for these priorities.[27] CTI also funds priority areas in key technologies, such as nanotechnologies and medical technologies. Overall, bottom-up approaches seem to dominate allocations of university block grants and SNF funding, followed by structurally motivated interventions like CTI's to the UAS, entrepreneurship funding or SNF NCCRs.[28] Compared to the general orientation of Swiss innovation policy, readiness to set priorities appears strong, especially in the university sector, where targeted ETH investments or SNF NPRs have a long tradition.

27. Each NRP is devoted to a single theme of socio-political relevance. The themes are selected by the Confederation on the basis of a consultation of interested milieus, including the public and public administration. Social and medical sciences are well represented. NRP programming started in the 1970s (Lepori, 2005*a*, p. 15).

28. NCCR are academic competence centres around a certain topic. Their main rationale is not the choice of topics (which is a strictly bottom-up process) but better structuring of the research landscape and creating groups and networks of a critical size.

On the basis of the national innovation systems (NIS) approach, most other OECD countries complement "thematic" priorities by "functional" and "structural" priorities in order to foster the long-term development and functioning of their innovation system. There is also a growing interest in and need for priorities determined by societal needs and opportunities. Thus, priority setting becomes increasingly context-dependent and involves a growing number of actors and stakeholders. The balance between top-down and bottom-up approaches is changing as well. However, owing to differences in national framework conditions and policy traditions, national priority setting is still implemented in a variety of ways (see Box 4.3).

Box 4.3. International trends in priority setting in science and technology

S&T policy in *Canada* still features a rather high degree of fragmentation. Over the last years the government launched several programmes and initiatives focused on single issues and aspects rather than on the innovation system as a whole. To arrive at a coherent national innovation strategy remains a challenge. Initiatives mostly focus on S&T infrastructure. Recently, the issue of technology commercialisation has been addressed. The structure of S&T policy making is characterised by a divide between bodies within the government that deal with science issues and those that concentrate on broader S&T agendas. For example, the Advisory Council on Science and Technology (ACST) almost exclusively deals with single issues while the Council of Science and Technology Advisors (CSTA) provides an overall evaluation of the performance of government departments and agencies in S&T areas.

S&T policy in *Ireland* has induced a rapid increase in R&D spending in recent years. Science, technology and innovation policy now ranks very high on the political agenda. For some years Ireland has set priorities on its own, replacing priorities that were prominent owing to participating in the European Structural Funds. Priorities are now set on the thematic as well as on the functional level, with some emphasis on the latter. Thus, a key instrument of the National Development Plan (NDP) 2000-2006 is the Programme for Research in Third-level Institutions (PRTLI) which offers the opportunity to build infrastructure and to develop the careers of Ireland's brightest researchers. Thematic priorities are set in a rather broad manner (biotechnologies, ICT). However, though the present NDP gives some guidance, a coherent strategy for S&T policy and priority setting is still lacking. Reasons may include the changing landscape of S&T policy actors.

S&T policy in *New Zealand* recently set four general long-term goals: knowledge, economy, environment, society. The two more mission-oriented goals (environment, society) are to be achieved by means of dedicated and thematically oriented funding schemes. Thematic priority setting covers a broad range of topics including generic growth technologies but also areas in which New Zealand has comparative advantages and strengths (*e.g.* agro-business). As the priorities are directly tied to instruments and funding schemes, they are very important for the country's research activities. The system of priority setting in New Zealand is not only very consistent but is also well established, implemented and monitored. It can thus be regarded as a very instructive example.

Box 4.3. International trends in priority setting in science and technology *(continued)*

The S&T priority setting process in *Korea* is highly formalised and government-driven. While in the past S&T policy focused on commercialisation and imitation of foreign technologies, Korea now concentrates on functional priorities in order to become more innovation-oriented. Thus, basic research, the development of core technologies and innovations with a ten-year horizon has been given priority in recent years. Ten priority industries and eighty target technologies are to promote industrial growth. Some of the priorities are clearly mission-oriented as they relate to national security, nuclear energy and a healthy society. The priority-setting process is characterised by less aggregation of thematic focuses than in most other countries and involves a wide range of actors at the political level, including the National Science and Technology Council and the ministries. It is clearly top-down in approach.

The system of science, technology and innovation policy and priority setting in the *Netherlands* is mainly bottom-up. It is highly complex but with well-differentiated levels. While functional priority setting mainly takes place on the highest policy level and ministries are responsible for mission-oriented co-ordination and priority setting, more detailed policy development is undertaken by a large number of executive agencies. The system is characterised by a high level of input from professional consultancies and reliance on expert-based technology foresight ("Technology Radar"). Though practices are very advanced at all these levels, the complexity of the multi-level, multi-actor priority setting process makes it difficult to ensure coherence of science, technology and innovation policy.

S&T policy of the *United Kingdom* is traditionally more science-oriented than in most other European countries. In principle, thematic priority setting is carried out by the Research Councils in a bottom-up process. However, the government has stimulated co-operation between the independent Research Councils in order to promote multi-council programmes of societal relevance with a clear mission orientation. Additionally, priority setting at the regional level has gained in importance, and foresight initiatives are prominent. Another British S&T strategy is to focus on a limited number of co-operative applied research initiatives (*e.g.* LINK) to promote knowledge-intensive business clusters.

Sources: Gassler *et al*. (2004); HEA (2003); OECD (2003*a*, 2004).

Systematic evaluations and strategic studies (foresight, technology monitoring, road mapping) are important instruments in support of the further development of Switzerland's innovation policy and its adaptation to future requirements.

Evaluations are established as good practice in Switzerland. Most programmes are subject to external interim or *ex post* evaluations. Foreign experts are frequently called upon as evaluators, but Swiss evaluators also show a high degree of professionalism and contribute to the development of sophisticated methodologies. Different methodological approaches are used to obtain scientifically sound results and recommendations. The background report for this review (Arvanitis and Wörter, 2005, pp. 72 *ff*) identifies a number of common results emerging from programme evaluations (for an overview see Table 4.2):

Table 4.2. Main programme evaluations and results

Programme	Method	Main results	
		+	-
CIM (1) (1990-96) CHF 102 million	Survey, econometric analysis – impact analysis	SMEs are more competitive, no windfall gains, soft measures, greater impact.	No funding effect in large firms and windfall gains likely.
CIM (2) (1990-96) CHF 102 million	Survey, interviews	Service offerings, CIM centres in line with expectations and firms perceived CIM very well.	More information necessary about diffusion level and possible clients and duties of CIM centres.
Microswiss (1) (1992-97) CHF 110 million	Descriptive analysis	Greatest impact on SMEs, soft measures more effective. Focus on new users.	Larger firms' windfall gains to the fore, lack of qualified staff, SMEs: cost aspects main obstacle.
Microswiss (2) (1992-97) CHF 110 million	Surveys, interviews	Participation and technical impact good, communication between centres and customers good, success greatest in further education and training.	Executives and heads of marketing less involved, economic impact partly lacking, non-technical topics not part of the training programme.
CTI-MedTech (ongoing programme, evaluated in 2004)	Survey, international experts	Well designed and meets the needs of the applicants, programme with diverse topics.	External experts to be more involved in project evaluations, accompanying research recommended, programme management to be broadened.
TOP-NANO 21	Evaluation completed. Report in 2006.		
CTI-UAS	Evaluation completed. Report in 2006.		
Energy 2000 (1990-2000) CHF 50 million annually	Evaluation-synthesis, empirical research	Quantitative goals, long duration, some sectors launched products early, behavioural change caused, quantified goals reached in large parts, "energy 2000" label, innovations.	Strong leadership missing – programme design not good, some sectors launched products late, no additional investment effects, no additional employment effects.
MINAST (1996-99) CHF 55.6 million public funding, CHF 73.0 million private investment	Survey, expert interviews	83% satisfied with the research partner, 92% interested in further research, 100 jobs created by 2000, 35 new products expected by 2003, efficiency of knowledge transfer promoted.	Project budgeting and project controlling carried out by both partners, complex and multidisciplinary projects to be led by industry partner, property rights to be contractually regulated from the beginning.
LESIT (1992-95) CHF 110 million	Patent analysis, survey	Research promoted in electrical engineering, skill level increased in physics, job market evaluated skills, R&D activities promoted, turnaround tendency in patent applications, involved firms improve market position.	No considerable promotion of research in physics, research quality not seen in citation index, skill level in electrical engineering crowding-out effects, few new patents filed.

Table 4.2. Main programme evaluations and results *(continued)*

Programme	Method	Main results	
		+	-
FP3 (1990-94) Swiss contribution: CHF 135 million	Data base of Swiss participation, survey, expert interviews	High additionality, new R&D networks built, economic benefit-oriented participation, FP3 compensates lack of ICT promotion.	Participants to be more scattered around sectors and branches, participation to be improved in manufacturing and non-manufacturing businesses.
FP4 (1995-99) Swiss contribution: CHF 372 million	Data base analysis, survey, interviews	Scientific benefit high, Swiss international network increased, participants more allocated.	Economic benefit lower, concentration of participants still high, budget mainly absorbed by federal institutions and universities, weak participation in humanities and social sciences programmes.
COST (1971-), project evaluation between 1996-2000	International experts, data base analysis, survey, expert interviews	Scientific benefits high, cost-benefit ratio satisfying, administration BBW good, open to new participants.	Economic benefits meagre, criticism directed to administration in Brussels, overlap of different programmes (COST, FP, EUREKA).

Source: Arvanitis and Wörter (2005).

- Windfall gains are more likely in large than in small firms.
- Soft measures like training or consulting are very effective.
- Programmes are generally well absorbed.
- International programmes lead to intensified network building.
- Some programmes funding applied research show good scientific results.

One caveat is that these summary results have to be seen in the light of the nature of CTI funding.

As of 2004, a strategic controlling of the entire education, research and innovation area is being put in place. This instrument could be further developed in order to mitigate the tendency of Swiss innovation policy to look to the past and to provide a platform for policy learning. Evaluations of institutions were of special importance in recent years:

- An auto-evaluation of the ETH sector followed by an international peer group led to positive conclusions and important inputs into the ERT Message 2004-2007 regarding tenure track, graduate schools and the Bologna process.

- SNF and CTI were evaluated in 2001/02 (SWTR, 2002*b*). This evaluation gave both institutions good marks in general and confirmed their positions in the Swiss innovation system. The bottom line for both institutions includes a "more of the same with more funding" message. For CTI more discovery-oriented projects without business firm participation and a stronger focus on new high-technology enterprises were recommended, while SNF recommendations mostly concerned internal governance structures. A number of recommendations have already been implemented by both institutions and the government, with the call for more financial resources partly reversed owing to federal budgetary constraints ("*Kreditsperre*", see Schweizerischer Bundesrat, 2002, p. 2367). An in-depth evaluation of the overall innovation system has not yet been conducted.

Policy learning involves a number of instruments and mechanisms, mostly on the "soft" side of the innovation policy spectrum. In this respect, there is some evidence for the existence of two bottlenecks in Switzerland: *i)* policy forums tend to be used to deal with complex co-ordination issues (see above on the Bologna process) rather than collaborative learning processes; and *ii)* the strong reliance on "militia" members from the academic sector could be more balanced if the recruitment strategies of agencies placed more emphasis on hiring full-time innovation policy experts. As Table 4.3 shows, there are many elements of distributed intelligence and learning, but it is difficult to find learning ensembles or a learning system (for a general discussion see Smits and Kuhlmann, 2004).

A potential route in this regard might be greater involvement of large firms in learning and mechanisms for the exchange of good practice. Such companies have ample experience with complex organisational and technological innovations and are leaders in many international markets. The public sector could learn and profit from their experience. If areas of strong common interest – internationalisation, portfolio building or organisational learning – can be identified and good learning frameworks installed, there would be little danger of opening the door to special interests. This proposal is prompted by the opinion, recurrently voiced by various stakeholders, that the interface is minimal between the large firms, which are one of the country's great assets, and the government.

Table 4.3. Some learning instruments

Instrument	Comment concerning Switzerland	Swiss position *)
Exchange of personnel between parts of the "triple helix"	Relatively little interchange between public sector and industry, strong presence of academics in policy advice	*(*)
International exchange and learning forums	Growing numbers of EU-CHE interfaces, many new ERA-Nets., EUREKA, ESA, etc., as common forums	**
Explicit learning forums	Not easily identified, view from outside is institutional boundaries and formal co-ordination bodies	*
Programmes as source for learning and intelligence	CTI set-up provides good learning opportunities for important features of the system: entrepreneurship, science-industry co-operation, etc.	**
Foresight, technology assessment, benchmarking	Some well-designed institutions are in place, but would merit more attention	*(*)
Discussion of evaluations, specific feedback	Evaluations seem to be generally discussed and the results taken up in policy formulation	***

1. The number of stars and 0 indicate the relative position of Switzerland: *** = fully in international mainstream; ** = well in line; * = only few/*ad-hoc* activities in Switzerland; 0 = absence of such a policy (instrument).

An example of an effective learning forum is the Austrian RTD Evaluation Platform (Box 4.4), started about eight years ago, which has many activities for integrating a better evaluation culture into the Austrian system.

4.6 Internationalisation issues

Swiss policy makers and research communities seem to have responded well to the challenge of stronger integration with European research. Swiss research has always been open internationally, and the Swiss research communities approached European research funding schemes step by step. Impact assessments of previous Framework Programmes (FP) show the high impact of Swiss FP contributions in the 1990s as regards new co-operation patterns, strengthening of scientific capabilities, establishment of new research fields as well as the high economic impact on both small and large firms (Balthasar *et al.*, 1997). Starting with the 6th FP, Switzerland no longer funds its participants on a project basis but participates fully. Annual payments before this switch were about CHF 120 million (for 2002, see Lepori, 2005, p. 20); for 2005 about CHF 200 million was transferred to Brussels.

Box 4.4. The Austrian Evaluation Platform: an example of mutual learning

Platforms for mutual learning can be important instruments for building consensus and putting policy issues higher on the agenda. For their part, evaluation issues need an underlying culture and common understanding. Both methodological questions and individual evaluations need broad discussion, transparency, standards, feedback and shared values. While the Anglo-Saxon and Scandinavian countries have a longstanding culture in this respect, evaluation of RTD policy in Austria was underdeveloped until the 1990s. Only a few elements, such as *ex ante* project evaluation, met international standards. Reasons included a lack of awareness among policy makers, few existing explicit funding programmes, the predominance of institutional block funding without quality criteria and, more generally, an innovation system that was still in the making.

In the mid-1990s a small number of administrators and researchers created the Austrian RTD evaluation platform (*Plattform FTEval)* as a loose network to discuss methodological issues and to present new evaluations. "Struggling for a higher rank on the policy agenda" (Stampfer, 1998) was its mission and main goal. A workshop series regularly brought together Austrian and foreign experts, and a newsletter documented and diffused the results. Over the years the community grew, partly because of the platform's work, partly owing to the growing need for legitimacy of public spending. "Value for money", outputs and impacts as well as indicators for measuring them became more pressing issues, as public R&D expenditure started to accelerate. The platform grew as three ministries, many important federal and regional funding agencies, the Austrian Council for Research and Technological Development, the Quality Assurance Agency and five evaluation research institutions joined the *Plattform*, which is now an association of more than 15 institutional members. Its annual budget of EUR 100 000-150 000 comes from membership fees and contracts.

The scope of its activities is broad. Apart from regular workshops and newsletters, Austrian RTD evaluation standards were developed, which include teaming up Austrian and foreign evaluators. Studies include an evaluation manual for the Austrian Council for Research and Technological Development. Training courses for programme managers assist them to get a basic understanding of project, programme and policy evaluation. In 2003, an international RTD evaluation conference was jointly organised with the OECD in Vienna; a second conference took place in spring 2006. Internationally the platform serves as a contact point for the European Commission, US networks and the German Evaluation Society, among others. To avoid collusion, the platform's mission does not extend to specific evaluations.

This initiative – with low costs and a "militia-based" administration – has helped to give evaluations a higher profile in Austria. Methods, standards and common understanding undergo continuous improvement. Internationally it is seen as a good practice learning initiative.

Sources: OECD (1998); Plattform Forschungs- und Technologieevaluierung (2003); Stampfer (1998).

The Swiss research community has responded positively to the long-term goal of a European Research Area (ERA) (European Commission, 2000); institutions such as the SNF are well integrated in activities to design a new European Research Council. SNF is also a member of EuroHORCs, the umbrella organisation of the European science funding councils. Swiss experts take part in European policy processes, SwissCore, located in Brussels, acts as a link between the FPs and the Swiss research communities. Switzerland is also a member of international institutions such as ESA, CERN (in Geneva) and the Institut Laue-Langevin. While European research agendas seem to be viewed positively, the relation between EU programmes and national policy making needs further clarification. ERA-Nets are considered good models and some Swiss institutions are involved. The need for a strong national policy is recognised. This implies that national priorities should not be cut as a result of Switzerland's relatively costly participation in European programmes such as ESA. The danger that such cuts may be taking place owing to an ongoing need for budget consolidation is also recognised.

Chapter 5

THE SCIENCE SYSTEM

5.1 Introduction

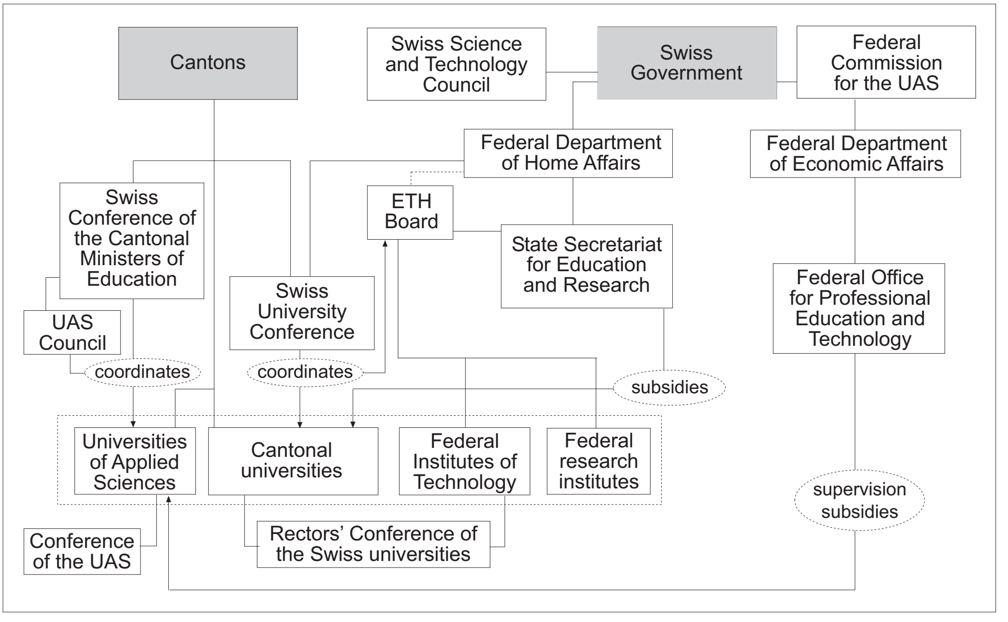
This chapter draws extensively on existing work, specifically the *OECD Tertiary Education Review* (OECD, 2003*b*), the ERT messages 2000-2003 and 2004-2007 (Schweizerischer Bundesrat, 1998, 2002), and a number of other Swiss policy papers. It does not offer much policy advice as the main indicators show very good performance and strong ongoing reform. A number of critical issues relating to the science sector are discussed elsewhere: university reform is covered in Chapter 4, while the strong reliance on "supply-side" technology transfer is fundamentally an industry-related topic and is discussed in Chapter 6.

A short description of the Swiss university system is followed by considerations on the process of university reform. The new universities of applied sciences (UAS) sector are covered next, before turning to science-oriented project and programme funding. Finally, selected internationalisation issues are discussed.

5.2 Features of the Swiss tertiary education system

Switzerland has a dual and diversified tertiary education system. There are, on the one hand, the ten cantonal universities and the two federal institutes of technology (ETH Zurich and EPF Lausanne) and, on the other hand, the universities of applied sciences (UAS), which were upgraded from upper secondary schools at the end of the 1990s. In 2004 there were about 110 000 students at Swiss universities and about 44 000 at the seven UAS. Responsibility for the various institutions is shared by the cantons and the Confederation. Universities are organised and regulated on the cantonal level, ETHs by the Confederation, and the UAS may be governed either by the cantons or federally, depending on their fields of study. Thus, a network of cantonal, federal or joint bodies runs the tertiary education sector. A variety of legal frameworks and agreements for universities and UAS regulate their creation, organisation and administration, and a huge number of policy makers and stakeholders are involved (see Figure 5.1 and Chapter 4) (OECD, 2003*b*; Bund und Kantone, 2002).

Figure 5.1. Organisation of Swiss universities and UAS



Source: OECD (2003*b*).

However, not only are competencies and powers divided between the federal and the cantonal level, they also share responsibility for funding. The Confederation accounts for 25% of total expenses of the cantonal universities and 28% of cantonal UAS. Research funding is mainly provided by the federal level via SNF and CTI. These two institutions are considered below. Overall Swiss universities perform quite well according to standard higher education indicators. For this reason, it is more rewarding to look at the Swiss higher education system with respect to its interaction with other actors of the Swiss science and innovation system.

While the two ETHs in Zurich and Lausanne focus on engineering sciences, mathematics, natural sciences and architecture, the ten cantonal universities offer a wide range of studies, with some profiling (*e.g.* Basle, Bern, Geneva, Lausanne and Zurich in medicine or St. Gallen in economics, law and the social sciences). The ETH domain also contains four national research institutes: PSI, WSL, EMPA and EAWAG.

The overall international performance of Swiss universities is very good, as reflected, among others, by the rankings published by the Shanghai Jiao Tong University (2005). There are six Swiss universities among the world's top 200 universities and among Europe's top 80 universities. ETH Zurich is ranked 27th worldwide and fifth – after the universities of Cambridge and Oxford, the Imperial College London and the University College London – in Europe. It is followed by the University of Zurich (world rank 57, European rank 13), the University of Basle (87th and 28th, respectively), the University of Geneva (world ranking group 101-152, European ranking group 36-56), the ETH Lausanne and the University of Bern (world ranking group 153-202, European ranking group 57-79). In spite of the shortcomings of such rankings, Switzerland can clearly rely on excellent universities as the basis of its science system. It has not only some excellent research universities but also a set of excellent higher education institutions.

The important position of the ETH domain (including the four national research institutes) in Switzerland is underlined by publication data. All six institutions rank among the top 30 of about 700 Swiss institutions in terms of absolute numbers of publications (ETH Zurich ranks 2nd, EPF Lausanne ranks 7th, PSI 9th, EAWAG 15th, WSL 27th, and EMPA 30th). The ETH domain's publication output has grown relative to overall publication volume since the beginning of the 1980s and accounted for almost 5% of publications in 1998-2002. The share is even higher in engineering, computing and technology as well as in physical, chemical and earth sciences (ETH Board, 2004).

Swiss universities also perform well compared to other countries in terms of their share of foreign students and graduates. More than one-third of all PhD students (37%) come from abroad (36% are women). This makes Switzerland the leading country in this respect, ahead of the United Kingdom, Belgium and the United States. Sweden, Denmark and Austria attain about half of this figure. There is also a large number of foreign university professors and other academic professionals in Switzerland. Swiss universities have an excellent reputation, and Swiss science is internationally recognised. This is a major asset as regards the European Research Area and the European Higher Education Area. Swiss firms have not recently faced any shortages when seeking to recruit good graduates (see OECD, 2004).

Swiss universities also seem to prepare their students quite well for the requirements of the labour market. Between 1985 and 1999 almost 40% of their graduates of a given year entered professional life immediately, and a further 25-30% found jobs within three months after graduation (Arvanitis and Wörter, 2005). The fact that students undergo a strong selection process during their studies, especially in the ETH domain, may contribute to this result. In addition, Swiss universities have a strong focus on technology transfer (see Chapter 6). In this respect and also in terms of general policy, university autonomy has been strengthened considerably in recent years.

A salient feature of Swiss university governance is the procedure for recruiting staff in the ETHs, which can serve as an example of good practice for other countries. Appointment of professors is one of the major responsibilities of the ETH management team. The presidents of the two ETHs have full responsibility and participate in all strategic decisions. They decide upon the call for the professorship according to the long-term strategic plans of the ETH and then appoint a delegate who organises the recruitment procedure. Next the ETH Board nominates the recruitment committee which includes external members. The detailed job description is advertised internationally. The recruitment committee also actively searches for and contacts candidates. Applications are screened by the commission and candidates are chosen for an interview and to give a lecture. The commission then makes its recommendation on the appointment to the president, who remains free to look for another candidate. The president must also obtain the funding and the infrastructure needed for the new professor. In addition to the strong role of the president and the "headhunting" which ensures a long-term, proactive recruitment policy, the institution provides various services for its academic staff, *e.g.* it assists in finding a job for the professor's spouse, in arranging schools for the children, etc. This approach has allowed ETH Zurich to attract successfully international faculty of high quality. About 40% of the academic staff are foreigners coming from positions at foreign institutions, about 30% are Swiss recruited from foreign institutions, and the remaining 30% come from faculty positions in Switzerland (Schmitt *et al.*, 2004; Herbst *et al.*, 2002).

5.3 Swiss higher education landscape 2008 and other important policy developments

As in many other European countries, the Swiss higher education sector is undergoing a series of reforms. Besides the very important step taken in 1996 to upgrade the former upper secondary schools to UAS, Switzerland has engaged in three further stages of reform. A timetable for the period 2000-07 was set by the Swiss government and parliament. In the first stage of the reform process, the Federal Council submitted a message on the education, research and technology system for 2000-03 under the heading "To reform and invest" (Schweizerischer Bundesrat, 1998). The two guiding principles were the intensification of co-operation between higher education institutions and the priority of quality over quantity. Policy measures concentrated on five strategic objectives:

- To create networks of higher education institutions.
- To integrate these networks into international co-operation programmes.
- To promote excellence in education and research.
- To apply knowledge more effectively.
- To improve the effectiveness of the mentioned networks.

In 2000 the new Act on the Promotion of Universities (*Universitätsförderungsgesetz*, UFG) came into force. It ensured a structural framework for co-operation relative to universities between the Confederation and the cantons and introduced new operating rules for universities. Funding based on the quality of the services provided by the universities replaced the former policy of "automatic payment". Further, under the UFG quality assessment is carried out nationwide using uniform criteria, and in 2001 the OAQ, a new and independent accreditation and quality assurance body, was established. Steering at the system level and co-operative activities were strengthened by setting up the Swiss University Conference (SUK).

The second stage of reform was triggered by the ERT Message 2004-2007 (Schweizerischer Bundesrat, 2002). The main issue addressed was the need for a considerable increase in funding to improve the productivity and valorisation of research. Overall funding increased from CHF 14 245 million for 2000-03 to CHF 17 346 million for 2004-07, an increase of 21.8%. Of the additional CHF 3 101 million, CHF 865 million are devoted to the ETHs (+ 12.4%), CHF 561 million to the cantonal universities (+ 26.6%), and CHF 285 million to the UAS (+ 33.4%). Basic funding for the cantonal universities increased by about one-third, and project-based funding rose by 17.7 %. The most striking feature of UAS funding is that CHF 40 million is provided for integrating the social sciences and humanities in the UAS, a topic that was not addressed in the previous ERT message. The largest budget increase is in the category "research, innovation and valorisation of knowledge". With a total of CHF 2 993 million, this is an increase of 43.0%. SNF (+ 46.3%) and CTI (+ 51.6%) will gain most from the additional CHF 900 million. Here the priorities are to improve the career prospects of early-stage researchers and to provide more funding for the social sciences and humanities (tasks assigned to SNF) and to focus on new technologies, life sciences, nanotechnologies, ICT and promoting entrepreneurial spirit (primarily assigned to CTI). The SWTR recommends, among others, the promotion of the social sciences and humanities as well as of the career prospects of early-stage researchers (SWTR, 2002*a*). Clearly, the increased funding is not distributed indiscriminately; it focuses on strengthening the linkage between research and its valorisation for the economy and society as a whole (Schweizerischer Bundesrat, 2002).

This step in the reform is accompanied by a major project called Swiss Higher Education Landscape 2008 ("*Hochschullandschaft Schweiz 2008*"). As the potential of the UFG for joint steering of the university sector has not been fully realised and since the UFG ends in 2007, discussions have continued, and the Swiss Higher Education Landscape 2008 aims at a fundamental structural reorganisation of the Swiss higher education system. By 2008, the system is to be unified and governed under a single framework law, such that the structure of all cantonal universities, the federal ETHs and UAS is treated equally. The heart of the process is thus an extensive reform of governance. In the report of the project group in charge (Projektgruppe Bund-Kantone Hochschullandschaft 2008, 2004) major challenges and weaknesses of the Swiss higher education landscape were identified. While the Swiss tertiary education sector has expanded over the last decades, research activities have become more important and there is a need to improve efficiency in order to ensure quality in the face of scarce funding. Indeed, the major weaknesses addressed by the report are lack of efficiency and transparency in the system's organisational structures[29] as well as in the allocation and use of available funds. Steering at the national level is largely lacking, tasks are not shared among institutions and beneficial competition does not always occur.

The main recommendations were to intensify co-operation between the national level and the cantons, while keeping political steering competencies clearly separate and mainly with the Confederation. Further, the latter continues to fund research through SNF and CTI. However, higher education institutions are to have extensive autonomy accompanied by various steering instruments such as performance agreements. The structural reform aims at reducing the number of bodies in charge of the higher education and research agenda and at streamlining procedures. There are to be three central bodies, the Conference of University Governing Institutions (*Konferenz der Hochschulträger*), which is mainly responsible for the steering and regulation of the overall system, the Conference of Rectors/Presidents of the Higher Education Institutions (*Konferenz der Rektoren/Präsidenten der Hochschulen*), which co-ordinates the institutions, and the Higher Education

29. There are indications of organisational weaknesses on both the overall level (see the section on the Bologna Process) and on the level of intra-university governance. A study by CEST, juxtaposing ETH Zurich and MIT (Herbst *et al.*, 2002) asks why, in relation to input, MIT produces more output in terms of PhDs, citation impact and other relevant indicators. In seeking an answer, the authors point to issues of organisation and list a number of success factors, including professional management, graduate schools, flexible centres and programmes instead of strict disciplinary boundaries, etc.

Council (*Hochschulrat*), which is an advisory body including experts from science, industry and society at large. Financial transparency and cost efficiency are to be provided by using a model of standardised costs per student. The institutions get block funding on the basis of their performance agreements and are obliged to report on their activities and spending. Finally, institutional profiling is to be encouraged. All these reforms centre on the Bologna Process and the European Higher Education Area, which aim at harmonising European study structures. Like most other European countries, Switzerland is heavily engaged in the debate and makes the issue of study structures its main reform objective.

In parallel, the initiative called *Hochschulmedizin 2008* deals with higher education and research in the field of medicine alongside the Swiss Higher Education Landscape 2008 in connection with the reform of the health system.

Sporn and Aeberli (2004) in an interesting study on (potential) profiles of Swiss higher education institutions in an international context suggest a reform of the Swiss system towards a system consisting of three types of higher education institutions pursuing different objectives: globally oriented institutions such as ETH Zurich, European institutions like the University of St. Gallen, and more distinctly nationally or regionally rooted institutions such as the University of Lucerne. They consider that this strategy would strengthen Switzerland's position within the (global and European) higher education area.

To summarise, most Swiss actors are increasingly aware that Switzerland's future prosperity is linked to the development of the science and education system and express a strong commitment to reform. The importance of this issue notwithstanding, it should be borne in mind that the Swiss innovation system consists – or should consist – of a broader set of interlinked actors and institutions. This issue is addressed in Chapter 6.

5.4 Universities of applied sciences – current developments

The establishment of universities of applied sciences (*Fachhochschulen*) is quite recent. This sector was created in the mid-1990s, in three European countries with similar upper secondary and tertiary education systems: Switzerland, Germany and Austria. All three countries faced the same challenges: *i)* medium or low participation rates in tertiary education; *ii)* proven dual systems, high standards of vocational training; *iii)* very good upper secondary (technical) schools, providing engineers without tertiary graduation; *iv)* new requirements owing to the transition to a knowledge-based economy. The creation of the Swiss UAS sector was initiated by the Conference of Directors of the Swiss Engineering Schools in 1990. The sector was created in 1996, with the individual UAS a cluster of upgraded upper secondary schools: 28 former upper secondary technical schools (mostly so-called "HTL"), 21 upper secondary schools with a economic or administrative focus and nine design schools formed the core of the seven UAS with nearly 200 study courses (see EFHK, 2002). In Austria, instead, UAS-type *Fachhochschulen* were created from scratch.

Table 5.1. Key figures on UAS in Switzerland and Austria

	Austria 1993 (newly established)		**Switzerland** 1997 (upgrading of *Fachschulen*)	
Course-providing bodies	18	*i)*	7	*v)*
Population	8 117 754	*ii)*	7 415 100	*vii)*
UAS per million population	2.22		0.94	
Studies/degree programmes offered	136	*i)*	220	*v)*
Range of studies offered per UAS	1-26	*i)*	9-81	*v)*
Places for first-year students at UAS	7 342	*i)*	14,137	*vi)*
Range of first year students' places per UAS	60-1 110	*i)*	422-3 246	*vi)*
Places at UAS degree programmes	25 554	*i)*	42 016	*vi)*
Range of places at UAS	120-3 576	*i)*	1 535-10 385	*vi)*
Average number of students per UAS	1 419	*i)*	5 135	*vi)*
Teaching staff at UAS	5 906 of which full time: 1 044 of which part time: 4 862	*ii)*	3 681 (full-time equivalents)	*vi)*
R&D staff (full-time equivalents)	169.8	*iii)*	989	*vi)*
Higher education budget for UAS degree programmes (EUR)	77 536 000	*iv)*	646 871 961	*vi)*
Expenditures for R&D at UAS (EUR)	21 144 000	*iii)*	114 035 656	*vi)*
% from the central state	*53.6*	*iii)*	*26.9*	*vi)*
% from the federal states/cantons	*26.4*	*iii)*	*48.4*	*vi)*
% from others (other public sources, private sources, international organisations, EU, etc.)	*20.0*	*iii)*	*24.7*	*vi)*

Sources: i) FHR, 2005 for the academic year 2004/05; *ii)* bm:bwk, 2004 for the academic year 2003/04; *iii)* bm:bwk *et al*., 2005 for the year 2002; *iv)* bm:bwk, 2002 for the year 2001; *v)* EFHK, 2002 for the year 2002, *vi)* information provided by BFS for the year 2004; *vii)* BFS (2005*d*).

The seven UAS cover the seven larger regions of Switzerland. They are decentralised, and most UAS have quite a large number of locations. After a period of fast growth, the UAS sector has a total of more than 44 000 students. About two-thirds of Swiss engineers are educated in the UAS sector. As the *OECD Tertiary Education Review* (OECD, 2003) and other sources show, many governance challenges arise from the fact that parts of the UAS system are governed and financed by the cantons, while others are federally governed and financed owing to the traditional federal control over technical schools. Overall governance (laws and licences) is at the federal level. The federal responsibility for the UAS lies with EVD, while EDI is responsible for the universities. The streamlining of the higher education system is discussed in the governance chapter of this review; it was also subject to an in-depth analysis in the *OECD Review of Tertiary Education* and has been addressed in a number of Swiss publications (Schweizerischer Bundesrat, 2002; and for a detailed overview OECD, 2003, pp. 62 *ff*).

"Reforming and investing … and stabilising" has been the motto of UAS policy (EFHK, 2002, p. 7). The EFHK review in 2002 evaluated the sector and gave marks from 1 (low level of development) to 4 (high level) for a number of the sector's key features. Formal and teaching-related features got higher grades than management and leadership. With a mark of 2.83 the "Applied Research Policy of UAS" achieved a good result (ranked four in twelve indicators).

Regarding research, the UAS are in a difficult position. There are relatively few permanent and full-time staff (but more than in the Austrian UAS-type *Fachhochschulen*). UAS are new institutions and lack a track record, while applied research and valorisation require customers' trust. Swiss innovation policy has devoted effort and resources to developing this sector. There seems to be some connection between the absence of direct funding of SMEs and the emphasis on providers of applied research. Some stakeholders hold that the sector lacks sufficient resources, does not grow fast enough and faces many difficulties. A comparison of the Swiss and Austrian UAS sectors (Table 5.1) shows that the Swiss UAS fare better in terms of structural indicators regarding size and receive more money for research than their Austrian counterparts. No real block funding is provided for UAS R&D but at least three significant funding initiatives help to develop applied research and industry co-operation at Swiss UAS:

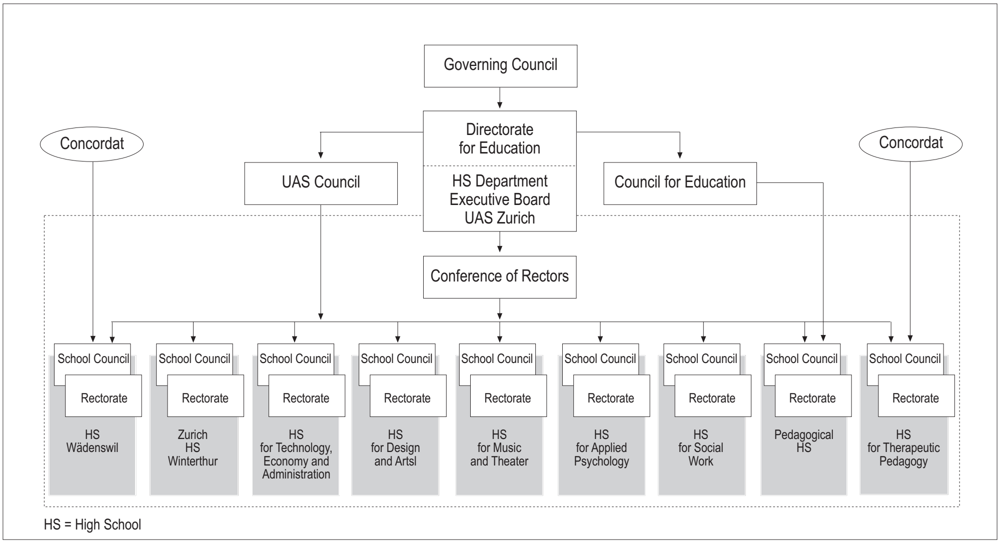
- DO REsearch (DORE) is a programme to raise the research competence of the cantonal part of the UAS sector, *i.e.* the non-technical fields. This common initiative of SNF and CTI aims at better research in the social sciences and humanities (SNF and KTI, 2003). For 2000-03, 119 projects were funded and received a total of CHF 6.5 million. More than 300 partners from industry and the public sector doubled the programme funding. International experts were positive about this approach, but proposed clearer criteria for the kind of research funded, a better research strategy and some upgrading of the quality of the projects.

- Funding the personnel costs of projects run by the (technical) UAS is a major pillar of CTI's strategy. This has to be seen in the light of Switzerland's overall policy for funding of R&D. Within CTI there is a UAS expert group and more than 20% of annual CTI funding is allocated to this sector. In 2004, 84 projects (apart from competence networks, see below) received CTI funding of CHF 21 million, and another CHF 31 million of private funds. Most of the projects are in "enabling sciences" and "engineering". A recent priority of CTI is linking funding to strategic portfolio building at the UAS, granting even more than the usual 50% maximum for such projects. CTI funding, with its external reviews and quality criteria, has been instrumental in setting standards within a short period of time. An evaluation of the agency's UAS funding policy was recently completed.
- The networks of UAS research groups in different fields are the third instrument. In 2004, 11 UAS networks received CTI bonus funding. These networks should fulfil an exchange and knowledge transfer function, but are viewed critically by experts in the field as being prone to over-administration and deadweight losses. They are considered to have been useful in the first phase of the UAS. Now, other, more industrial cluster-oriented instruments are under discussion.
- A very important source of research funding in the UAS is the dedicated funding within the basic funding made available for establishing research competencies by the Confederation through OPET.

One trend seems to be the link-up of UAS with existing regional strengths and clusters. One example is UAS Aargau/North West Switzerland (FHNW) which is located in the region where most of the plastics industry, large parts of machinery construction and power engine industry (ABB, Alstom) and the life sciences are clustered. This UAS has about 250 full-time professors, mostly with industry and market experience; part-timers from industry are also an important resource. Applied research is performed by the professors and their staff and industry requirements are addressed in the curricula. This UAS has an annual R&D budget of CHF 20 million (20% of its overall budget), CHF 7 million from industry and the rest from the cantons and CTI. A large share of contributions comes from big corporations, but medium-sized firms are also important partners. Diploma theses act as a first stepping stone. Co-operation with small firms poses specific challenges.

While the overall development of the UAS appears positive, a closer examination reveals some areas of concern. One issue already discussed is UAS governance. Apart from the disadvantages of shared governance between the federal and cantonal levels – which implies time-consuming procedures involving federal and cantonal actors – the seven UAS also have rather complex internal governance structures. Taking the UAS Zurich (ZFH) as an example (Figure 5.2), one can easily understand that much effort is needed to co-ordinate the various units and that the existing governance structures may be unable to fulfil this task satisfactorily. However, reform is on the way and in 2006/07 the eight institutions of the ZFH will be integrated into three autonomous higher schools with strengthened steering structures at the institutional level.

Figure 5.2. Current governance structure of the UAS Zurich (*Zürcher Fachhochschule*)



Source: Sporn and Aeberli (2004).

The highly integrated Swiss UAS set-up thus seems to be more a formal labelling than a functional organisational structure. This is pointed out by Sporn and Aeberli (2004) who consider the present co-ordination and steering mechanisms paralysing, particularly as they do not allow for the strategic positioning of individual UAS. In particular, they feel that co-operation beyond cantonal borders (and between institutions belonging to the same UAS) is in urgent need of improvement.

Further, the idea that UAS might act as an intermediary between basic science and the market deserves more thorough discussion. An alternative approach would be for UAS to develop their own competencies and get their main inspiration not from science or potential ETH/university networks, but from the problems and needs of "their" business firms.

In order to enable the UAS to fulfil their role with respect to their business sector clients, it seems necessary to reconsider one specific feature of the Bologna reform as implemented in Switzerland (Hotz-Hart *et al.*, 2006). Currently, the UAS are essentially constrained to provide bachelor's degree courses while master's degree studies are almost exclusively offered by the federal institutes of technology and the universities. Without substantially increasing the scope of master's degree studies at the UAS there is a risk that their knowledge base dries up and that they will end up as mere teaching institutions without being able to fulfil their wider tasks in the area of R&D and innovation.

Challenges for the future of the sector and for enabling even stronger applied research capacities include a drive towards better portfolio building and co-operation around demand-driven structures such as industrial clusters or networks. An alternative or complementary approach might be to grant the UAS enough autonomy to enable them to develop an independent profile *vis-à-vis* their clients – even beyond the region in which they are located – and to compete with established universities in certain areas. Transfer routes between UAS and universities still seem complex, but large-scale reform is under way. All in all, the UAS sector seems to be a very successful innovation in the Swiss system, as regards both teaching and applied R&D. It proves the ability of the Swiss innovation system to come up with new structural elements if the need is there.

5.5 Funding the science sector

5.5.1 Introductory remarks

The university sector receives significant funding as well as incentives to act in specific ways. On the one hand, block funding is linked to certain indicators (OECD, 2003*b*, p. 103). On the other, a large share of the funds goes to quality-assessed projects, including most CTI and nearly all SNF funding. While CTI's ultimate goal is to boost economic growth, scientific excellence is the SNF's exclusive or main criterion. It should be mentioned that CTI instruments provide funding for 800-1 000 research posts in public research organisations. A number of smaller, private non-profit foundations fill niches in the overall portfolio, while ETH Zurich, for example, also supplies competitive grants from internal funds. EU funding or COST allows for the setting up and financing of transnational scientific projects.

5.5.2 The SNF

The single most important funding institution is the SNF, created in 1952 as a foundation by the Swiss Scientific Academies following an initiative of Bern university professor Alexander von Muralt. It is an institution with strong self-governance and a very good track record, as an international evaluation recently confirmed. As already mentioned above, SNF has a broad variety of instruments at its disposal, the three main ones being bottom-up projects (65-75%, varying), competence centres (10-15%, varying) and personnel grants (10-15%, varying). With an annual budget of about CHF 400 million, SNF's position is strong and it is well-endowed[30] by international standards. Nevertheless, slow budget growth, a fast rise in applications and the large number of excellent Swiss researchers led to a downturn in acceptance rates and to a relatively small average size of project grants. However, as will be seen, future prospects appear brighter (see also SWTR, 2002*b*).

The importance of an institution like SNF lies in the strict link between quality and funding. According to SNF, the evaluators and the Swiss government, this is achieved best via bottom-up, individual project funding. The ERT Message 2004-2007 states: "The Federal Government shares the view that free and project-oriented scientific research in all fields should be the main benefactor of rising SNF budgets after years of stagnation" (Schweizerischer Bundesrat, 2002, p. 2419, own translation). Accordingly, annual budget increases of 10% are to be provided, with special attention to the humanities at universities and the UAS, clinical research, interdisciplinary research, promotion of women and international co-operation. This implies a certain balance between bottom-up principles and more top-down signals. Apart from project funding, ongoing or future priorities involve human resource development, namely the establishment of graduate schools, funding of post-docs abroad and SNF chairs. Problem-oriented research is based on national research programmes (NRP) and national priority programmes (NCCRs, also known as *Nationale Forschungsschwerpunkte* – NFS), with groups of scientists interacting around an important topic. NCCRs are scientific research networks – run on behalf of the Swiss government – that are to a certain extent open to industry collaboration (at industry's own cost)

30. An international comparison (EU Commission and FWF, 2004) shows Switzerland holding a medium position regarding "share of competitive science funding per inhabitant". There are huge differences across countries. Sweden has six times more competitive project funding per inhabitant (*i.e.* not per researcher) than Austria; Switzerland and Denmark are on the middle ground, and Germany (DFG grants only) is behind Switzerland.

and have a transfer component. An NFP has a socially important mission. In 2002, the SNF awarded a total of CHF 368.5 million for promotion of research and fostering of young scientists, 18.7% of which was devoted to national programmes (NRP: 2 %, NCCR: 15.6%; Swiss Priority Programmes: 1.1%). As NCCRs structure the research landscape in Switzerland they play an important role by improving co-operation and thus avoiding duplication. Further, they promote scientific excellence not only at the national but also at the international level (Edler and Rigby, 2004). NCCRs are discussed again in Chapter 6, when dealing with competence centres in an international context. For most of these instruments growth has been promised, but has been partly withheld owing to overall budget constraints (see Schweizerischer Bundesrat, 2002, pp. 2418ff; Lepori, 2005*a*, 2005*b*).

SNF is not only a well-designed institution with adequate instruments; it is also well-endowed. More money should be available, but there is a growth scenario: the ERT Message 2004-2007 envisages budget increases of nearly 50% as compared to 2000-03. However, budget cuts are already taking effect.

Are there missing elements? The SNF/CTI evaluation (SWTR, 2002*b*), the *Neun Punkte Programm* (SWTR, 2002*a*) and other sources (Schatz, 2003*a*) call for larger and longer-term grants for truly outstanding researchers. This means not just larger average project grants, but a few big chunks of money with a double goal: to give generously to the best and to achieve wide media coverage and public attention, thus raising awareness of science. The Netherlands, Germany and Austria use this instrument very successfully (see Box 5.1).

Another issue worth considering is the use of Swiss scientists as peers. SNF uses a mix of foreign and local peers. Even taking into account the large number of excellent researchers in Switzerland, the incidence of "Swiss reviewing Swiss" may not be entirely satisfactory. Even the most advanced small countries have only a limited number of excellent people in any field. This issue may become more pressing if SNF raises the amount of funds per grant. The Austrian Science Fund (FWF), for example, relies entirely on international reviewers.

Box 5.1. Selected scientific awards

Three national awards provide incentives and support for outstanding individual scientists. The award of a large sum provides excellent scientists with an opportunity to further develop their research agenda and their team.

The German Leibniz Prize

The *Gottfried Wilhelm Leibniz Prize* is Germany's highest scientific award. Since 1985 it has been awarded annually by the German Research Foundation (DFG) to scientists of any discipline performing research in Germany. The prize aims at improving the working conditions of outstanding scientists, at widening their research opportunities and at lowering their administrative burden. The prize is EUR 1.55 million for experimental, instrumentation-based fields and EUR 770 000 for scientists working in more theoretical areas. The money is granted on a project basis for up to five years. In particular, the money is spent to promote young up-and-coming scientists with a specific research project and to intensify international collaboration. Thus, the prize is conceptualised as an advance payment for future performance and output. The prize may be divided among several outstanding scientists. Candidates cannot apply for the award themselves but have to be nominated by others, *e.g.* by heads of higher education institutions. A special jury recommends candidates who are expected to realise high scientific potential in the near future to the general research support grants committee (*Bewilligungsausschuss für die Allgemeine Forschungsförderung*), which makes the final decision. By 2005, 228 Leibniz Prizes had been awarded, including 49 for the humanities, 64 for the biological sciences, 81 for (natural) science and 34 for engineering. The awards are coupled with a large ceremony and strong public relations activities, making them a major communication instrument for the excellence of German research and the role of science in society.

The Austrian Wittgenstein Prize and the START Programme

The *Wittgenstein Prize* is the highest Austrian science prize and was first announced by the Austrian Science Fund (FWF) in 1996. It is awarded to outstanding scientists who have produced scientific results of importance for the Austrian research system. It includes an amount of up to EUR 1.5 million and is awarded once a year. Normally the award goes to one or two scientists, each getting the full amount. The money is granted for a period of five years and is intended to improve the research opportunities of the winning scientist(s) and his or her research team. The prize is open to any scientific field without any quota. Potential candidates have to be nominated and are subsequently subject to an international peer review. Decisions are taken by an international jury on the basis of at least six reviews. The prize is awarded by the Austrian Minister for Education, Science and Culture. According to the president of the FWF, the Wittgenstein Prize aims not only to foster outstanding scientific research but also to give science a personal face in order to increase public interest in scientific research. In particular, the winners are expected to train and promote young scientists. Another programme worthy of mention is the *START Programme* aimed at outstanding young researchers of any discipline aged 35 or under at the time of application. Researchers have the opportunity to plan their research and to build their own research groups. The prize amounts to up to EUR 200 000 a year and is awarded for six years with an interim review after three years. The prize is publicly announced once a year. Candidates who are not yet full professors can apply and applications are first checked by the local committee of the FWF and the Wittgenstein/START jury and are then subject to an international peer review. Final decisions are taken by the jury on the basis of four reviews. On average about five researchers annually receive the START Prize.

Box 5.1. Selected scientific awards *(continued)*

The Dutch Spinoza Prize

The *Spinoza Prize*, established in 1995 and awarded by the Netherlands Organisation for Scientific Research (NWO) is the Netherlands' most prestigious science award. It is conceived as a personal award for outstanding researchers of international reputation. A maximum of four prizes is awarded annually. The winners receive EUR 1.5 million to use for their research for a period of five years. However, the recipient has to provide a financial plan including costs of staff, materials, travel costs, etc. Candidates for the Spinoza Prize are nominated by the principals of universities, the chairs of the departments of Literature and Physics of the Royal Netherlands Academy of Arts and Sciences (KNAW), the chair of the Netherlands Society of Technological Sciences and Engineering, the Dutch National Network of Female Professors, the chair of the Social Sciences Council and the chairs of the NWO research councils. Each of these may nominate no more than two candidates. The nomination procedure is strictly confidential and even the nominated candidates are not to be informed. Based on the advice of the Spinoza selection committee, the Governing Board of the NWO takes the final decision on the recipients of the four prizes. Criteria for selection are not only the place of tenured position, the age and the performance of the nominated scientists, but also whether he or she is an inspiring mentor able to attract young researchers, including from abroad. The prize offers great opportunities and benefits for the candidate's research activities.

Sources: *www.dfg.de; www.fwf.ac.at; www.nwo.nl*

The good practice programmes of SNF include the Junior Professors scheme (*SNF Förderungsprofessuren*). Since 2000, the agency has funded outstanding young senior post-docs at Swiss universities to enable them to carry out their research more independently. Young scientists can build up their own first team outside of the strict hierarchies, with a status equivalent to an assistant professor, while still being part of a department. Up to now the programme has brought more than 200 researchers to Swiss universities, following a rigorous, two-stage and highly selective competitive tender, often with a success rate of only 10%. Most applicants come from universities other than the host institution; they are often Swiss researchers seeking an opportunity to return from abroad. The programme is open to all disciplines and tries to raise the number of positions for women. The SNF grant includes the salary, a bench fee and money to employ some junior researchers. The junior professor becomes an employee of the host university but does not receive substantial university funds. Research and publication are the main focus of their work. The advantage of this programme lies in: *i)* the career opportunity it provides young people; *ii)* the inflow of outstanding young people who do not have to "serve a master"; and *iii)* the contribution it makes to turning the Swiss university system towards a more tenure-track path. Some disadvantages (and opportunities for improvement) involve: *i)* potential career dead ends owing to the four-year limit on contracts or failure to integrate; *ii)* potential integration difficulties into teaching and curricula; *iii)* potential overload of the recipients, who act as professors but lack much support and are often under pressure to write a "habilitation" (though this is not a formal requirement). It seems that owing to the strict selection process, most junior professors chosen (by SNF) have a good chance to get a full professorship (from the universities) after the four-year term (Jurt, 2004). The challenge for the future lies in better linking funding programmes, career reform towards tenure track and general university reform.

To summarise, SNF plays an important role within the Swiss innovation system. Further strengthening this institution, *i.e.* providing it with more money for funding, is a good strategy for three reasons:

- SNF sends the right quality signals to the science system, and bottom-up projects play a key role in this respect.
- As Chapter 6 will argue, SNF-CTI co-operation could be stronger in the future with respect to research with a mid-term commercialisation perspective.
- The impact of some SNF funding initiatives on university structures is delicate but important, as programmes such as NCCRs or Junior Professors show.

5.5.3 A multitude of other actors

Although this review does not aim to provide comprehensive coverage of all actors in the area, it is worth recalling that the rich tradition and great achievements of Swiss science have also been shaped by a number of other important actors, including:

- The innovation promotion agency CTI. CTI is the most important source of funding with respect to the creation and maintenance of research capacity in Switzerland's UAS. CTI also funds a significant part of the application-oriented research conducted at the federal institutes of technology. In addition, it contributes to the formation of the new generation of researchers by funding about 1 000 doctoral students and junior academic staff at Swiss universities each year.
- The Confederation of the Swiss Academies of Sciences.
- Private non-profit foundations like the Hasler or Gebert foundations, visible contributors but not the equivalent of institutions such as Volkswagen Stiftung or The Wellcome Trust.
- Private universities such as IMD in Lausanne.

- A certain number of research centres, sponsored either by industry or by government, ranging from the four important ETH sector research institutes to privately sponsored institutions like the Fredrich Miescher Institute or the Basel Institute for Immunology. Other notable institutions with strong publication records include hospitals, IBM Rüschlikon (also private), the Swiss Risk Research Institute or the Cancer Research Institute ISREC. Large enterprises such as Novartis, Roche and Nestlé contribute strongly to scientific publishing.
- Avenir Suisse operates as a foundation and independent think tank. It was created in 1999 by 14 large Swiss firms. It deals with the socio-economic development of Switzerland, concentrating on a number of issues including education, research and innovation. Quality of schools, the Bologna Process and international competition in higher education as well as technology transfer issues are its main topics.
- Other project funding for scientific research comes from departments and cantons through commissioned research (*Auftragsforschung*).

All these institutions have important primary or complementary functions either in funding or performing or promoting high-quality research.

5.6 Internationalisation issues

5.6.1 CERN

Switzerland – together with France – hosts one of the largest and best-known scientific research facilities in the world. When scientists want to learn more about the secrets of the universe, they come to CERN. Occasionally they come up with very practical inventions such as Tim Berners-Lee’s World Wide Web. Thousands of foreign researchers work and live in the area or visit CERN from abroad. CERN is the seventh largest producer of scientific publications in Switzerland (Lepori, 2003). This fact and the underlying potential do not seem to be adequately reflected in some presentations of the Swiss innovation system. This may largely be a reflection of the immense richness of Switzerland’s research landscape but it may be also due to a strong concentration on current challenges (such as university reform).

5.6.2 International funding of research

Since 1987 Switzerland has participated in the Framework Programmes of the European Union on a project basis, and since 2004 it has unlimited access and has moved from a project-to-project to a lump-sum finance model comparable to that of EU member states. Its record in participating in these large international programmes has been very successful. In FP5, Switzerland was involved in about 1 600 projects, for CHF 481 million in funding. Scientific institutions were able to acquire most of the returns; participation and funds are concentrated in a few institutions. The ETH sector accounted for 32% of Swiss participation in FP5 and for 34% of the funds, and the university sector accounted for 24% of participation and 26% of funds. However, the concentrated distribution of EU funds to the ETH sector has diminished slightly from FP3 to FP6. As regards thematic orientation, Swiss researchers are strongly represented in the fields of life sciences and ICT. The Swiss institutions that were most successful in raising money from the LIFE programme of FP5 were the University of Zurich, the University of Lausanne and the ETH Zurich. For the IST programme, the EPFL, the ETHZ and the University of Geneva are in a leading position (BFS, 2004; Bieri *et al.*, 2005). Policy documents by SBF and SWTR show a positive attitude towards future involvement in European Research Policy and the European Research Area, in particular as regards the new European Research Council (ERC), whose aim is funding high-end scientific projects. The Swiss science system will certainly perform well in the context of this new and prestigious funding instrument which is expected to become the European equivalent of the US National Science Foundation.

Participation in the science-driven COST initiative fosters internationalisation of scientific research. The institutional distribution of a total of CHF 12 million to COST in 2005 again shows that the ETH sector benefited the most, accounting for 38% (CHF 4.69 million) of the funds, while the universities gained about 31% (CHF 3.69 million) (SBF, 2006). Besides the Framework Programmes and COST, a multitude of other participations and funding streams exist, *e.g.* in the context of ESA. While ESA generates a two-way flow of far more than CHF 100 million a year, the main beneficiary is not the academic but the private sector, namely Contraves (Lepori, 2005, p. 30).

Another aspect of international funding of Swiss scientific research is funding by private sources from abroad. However, it has been difficult to obtain hard data on the attractiveness of the Swiss ETHs and universities as contract research partners for foreign firms. According to a flow chart of R&D funding provided by the *Bundesamt für Statistik* (BFS, 2006), foreign investment into the overall Swiss R&D system equals CHF 685 million, all of it going to private sector R&D.

Chapter 6

THE BUSINESS SECTOR IN A NATIONAL INNOVATION SYSTEMS PERSPECTIVE

6.1 Introduction

This chapter concentrates on the source of income and wealth creation – the business enterprise sector. It focuses on business firms, in particular on their innovative behaviour and their ability to grow and improve their competitive performance by introducing new products, processes and services.

This review primarily addresses the role of policy in matters relating to innovation. What can Swiss innovation policy do to support private sector innovation, ultimately with a view to growth performance? What instruments are available and how do they fit into the overall economic framework? Do they constitute the best options available to help innovative firms succeed? Are the public support mechanisms complete, systems-oriented and portfolio-oriented, and are they successful?

This chapter first covers three relevant features of the Swiss industrial landscape: the innovative behaviour of large and small firms, new technology-based firms (NTBFs) and their support structures, and industrial clusters. It then looks at existing forms of public support for private innovation, including CTI and university transfer mechanisms. Both of these traditionally address public actors in Switzerland, namely universities, but their main mission is to spur innovation by firms that are sufficiently skilled to formulate advanced needs. Some suggestions will be made about filling possible gaps and a number of examples of foreign good practice illustrate potential approaches. It turns next some important service industries and their potential for contributing to innovative activity in the Swiss economy. A final section focuses on international issues such as outward investment by foreign firms.

Swiss business enterprises are very innovative in many respects. Still, they have not achieved their overall growth potential in the last 15 years and a shift to an accelerated growth path will require a pick-up in productivity. Innovation will be a key factor in improving economic performance. Experience in OECD countries shows that well-designed innovation policies, using an adequate mix of policy instruments, can contribute by spurring private sector innovation.

Switzerland's innovation policy tries to help spur industrial innovation, but – in terms of public support for R&D – nearly exclusively through what in this review is called "supply-side" instruments. These include sophisticated forms of subsidy to universities and UAS in order to help firms. Scientists define projects with industry participation, while the concept of valorisation of knowledge leads to the creation of transfer centres and networks of transfer institutions. This approach is well-founded and should, in general, be maintained, although it seems to have limits. On the other hand, there is no public support for mobilising demand for R&D and related services, specifically in small firms. One notable exception regards new technology-based firms (NTBFs), for which Swiss innovation policy applies a mix of supply- and demand-side instruments. While the United Kingdom, for example, generally takes a cautious approach to policy intervention, a recent report dealing with business-university co-operation states that the "main challenge for UK is not about how to increase the supply of commercial ideas from the universities into business. Instead, the question is how to raise the overall level of demand by business for research from all sources." (Lambert, 2003, p. 3) This may also constitute good advice for Switzerland.

6.2 Some properties of the system

6.2.1 Framework conditions

Many of the framework conditions for innovation are good. Switzerland generally provides supportive framework conditions for research and innovation, with a reliable legal framework, including for intellectual property rights, generally favourable taxation, a highly developed financial system, a well-educated labour force, etc. The international openness of labour markets *vis-à-vis* the European Union facilitates the recruitment of personnel, including human resources for science and technology (HRST).

Nevertheless, there is considerable room for improvement, in particular in sectors where small companies active on a regional or national scale but without graduates at management level predominate, *e.g.* in much of the construction sector (OECD, 2006*a*). A lack of competition in sheltered parts of the economy is one of the major causes for sluggish productivity growth. Increasing competition through reform is therefore a major policy option for boosting productivity. Fiercer competition can also be expected to have a positive impact on economic performance by stimulating innovation.

Entrepreneurship is another area for potential improvement. Barriers to entrepreneurship include difficulties in financing new and innovative businesses, regulatory burden and opacity, and a punitive bankruptcy law. Double taxation of dividends makes equity financing expensive compared to internal funds and bank loans. The supply of venture capital is small and tends to be used by older firms for low-risk projects rather than by younger and innovative firms. Together, the bankruptcy law and the high cost of equity financing slow the growth of small and new firms.

6.2.2 Innovation dynamics of large and small firms

The overall innovation performance of Swiss firms can be qualified as good and, in many instances, excellent by international standards. A number of multinational enterprises (MNE) are of Swiss origin or have their head-quarters in Switzerland, some of them operating in areas of high technology and successful in an environment where sustained innovation is indispensable for success. Furthermore, there are a number of sectors of traditional Swiss strength, such as machine construction, with firms of various sizes. The SME sector is an important pillar of the Swiss economy; nearly 90% of all firms employ fewer than ten people, and only 0.3 % of firms have more than 250 employees.

As regards private sector R&D, Switzerland's historically excellent position slowly eroded relative to other countries in the 1990s. While it led the world in 1989 for business enterprise R&D as a share of GDP (ahead of Germany and Japan, the only other OECD countries at the time with business R&D intensity of over 2%), in 2000 it had fallen to fifth position after Sweden, Finland, Japan and the United States. Since then, the growth of business enterprise R&D has picked up but Switzerland has not regained the first position.

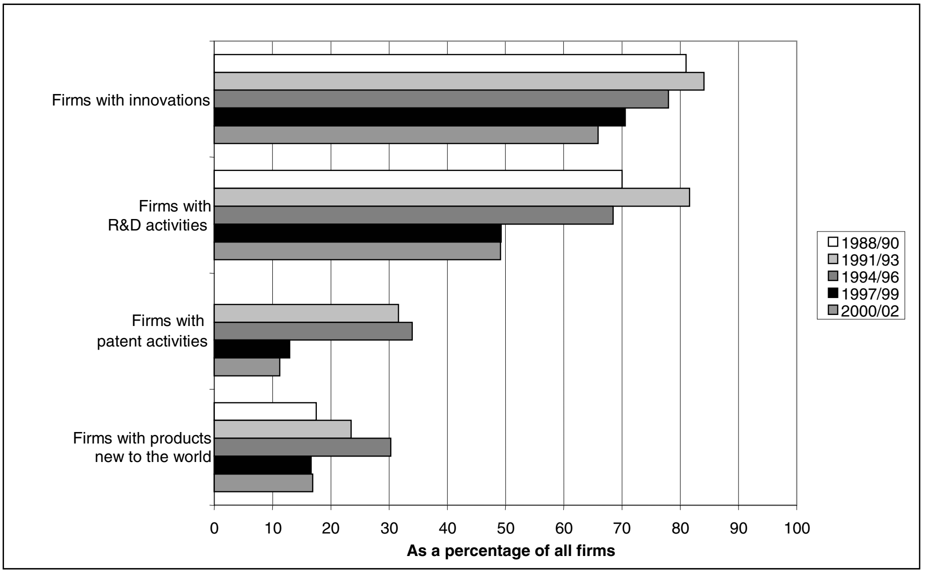
Over the years, R&D spending by Swiss companies abroad has grown much faster than investment at home. In 1989, about CHF 6 billion was spent within Switzerland and about 5.5 billion abroad. By 2000 the situation had reversed: while industry R&D spending at home was about CHF 8 billion, spending abroad was CHF 9 billion (EVD, 2003). The strongest motives for going abroad include proximity to markets and leading universities/research institutes, better access to qualified staff and stronger direct and indirect R&D funding (EVD, 2003, p. 30). The last of the motives may to some extent reflect a lack of public support to industry in Switzerland. Outward investment is driven by 12% of the innovating Swiss firms in sectors with high R&D intensities (Arvanitis *et al*., 2004, p. 44).

The Swiss Innovation Survey (Arvanitis *et al.*, 2004) provides an overview of the innovative capacity of Swiss firms. The survey is based on a representative sample of more than 2 500 responding firms in the manufacturing and services sectors. The most recent survey is the fifth of its kind since the late 1980s, and therefore allows for analyses of input, output and market-related data over time. According to this source, the share of innovating firms in industry exceeds 65%, with most industries' share between 60% and 70%. Overall, new products are more frequent than new processes. In the services sector (including construction) about half of respondents claim to innovate, but there is greater variation across industries: while information technology/research-oriented services and industry-related services come close to the manufacturing average, most other service industries report less innovation. In manufacturing, the textile and automotive industries both report strong process and product innovation, while in electronics, machinery or chemistry innovation is more product-driven.

For the period 2000-02, more than 34% of all responding firms reported R&D expenditures (49% of all manufacturing enterprises and 24% of services sector firms). The strongest industries in these terms are chemicals (including pharmaceuticals), textiles, machinery, electrical engineering, electronics, the watch and the automotive industries. There is high R&D investment (in the range of 5-7% of turnover) in electronics, the watch industry, automotive and energy, followed by chemicals/pharmaceuticals, machinery and electrical engineering with about 3% each. There is a similar sectoral pattern for patenting. The few industries that show a substantial share of firms with a portfolio of more than five patents include the watch industry, electronics, metals and chemistry/pharmaceuticals as top performers. Innovation behaviour across all industries is correlated to size As regards R&D expenditure, firms with fewer than 50 employees invest markedly less and firms with more than 1 000 employees markedly more, while the size classes in between are close to average.

Switzerland's innovation performance has deteriorated sharply over time. As Figure 6.1 shows, all indicators show a downward tendency with stabilisation setting in only lately. Patenting and R&D activities suffered severe declines. This goes hand in hand with a reported concentration on core activities and more short-term innovation projects in many industries. For the service industries the picture is less clear, partly owing to a lack of data. The reduction in industrial innovation is a matter of particular concern (Arvanitis *et al.*, 2004, p. 64).

Figure 6.1. Innovation activities in industry, 1988/90-2000/02



Source: Arvanitis *et al*. (2004).

In a comparison based on the Community Innovation Survey (involving the performance of member countries and the EU average) Switzerland still ranks at the top: it takes first place in Europe for the number of innovating firms, second for innovation expenditures, fifth for number of innovators basing their new products and processes on R&D. As regards R&D input of firms Switzerland ranks second (after Sweden). In terms of size and innovation, small, medium and large firms have an outstanding position in the international arena. Medium-sized firms appear particularly strong. (For overall comparisons, including of individual sectors, see Arvanitis *et al.,* 2004, p. 95 *ff*). However, as mentioned, the evolution of indicators over time has been less favourable.

6.2.3 New technology-based firms, risk capital and venture funding

There is a range of evidence of dynamism among NTBFs:

- In the last six years, the ETH sector has spun off about 140 firms. This is a considerable achievement (ETH-Rat, 2005).

- CTI's start-up initiative (CTI Start-up) lists 100 successful firms founded in the last ten years which already employ more than 25 people.[31] Together, these 100 firms account for more than 8 000 new high-technology jobs, of which 45% are in ICT, 39% in services and 10% in biotechnology.
- In the Zurich area alone there are about 100 biotechnology start-ups, indicating very active development in this area.
- ETH Zurich lists 55 spin-off companies younger than five years, and the University of Basle a total of 16 since 1999.
- For 2002, Swiss universities report 55 spin-offs, 30 of them on the basis of a licence agreement.[32]
- Basel's two large pharmaceutical companies play a strong role in spinning out but also in spinning in, *i.e.* acquiring promising biotechnology companies, both globally and locally.
- While the role of the cantons is not easy to assess owing to a lack of formal cantonal innovation policies, there is no doubt that the regional level plays an important role in the success of young firms: a number of technoparks – such as the large one in Zurich with about 200 tenants – house and cluster young firms. Cantons also can provide cheaper building sites and negotiate individual corporate tax rates with (new) firms.
- The question arises as to why no "Rüschlikon Valley" clustering of ICT-related activities has evolved. Answers may include risk adversity, a lack of strong leading firms and lack of a leading role by Telco Swisscom, and weak push from universities in the 1980s and 1990s. Opportunities for NTBFs in ICT are seen in niches such as cryptography, finance or security.

For venture capital (VC), the Swiss market is described as quite small, with the typical continental European "finance gap" between seed money and large-scale investments for NTBFs. This gap – if it really exists in the Swiss case – threatens the growth of high-technology firms and starves them

31. *www.venturelab.ch/dt/top100.asp*.

32. This scattered evidence has to be contrasted with the overall number of entrepreneurs starting a company. In 2003, 11 200 start-ups were reported, mostly very small enterprises in the services sector with a strong but slowly declining role in the informatics sector (BFS, 2005*e*).

on the way to an initial public offering (IPO).[33] However, Swiss (cantonal) banks and industry-financed funds (like the Novartis VC fund) are reported to play an important role. In a European perspective, the country ranks below average (64%) for high-technology venture capital while early-stage VC is clearly above EU average (154%). The Global Entrepreneurship Monitor (GEM) survey describes the Swiss VC market as modest, with growing problems and fewer private actors in the early stage (Volery *et al.*, 2004, p. 25).

Public support for entrepreneurship is provided through CTI's start-up funding programme plus a mobilisation initiative called Venturelab. More than 1 000 students a year take part in entrepreneurship workshops and about 60-80 start-up firms enter the CTI coaching programmes. The CTI Start-up label is seen as a trigger for VC: 21 young companies so labelled were able to obtain CHF 90 million in VC in 2004 (KTI, 2005). The agency launched its start-up programme in 1996 and has since labelled more than 100 firms out of 1 000 evaluations, of which 40% from the life sciences and another 40% from ICT. An evaluation in 2003 stated that this initiative is recognised by VC funds and other investors. It was recommended that CTI should broaden the programme and sponsor comprehensive management teams to support the foundation of high-technology firms, complemented by teaching and awareness activities. CTI Venturelab and the relatively new Start-up and Entrepreneurship programmes were the result of this evaluation. The new Discovery Projects, with up to 100% CTI funding for scientists' risky ideas, also belongs to this category. A growing number of private actors such as the De Vigier Foundation are also actively supporting young high-technology firms.

Entrepreneurship as an attitude within society is compared internationally on the basis of a number of indicators (Volery *et al.*, 2004) relating to identification, evaluation and commercialisation of new ideas, the common form of realisation being a start-up company. In the Global Entrepreneurship Monitor (GEM), Switzerland has an average position.

6.2.4 Clustering, networking and regional initiatives

Swiss policy on clustering seems at first glance rather hesitant, in contrast to neighbouring Austria, for example. However, there are a number of traditional industry-driven activities, as well as various policy initiatives

33. This "continental European" phenomenon seems to go hand in hand with the aspiration of many entrepreneurs not to become another Bill Gates, but to run their own 10-20 employee enterprise ("lifestyle companies").

based on the so-called new regional policy. The latter attempts to build up larger structures in seven regions by applying a number of policy instruments and approaches, including clustering (for a critical view, see Wüthrich, 2003). At the cantonal level, some kinds of integrated policies have been put in place around certain important topics. Clusters rely heavily on linkages between similar and complementary firms within a certain geographical area. Framework conditions shaped by public policy and a sound scientific and educational base are crucial. Cantonal industrial support policies are not very pronounced, though some cantons actively attract inward foreign investment. Joint projects or networks tend to fall into an area between cantonal and federal SME and CTI support (see OECD, 2002*b*).

In Switzerland regional strengths in biotechnology, machine construction or finance appear to be promoted through both material and intangible public support (infrastructure provision and common working groups). One study (Berwert *et al.*, 2004) identifies five interrelated clusters, specifically in the central Swiss area: agro-food; service-related industries; metals/machinery and construction; electrical equipment and chemicals/pharmaceuticals; and textiles. SECO presents six technology fields/clusters on its website: biotechnology, medical technologies, ICT, micro- and nanotechnologies, services and environmental technologies. In addition, energy/energy technologies is an active cluster with strong innovation and links to scientific institutions. Examples of regional clustering include design clusters and nanotechnology clustering in the Lake Constance region and a number of Greater Zurich initiatives. Zurich has an explicit policy in fields such as biotechnology (including MedTech and automatisation), finance and the creative industries. Some clusters receive public support in the first years but there seems to be disagreement over whether to abstain from support, to support individual firms on the cantonal level or to promote clusters.

There appear to be advantages to bottom-up approaches based on experience rather than on policy design, and industry-driven rather than government-driven approaches (but with government support where appropriate). The UAS sector can help build strength in (emerging) clusters. Generally, the best idea might be to support clusters for which industry has a record and displays considerable initiative of its own. Box 6.1 shows how a midwestern US state built up a significant industry-led and mostly industry-sponsored life sciences cluster.

Box 6.1. Biocrossroads: biotech clustering in Indiana, United States

Drawing comparisons between US federal S&T policy approaches and those of (smaller) European countries is often difficult and sometimes misleading. This is due to size differences and also to differing policy portfolios. Examples include the important role of public high-technology procurement and the existence of many national laboratories in the United States. For their part, many European countries rely on direct federal funding of private S&T activities via projects and programmes. Public university dominance and block funding are also typical of European innovation systems. While the characteristics of the Swiss system lie somewhere in between, the size factor alone makes it difficult to use the US federal level as a benchmark.

At the level of individual US states there are interesting models of technology policy measures. Indiana, a midwestern state with 6 million inhabitants, has a number of interesting features such as a strong manufacturing base (machinery) and a large and successful health industry. The latter accounts for about 275 000 jobs, mainly in the private sector. This is, in relative terms, the second highest concentration of biopharmaceutical employment in the United States. Notable strengths are biomedicine/biotechnology with Eli Lilly the best-known and largest company. Other headquarters and affiliates include Roche Diagnostics, Guidant, Bayer, Dow AgroSciences and Wellpoint. Indiana also hosts very successful firms in the field of medical technology/implants, including Stryker or Zimmer, the world's largest orthopaedics firm. The university sector with Purdue University, the University of Indiana and Notre Dame University plus the second largest US medical school, is strongly focused on biotechnology. It attracts a considerable amount of federal (National Institutes of Health, National Science Foundation, etc.) and foundation (Lilly Endowment, etc.) money. The universities invest in technology parks and other outreach activities.

Policy makers in Indiana faced a number of challenges a few years ago. Biotechnology trends drew more and more enterprise activities towards the East or West Coast for collaboration, spin-in and human resource activities. The absence of an Indiana venture capital (VC) market made continuous financing of start-up companies impossible. Though Indiana was recognised as a top emerging biotechnology area, public and private actors saw the need to develop stable platforms to strengthen the cluster.

In 2002, BioCrossroads was founded as Indiana's life sciences cluster initiative on the basis of two analytical studies. The interesting feature is the combination of a public mission with mostly private financing. The Central Indiana Corporate Partnership, a group of leading businesspeople and academics, was the driving force, actively supported by state and city representatives. The mission aims at better leveraging of the state's existing life science assets to create new jobs and spur new business opportunities. A large board of leading figures from the public and private sector steers the activities of a small management group.

Activities include: *i)* measures to boost entrepreneurial culture; *ii)* the identification and development of promising new fields (*e.g.* building bridges to the sports business, as Indianapolis houses a number of nationwide sports accreditation bodies and agencies); *iii)* human resource and marketing activities; and *iv)* measures to build up a VC market. In 2003 a number of institutional investors, co-ordinated by Biocrossroads, collected USD 73 million and created the Indiana Future Fund (IFF) to invest in regional and national VC funds and better direct venture capital to specific types of investment, mostly in Indiana. The money comes from public pension funds, corporations, university endowments and foundations. This fund is managed by Crédit Suisse. Universities act as investors and there is an interesting balance between large firms, public actors and private non-profit institutions at the level of cluster policy making. IFF is complemented by the USD 4 million Indiana Seed Fund for regional seed and pre-venture investment managed by BioCrossroads. Another instrument is the publicly financed Indiana 21st Century Fund to foster science-industry co-operation.

Source: www.biocrossroads.com

6.3 Industrial innovation and public policy

6.3.1 Helping SMEs to innovate

For specific issues and framework conditions of importance to a particular class of drivers of innovation in the business sector, SMEs, the picture is more differentiated. The well-being of SMEs is important because they are responsible for most business sector employment and play an important role in the renewal of economies. They are a potential breeding ground for new technologies, new forms of organisation and processes, and at the same time constitute a stable, locally rooted part of the economy.

The *OECD Economic Survey of Switzerland 2006* observes: "Firms are typically much smaller in Switzerland than in most other countries: close to 90% of firms count less than 10 full-time employees and account for 25% of value added. Innovation capability decreases with firm size and anecdotal evidence suggests that very small firms face major difficulties to absorb new technologies, due for example to the lack of a qualified engineer on the payroll. The innovation capabilities of SMEs may also be more sensitive to the business cycle than those of large firms, since they tend to derive a larger share of their profits from the domestic market. Finally, product market regulation remains much more stringent in Switzerland, implying that competition and incentives to innovate are low in sheltered sectors." (OECD, 2006*a*)

The Swiss economy is in a slightly less advantageous position than framework conditions suggest, *e.g.* for the creation of companies (such as IPR protection or the quality of R&D facilities). While the Swiss propensity to set up new companies is among the strongest in European countries, it is still below the world average and has not progressed over the last years. Even more importantly, "[E]stablished companies have a low entrepreneurial orientation, as compared to other European countries. All in all, a low percentage of Swiss jobs are provided by firms having an entrepreneurial spirit, suggesting a low rate in business renewal." (Haour *et al.*, 2006, p. 1) While "entrepreneurship" is a rather soft concept which includes attitudes, the Global Entrepreneurship Monitor provides good international comparisons and an appraisal of the dynamism of different economies. The GEM 2005, like that of 2003, observes that Switzerland's position is weak in the financing and funding especially of young (and often very small) SMEs, in particular owing to a lack of equity and credit-based financing (Volery *et al.*, 2003, 2006). Switzerland seems to be a special case: endowed – by international standards – with an extraordinarily large amount of equity, it channels these riches into new and risky businesses to a very limited extent (Volery *et al.*, 2003, p. 24).

In the Swiss Innovation Survey (SIS) (Arvanitis *et al.*, 2004), "lack of finance" is identified as a significant barrier to innovation. Swiss firms rank constraints related to risk, cost and available financial sources as the most important. Five out of the six top-ranking "strong" and "very strong" barriers are related to this issue (Arvanitis *et al.*, 2004, 77 *ff*): high cost of innovation (rank 1, more than 40%), long payback periods (rank 2, more than 30%), lack of equity (rank 3, also more than 30%), high market risks (rank 5, more than 25%), lack of borrowed capital (rank 6, more than 25%). All lower-ranked factors/barriers are below 20%, many around the 10% threshold, including regulatory, organisational and human resource factors. Unfortunately, international comparisons are rather difficult as the European Innovation Survey and the SIS use partly different questions and scales. Yet the authors of the SIS conclude that Switzerland is one of a group of countries that is most affected by financial barriers, in terms both of equity and borrowed capital (Arvanitis *et al.*, 2004, p. 129). This evidence is in line with the GEM results reported above. All the major barriers found in the SIS mainly affect SMEs, with high cost and lack of financial resources in the lead (Arvanitis *et al.*, 2004, pp. 81 *ff*). Interestingly, less than 10% (rank 19) of Swiss firms perceive a lack of public R&D promotion funds as a strong or very strong barrier. Yet public funding, *e.g.* of SMEs' innovation projects, may help to improve the availability of equity.[34]

Switzerland's decision not to provide direct public support to business R&D is a strong policy tradition (see European Commission, 2005*b*). In a comparison of 11 industrialised countries, only Japan shows a comparably low percentage of government financing to business sector R&D (data for the mid-1990s, see Lepori, 2003). Switzerland is one of the very few OECD countries that rigorously refrain from providing direct financial support to firms for R&D or innovative activities. The Nordic and continental European countries use such instruments, as does the United Kingdom, especially through a number of SME-related programmes. A close look at the United States shows that many of the 50 states engage in industrial innovation promotion activities, and the federal level enters via public procurement activities or long-term contracts through the Defense Advanced Research Projects Agency (DARPA). The US federal innovation system includes science-industry co-operation centres such as the NSF's Engineering Research Centres (ERC), long-term innovation funding such as the Advanced Technology Program (ATP) or SME-specific innovation funding like the Small Business Innovation Research (SBIR) scheme.

34. The lack of equity capital is especially problematic as innovation projects are usually financed from this source (Arvanitis *et al.*, 2004, p. 82).

This review shares Swiss policy makers' concerns about opening a Pandora's box that would lead to a proliferation of public funding schemes. Some OECD countries, such as Austria and the Netherlands, currently need to streamline their innovation policy portfolios (OECD, 2005*b*; Schibany and Jörg, 2005). At the same time, policy should be flexible enough to allow direct funding when it is needed and is likely to be the most efficient way to support R&D and innovation, *e.g.* in SMEs. Results of both the SIS and the GEM suggest at least the need for open discussion and perhaps some experimental policy action.

The Swiss tradition of refraining from directly funding business firms should be respected and, in general, should continue. At the same time, this general rule should not strictly preclude exceptions, when net benefits can be expected to be high and direct funding is more effective, *e.g.* when sustainable changes in firms' behaviour are part of a programme's rationale.

Given the Swiss approach it is recommended to start with a more in-depth *external* view of this issue. Long-held views may be locked in by mutual confirmation among policy makers, enterprise representatives and experts and may block discussion of alternatives. Based on Swiss evidence as well as the experience of other OECD countries, steps to provide optimal support for innovation in Swiss SMEs might include the following:

- Consider a comparative study on the innovation behaviour of small Swiss firms, including those operating in traditional sectors, preferably with participation by foreign researchers. A study giving special attention to problem solving and capability building in SMEs could provide evidence on a number of issues. What is the dynamics of the population of innovative firms? How do such firms upgrade their capabilities and innovative activities? How and by whom are problems and potential solutions in science-industry co-operation projects identified?
- If this study shows a need (it may find that the public support portfolio does not require another kind of intervention), CTI could set up a small pilot programme with a few percent of its budget or some extra funding. Funding for such a programme should be closely linked to problems and demand as defined by firms and should aim exclusively at SMEs to help them, for example, with their first steps towards in-house innovation.
- The funding could take the form of grants (with public funding limited to a maximum of 50%) for smaller SME innovation projects, accompanied by coaching and marketing support. An interesting option could be the "first graduate engineer" or an "innovation assistant" within a firm. Such programmes exist in many European countries and regions (Leitner and Ohler, 2000). Another example is the United Kingdom's SMART programme (and its follow-up, the Grant for Research and Development Programme) (Bodenhöfer *et al.*, 2004, pp. 98 *ff*). However, it is strongly

recommended that, if implemented, there should be a single, not too large programme.

The French OSEO/ANVAR programme illustrates important features of SME support (Box 6.2).

Box 6.2. OSEO/ANVAR: supporting SME innovation in France

French innovation policy is best known internationally for big schemes, grand schools and technology procurement initiatives. Nevertheless, in France SMEs are the backbone of the economy. The French government supports the innovative activities of these firms with well-established, regionally based instruments.

ANVAR (*Agence National de Valorisation de la Recherche*) was founded as an innovation promotion agency by the French government in 1979. Since 2005 it is part of the OSEO group, together with the SME development bank BDPME, its affiliate Sofaris and the SME agency ADPME. Under the joint authority of the ministries for industry, small business and research, OSEO serves as a one-stop shop for fostering innovation. "On the occasion of the renewal of its contractual arrangement with the State for the period 2004-07, ANVAR's role has been formally consolidated as main organiser and co-ordinator of innovation support measures at the regional level." (European Commission, 2005) While the other branches of OSEO provide guarantees and comparable instruments, ANVAR combines advice and soft loans for SMEs (in the French context, firms with fewer than 2 000 employees). There is a special focus on young and newly founded firms and research organisations can also be supported. Its mission is to tackle the technical, commercial, financial and human challenges of innovation, based on the evidence that smaller firms have difficulty financing risky projects at different stages of the innovation process. The agency can also finance feasibility studies and has included the services sector as a target group of special importance. The overall ANVAR budget in 2004 was EUR 160 million.

Three issues are of key importance: regionalisation, consulting and soft loans. "Regionalisation" means that all fieldwork and funding have been decentralised. All applications are fully managed by the 24 regional delegations. "Consulting" means that the regional *chargés d'affaires* provide advice, networking, partner search, other funding options and information. Training and help in technology transfer issues complement the portfolio. These delegations therefore need experienced employees, which is not always the case. "Soft loans" means that funding consists of a credit to be paid back if the project succeeds, otherwise it becomes a subsidy. An agreement with the assisted company defines the criteria of success and eventual payback. ANVAR uses 85% of its budgets for interest-free loans to SMEs and laboratories; these cover up to 50% of the expenditure relating to the innovation or transfer project.

Other instruments include subsidies for preparing start-up businesses, together with the research ministry, subsidies for students working on innovative projects with companies, and subsidies for recruiting R&D engineers in SMEs. With CORTECHS, France also has a second instrument for supporting the recruitment of technicians on innovative projects.

An evaluation based on a questionnaire covering successful and rejected applicants indicated that ANVAR's instruments are efficient and effective. Young and small companies reported a very high net impact. Overall, 20% of respondents reported that they would not have started the project at all, and 50% would have done the work at reduced scale or at a later stage (De Laat *et al*. 2001, p. 29). Non-financial support was rated especially high by small and young firms. The evaluation generally recommends that ANVAR focus even more on very small and new firms. Moreover it suggests that the expert "militia" team should change from time to time and should include foreign expertise.

Sources: European Commission (2005); De Laat *et al.* (2001); Warta and Rammer (2002); *www.oseo.fr.*

6.3.2 The case of CTI

The CTI dates back to 1943, when it was founded as a commission for the promotion of scientific research with a macroeconomic rationale. CTI is a federal commission, part of EVD's BBT, and acts as the main federal innovation funding agency. Its central mission includes two terms: "Science to Market" and "Valorisation of Knowledge", which point both to the ultimate economic goal and the Swiss "supply-side" policy principle. CTI builds its interventions on the premise that Swiss science is excellent but that there are bottlenecks for the application of scientific results. Its 2002 self-evaluation sees the agency's focus as support to firms for the use and transformation of new technologies and new knowledge into new products and processes.

CTI's four sections assemble some 50 additional experts who – together with others – also act as evaluators. Though professional, full-time staff manages the organisation's daily business, the "militia" element appears to be strong, especially in evaluating proposals and coaching of research teams. Experts come from both science and industry, raising the issue of expertise versus potential proximity to projects. Foreign evaluators seem to be the exception rather than the rule, as pointed out in previous evaluations of CTI programmes (Sturn *et al*., 2005).

CTI has a slowly growing annual budget of around CHF 100 million in the multi-annual federal budget already described.[35] This sum represents about 3% of the overall public R&D budget. Funding of "applied" projects concentrates on a mix of bottom-up and top-down principles; the recipients are higher education and research institutions, with industrial partners contributing as a rule at least 50% of the costs. Typically, a firm articulates an R&D problem or an academic has an idea about problems innovating firms might have. The academic then writes a proposal which is reviewed by experts and co-funded by CTI and the industrial partner. CTI provides financial support for industry-commissioned R&D performed by academia.[36] The UAS and the ETH sector receive most of the funding. *De facto* the main

35. The last *ERT Message* foresees CHF 580 million for the four year period 2004-07, but a number of budget cuts reflect the difficulties the Swiss government faces for maintaining an expansionary perspective even in areas that contribute to future growth such as higher education and innovation.

36. In the Austrian FIT-IT programme which funds embedded systems and similar enhanced IT projects, one funding line is very similar. Evaluators found that it was mostly university professors who "found" the problem, created the idea, wrote the proposal, etc. (Zinöcker *et al*., 2005).

industrial target group is SMEs. CTI calls this overall approach the "subsidiarity principle" (see also SWTR, 2002*b*). The agency also depends on the principle of "technology transfer via brains". The underlying bottom-up principle is strong, while the top-down elements are moderate, such as the setting of a number of priority areas which provide a structure for project appraisal and soft prioritisation. They do not imply strictly defined programmes.[37] The thematic areas make up a balanced portfolio (KTI, 2005):

- Life sciences in general with strong expectations regarding small high-technology firms. Apart from funding projects, CTI runs or sponsors a number of outreach, platform and network activities.
- Biotechnology (Swiss Biotech Association, Swiss Biotech Report).
- Medical technologies, as part of life sciences are supported by project funding and information platforms. Science linkages are considered especially important for this sector. A recent evaluation, mentioned above, confirmed the importance of this initiative.
- Micro- and nanotechnologies, funding projects, platforms and competence clusters. One initiative was taken over from the ETH Council, which started funding nanotechnology. As SNF is also engaged in this field, patterns of co-operation exist. Another line (KTI, 2005) encompasses engineering technologies.
- Enabling sciences and engineering, both of which have a strong ICT component; the second aims at small and very small enterprises.

CTI concentrates on technological innovation. For the few measures regarding the humanities and social sciences, see the UAS-targeted DORE programme. DORE is now entirely run by SNF. Evaluations of CTI funding programmes show that funded firms have better innovation performance than firms from a control group of non-funded firms (Arvanitis *et al.*, 2005). Another line of CTI priority setting addresses structural issues. Four main strands can be identified:

37. Given the discussion of cluster-based policy in Switzerland, it is difficult to say whether KTI priority areas in their present form can explicitly serve and be seen as cluster funding programmes.

- Projects at UAS apart from the DO-RE initiative. For a description see Section 5.4 on UAS.
- Funding of start-ups and fostering entrepreneurship in Switzerland. This programme was discussed in connection with of the creation of new technology-based firms.
- A number of international engagements like IMS or EUREKA complement the CTI portfolio. CTI also acts as a Swiss member in CREST and other European S&T policy forums. The agency shows strong involvement in various ERA-Nets. Outside Europe, activities with China are gaining in importance.
- CTI contributes significantly to fostering knowledge and technology transfer between industry and academia by promoting co-operation between the two sectors. CTI WTT (knowledge and technology transfer) was established recently and aims at actively connecting demand and supply. WTT consortia, jointly launched by CTI and SBF, aim to stimulate future demand for knowledge and technology among SMEs.

CTI's experience raises two interesting questions: First, does CTI complement science funding in a way that orients knowledge towards industry? Second, is CTI funding inspired, triggered and driven by industry needs?

The answer to the first question is generally affirmative if: *i)* professors have industry contacts or if firms have achieved a certain ability to formulate technological problems calling for scientific co-operation; *ii)* CTI funding induces "additionality effects" where it should, *i.e.* in the firms (which are not funded directly themselves); *iii)* there is a link between SNF and CTI, with some work done jointly. A potential gap between the two agencies is now being closed; while a typical CTI project is applied and short-term (duration of 12-24 months), a new line called "Discovery Projects" funds more advanced and science-driven projects, again drawn up by scientists and funded up to 100% by CTI. SNF funding continues to be more science-oriented and curiosity-driven.

The second question is harder to answer. Basically CTI funding – with the possible exception of the Start-up programme – follows the "supply-side" approach discussed above. The underlying rationale seems to be partly inspired by a linear model in which science outputs shape innovation. As experience in other countries as well as the literature show, however, innovation often shapes science, with strong interdependencies (Rosenberg, 1982, 1994). Furthermore, firms sometimes need support to move up the innovation ladder, first towards better insight and better ability to formulate what they need from science. For this reason, funding agencies need to know more about firm behaviour, especially of firms that are as yet unable to engage in advanced co-operation projects with top scientists. Put simply, what CTI does is good and necessary. At the same time there should be a discussion about whether CTI covers all important lines of action. One programme for direct SME support[38] is described in Section 6.3.1.

Such a programme would require only a small part of the extra money proposed by the SNF-CTI evaluation or the money foreseen in the ERT Message 2004-2007, which would provide a budget 50% higher than in 2000-03. For standard projects, more funding should be made available to allow for larger projects where required. These projects could be partly linked to Swiss or regional cluster development.

Another requirement for CTI is related to the principle of distributed intelligence. A strong strategic unit would help in analysis, implementation of an international good practice approach, and programme formulation. It would not shift policy competencies from the department level or distort the system but would add to the overall capacity of the Swiss innovation system. This recommendation is not specific to CTI but is relevant for most science and innovation funding agencies.[39]

6.3.3 Relying on "supply side" technology transfer instruments

Technology transfer and the valorisation of science-sector know-how are important priorities for the Swiss innovation system. Universities and research centres are encouraged by a number of support instruments to: *i)* formulate an explicit IPR policy; *ii)* establish transfer centres and incubators; *iii)* take up entrepreneurship in the curricula; and *iv)* support networks of transfer centres. A large number of transfer offices with scouting, incubating, negotiating and licensing tasks are already established, mainly at universities. These offices are supported by the Swiss Transfer Association (SwiTT), an association of transfer professionals from Swiss universities and the UAS. Various IPR regulations have been created or modified at universities in recent years (see also European Commission, 2005*b*).

38. The suggested introduction of vouchers to allow SMEs to pay for academic research services may not completely resolve the issues that have arisen. The real challenge seems to be to help SMEs resolve their basic in-house innovation issues. The cantons could directly fund firms but do not do so.

39. See also the evaluation of the two major Austrian Funds FWF and FFF (Arnold *et al.*, 2004).

The goal of valorisation can be found in the ETH law, in the CTI and SNF missions and in university reform initiatives. It relies on the idea that talented, industrious and well-funded scientists have been steadily accumulating knowledge and that better mechanisms are needed to bring this knowledge to business enterprises everywhere. It has inspired a multitude of activities encouraged by public policy. Within the science system, including ETHs and research centres, cantonal universities, UAS and research institutes, nearly 40 technology transfer institutions perform various activities. For 2001, the results were as follows: 240 invention disclosures led to 132 patents; 157 non-disclosure agreements and 60 new confidentiality agreements were signed. Higher education institutions negotiated 200 new licences, only a small fraction of them linked to active patents. The overall patent portfolio consisted of about 1 000 patents and 300 non-disclosure agreements. Every second patent led to a licensing contract and every second licence generated income. Revenue figures tend to be poorly reported, but appear to be rather low (Vock, 2003, p. 196). Another source (EVD, 2003) presents other data and talks about "several million Swiss francs" of annual revenue for the entire public sector. A further source reports CHF 15 million of total income for 2002 (Vock *et al*., 2004).

The valorisation of knowledge via patenting and licensing is only one of the activities performed by transfer centres. Others include entrepreneurship education, contracts with industry, university marketing, information about research and above all helping university spin-offs to become successful technology-based start-ups. The SWTR recommends deepening the relationship between SMEs and the higher education sector (SWTR, 2002*a*). Universities such as EPF Lausanne have internal seed funds ("innogrants") with a broad portfolio of support instruments. According to EPF Lausanne, the obstacles to innovation are bad risk management, lack of funding, focus on technology and narrowly "disciplinary" research in academia. It provides money and time in the following ways: "ignition" projects support new ideas for 6-12 months, implementation projects provide "innovation fine tuning" for up to two years, personnel can have a leave of absence to implement their innovations, and there are internal interdisciplinary poles of excellence and various student entrepreneurship programmes.[40]

Policy papers emphasise the economic expectations raised by supply-driven valorisation and report a lack of co-ordination, mainstreaming and common standards in the Swiss transfer landscape (EVD, 2003; Schweizerischer Bundesrat, 2002). The Swiss Network for Innovation (SNI) was set

40. *http://vpiv.epfl.ch/IN-projects-en.htm*

up in 1999 at the federal level to improve the efficiency of higher education institutions in technology transfer and in valorising their knowledge. It had 38 members from universities, ETHs, UAS, several other research institutions and enterprises. However, owing to lack of support from the universities and the UAS, SNI only partly achieved its envisaged goals and was dismantled in 2004. Another attempt at creating an information platform ("technovation") in support of universities' technology transfer centres was eventually cancelled for the same reasons. In 2000-03 the SNI received federal support of about CHF 8 million (Schweizerischer Bundesrat, 2002).[41] The latest attempt by the Swiss government to improve the efficiency of the transfer system was the creation in 2005 of a limited number of transfer consortia. Using targeted measures, the transfer consortia are to reinforce universities' capacity to transfer knowledge and technologies to businesses (push process). Initiatives will also be generated to encourage companies to communicate their need for knowledge and technology more clearly to the universities (pull process) and thereby deliberately and effectively increase collaboration. The universities of Bern and Zurich run Unitectra as a joint technology transfer institution, providing strategies, contracts, IPR services and portfolios, spin-off support and educational services regarding transfer. From 1999 this joint institution has managed more than 1 500 technology transfer agreements and generated total licence income of CHF 50 million for the two universities combined, *i.e.* on average, CHF 5 million a year per university.[42] The SWTR sees the technology transfer issue as central to the development of science and technology in Switzerland. However, it does not recommend new instruments or organisations but improvement and expansion of existing initiatives (SWTR, 2002*a*).

All these activities are in line with international trends. Stronger institutional ownership of IPR, explicit IP policies and building up of portfolios, establishment of transfer institutes and government funding for such initiatives in the higher education sector have become good practice in OECD countries although strategies may differ. "There is no 'one size fits all' approach to technology transfer" (OECD, 2003*c*, p. 13).

While the overall approach can be qualified as positive, two issues deserve attention:

- Switzerland's high expectations with respect to technology transfer may be disappointed in a few years' time. Wherever an innovation system

41. *www.swiss-science.org*

42. *www.unitectra.ch*

bottleneck is identified, “more transfer” seems to be the response. Technology transfer institutions may work very well (see Box 6.3) but they cannot solve all problems. Income from licences generally does not live up to expectations, many firms remain unaware of the merits of academic research, and the pool of potential start-ups is generally not very large in smaller universities.

- The idea of networking transfer activities needs to be reassessed since it could result in a lack of determination and an “entrepreneurship bureaucracy” layer in the longer term. International experience (see Box 6.3) shows that a very high degree of professionalism and concentration on core business are the two key factors of success.

There is a strong case for realism and a balanced policy portfolio, including demand-side measures, *i.e.* instruments that support capacity building within firms.

6.3.4 Science-industry co-operation

Co-operation between Swiss business enterprises and academic institutions – based on the high research intensity of the former and the high quality of the latter – appear strong, and the Swiss Innovation Survey (Arvanitis *et al.*, 2004) shows a degree of interlinkage far above the EU average. On the other hand, mid-1990s Eurostat data reveal that Swedish and Finnish firms place much stronger reliance on co-operation with universities and research centres than their Swiss counterparts (InnoNation Schweiz: EVD, 2003). InnoNation Schweiz states that – given the potential of Swiss firms and universities – co-operation could be stronger. It recommends concentrating on existing avenues, including more funding for SNF and CTI, long-term projects run by CTI, more technology transfer, improved information platforms and, finally, better co-operation within the higher education sector.[43] However, public policy already supports linkages of this kind. As outlined above, practically the entire CTI portfolio consists of programmes to fund scientists if they collaborate on a bilateral basis with firms. Beyond single activities, large-scale public-private partnerships also seem important: The most notable is Systems X, a joint venture between ETH Zurich, the University of Basle, Novartis and Roche to build up a systems biology campus in Basle, with ETH Zurich as the driver. Issues related to proximity to or distance from industry and to a distinct campus or

43. The last includes the idea of transferring ETH/university basic research results to the UAS sector, where applied research is performed. Instead, it may be preferable for UAS to get their inspiration from firms.

integration into industrial compounds have been the subject of extensive discussions.

Box 6.3. YEDA, the IPR arm of Israel's Weizmann Institute

Policy makers and university leaders all over the world try to find out what works best for transferring university research results. On the one hand, a number of good management and human resource issues arise. On the other, there are potential tensions between the scientific mission and open publication principles, the issue of applied research within scientific institutions and the striving for high returns and strict IPR protection which raise difficult questions.

The Weizmann Institute in Rehovot (Israel) is an example of an effective technology transfer policy at a scientific institution. Founded in the 1930s, the institute is a major international scientific player in the fields of mathematics and computer sciences, biology, chemistry, physics and interdisciplinary research. As a research centre and "graduates only" university, the main outputs are PhDs and publications in international journals. "Remind yourselves every morning that we are an institute of basic research. Yes, we like to make money and receive royalties; yes, we know how to raise funds; but we are, first and foremost, an institute of basic research" (Weizmann Institute, 2001, p. 21). About 1 200 researchers and graduate students benefit from a sound financial base. The institute is partly block funded by the State of Israel (about 35%), part of its overall budget of USD 170 million comes from various project-funding sources (about 30%). A third part stems from generous donations and from a considerable endowment. The institute is also a landowner. Finally, a huge stream of royalties from patents feeds the budget and the endowment.

The institute has a very restrictive policy regarding contract research and consultancy by the faculty. To be a Weizmann researcher means to do basic research. At the same time patenting and licensing are important. With YEDA, founded in 1959, the institute has a professional IPR management company with a long-standing record of systematic screening, spin-off activities and building of a patent portfolio. "YEDA is an active IPR commercialisation firm and not a technology transfer office" (CEO YEDA). About 70 patents a year, most of them in life sciences and IT, are taken up and held by YEDA. The management looks for potential industrial users and negotiates all contracts. From modest beginnings, it built an attractive portfolio. About 30 new licensing contracts are concluded each year. Currently, revenues come close to USD 100 million a year. This is probably the highest "rate of return" worldwide relative to the size of the research institution or university concerned. Each year, three contracts bring in more than USD 20 million each. Since this extremely high level of returns cannot be expected to continue forever, parts of the royalties are used to further build up the endowment. The returns are divided as follows: except for the YEDA management fee, about 40% belongs to the individual researchers: "We think it is good if a few Porsches are parked on campus" (former president of the Weizmann Institute). The rest goes to the institute's budget and endowment.

Management of YEDA – a 100% affiliate of the institute – reports directly to the Weizmann top executive level, but is independent in its operative decisions. It is seen as very important to treat all transfer activities as a top-level issue, to have highly skilled professionals working in this area and not to rely on external public networks. "We tell our scientists: Don't do the research for the money. Do it for the Nobel Prize. The rest will follow." (CEO YEDA).

The Weizmann campus is surrounded by a big industrial park, which houses local and international biotechnology and IT companies. The number of spin-offs is large, and about 30 firms have evolved from YEDA patents.

Sources: Stampfer (2004); Weizmann Institute (2001).

A rise in science-industry co-operation, both bilateral and multilateral, can be observed in many OECD countries. A multitude of funding initiatives aim to stimulate and support this type of collaboration (OECD, 2001*b*; OECD, 2002*a*; MAP-TN, 2004; OECD, 2004, p. 87 *ff*). The main rationales for funding programmes like science-industry competence centres include:

- *Spurring interdisciplinarity with a user perspective*. Problem-oriented research should be more determined by industrial or societal needs. In competence centre programmes a number of industrial and academic partners agree on a common topic, goals and research programmes for co-operative centres. This automatically leads to a bottom-up design process and interdisciplinary, user-oriented research agendas. In Switzerland the situation seems instead to be that public support is given to disciplinary, one-to-one co-operation which tends to be defined by academics.

- *Acting against the decline in long-term industrial in-house R&D*. In most countries small and large firms are reducing their R&D portfolios and tend to concentrate on short-term research with a fast track to application. This tendency towards a hollowing out of the industrial knowledge base is compensated by centres for longer-term collaborative research, co-defined by industry. In addition, measures are taken to strengthen inter-firm co-operation. Again – with the notable exception of big ventures such as Systems X – Switzerland relies only on one-to-one instruments. The Swiss Innovation Survey (Arvanitis *et al*., 2004) observes a concentration on core activities and more short-term innovation projects in many industrial sectors. Some support activities with network characteristics are being set up between universities, UAS and, to a lesser degree, business firms.

- *Helping the development of new careers and new management styles*. Demand for PhDs who graduate in an industry-relevant field and already have an idea of relevant problems is increasing, not least owing to the greater complexity of industrial R&D. A second issue involves management of collaborative R&D which is becoming a key qualification for innovation systems. Competence centres can provide both. As Chapters 4 and 5 indicate, the three strands of the "triple helix" could be more strongly linked in Switzerland.

Over the last two decades some 15 countries have introduced "collaborative research centre" or "competence centre" funding programmes with strong university and industry involvement (see Box 6.4). Impact analysis conducted in some countries shows considerable additionality effects, specifically with respect to changing the long-term behaviour of the actors involved (Arnold *et al*., 2004*a*).

Box 6.4. Competence centres for long term science-industry co-operation: the Swedish example

In Swiss S&T policy the term "competence centre" is used for large-scale network-oriented funding of scientific excellence. The National Competence Centre for Research (NCCR, see Section 5.5.2) programme links university researchers and includes firms as observers. This kind of competence centre programme is very different from what the term suggests in common international usage. Since the 1980s a number of countries have established competence centres within their innovation systems, less to explore new scientific frontiers than to strengthen the linkages between science and industry. This is accomplished within large programmes structured and managed as public/private partnerships (P/PP). They are characterised by the creation of temporary centres to run a multi-annual research programme, drawn up and co-funded by one or a few universities or research institutes and a number of firms. A public funding authority provides the structure, a competitive selection procedure and a considerable share of the funding. Most of the programmes do not pre-select fields or topics, but make priority setting a bottom-up process. Whether business firms can be seen as directly benefiting from public subsidies depends on how the programme is organised. Competence centres typically run for seven to ten years, have their own management, include five to 20 long-term industry partners and have an overall annual budget of USD 2-7 million.

The US Engineering Research Centre (ERC) initiative of the National Science Foundation (NSF) was the first to appear, followed by the large Australian Cooperative Research Centre (CRC) programme and the Networks of Centres of Excellence funding scheme in Canada. In Europe, countries such as Austria (K *plus* competence centres), Hungary (KKK programme) and Estonia followed suit. In Germany, competence networks (*e.g.* in nanotechnology) do not have a great deal of funding at their disposal, while in the Netherlands a few large Top Technology Institutes (TTI) have been created. One of the best developed competence centre initiatives is the Swedish programme run by VINNOVA. All these initiatives are well documented (MAP, 2004).

In the Swedish innovation system a few large firms with very large R&D budgets dominate the scene together with a handful of universities (see OECD, 2005*b*). Swedish actors are responsible for most research expenditure and have the highest R&D intensity of all OECD countries. Challenges at the beginning of the 1990s included a stronger innovation orientation among SMEs, a broadening of the universities' research agenda, and the beginning of merger and internationalisation processes involving large Swedish firms. One of the key goals of a systems-oriented R&D policy was to link science to industry more strongly in order to change collaborative behaviour and to facilitate the mutual influence of academic and industrial research agendas.

The programme was launched in 1993, with a promise to fund competence centres for up to ten years with about 30% of the overall budget. Universities provide another 30% and industry (a number of firms per centre) the remaining 40%. In a two-stage process based on foreign peer review, 28 centres were selected out of hundreds of proposals. The centres started in 1995. It is important to see that the broad thematic range was largely the result of a bottom-up process. The programme became the flagship of NUTEK, the precursor of VINNOVA, the present technology funding agency. (A few centres are sponsored by STEM, the Swedish energy agency.) The centres are all housed at a university, with renowned institutions like KTH or Chalmers hosting a large number. About a third of the 230 participating firms are SMEs. A typical Swedish competence centre has about ten partner firms, an annual total budget of about EUR 2 million and 20-30 staff (full-time equivalent). There is a strong focus on: *i)* the model of the "industrial PhD" who learns from both worlds; *ii)* defining pre-competitive, long-term and multi-firm projects with shared and open IPR; *iii)* negotiation of a multi-party agreement before starting the centre; and *iv)* clear programme management, supported by leadership programmes. All these elements help the firms to strengthen their long-term research capacities and the universities to provide relevant research and a management style compatible with industry needs. Quality control is rigorous: each centre is evaluated by international experts every three to four years. After ten years, public agency funding is terminated.

Box 6.4. Competence centres for long term science-industry co-operation: the Swedish example *(continued)*

As the programme has now operated for nearly ten years, with a total budget of about EUR 550 million, VINNOVA commissioned an impact study (Arnold *et al*., 2004*a*, 2004*b*). The very positive conclusions reveal not only an increase in long-term industry participation but also the building of interdisciplinary research environments at the universities, which has affected traditional, discipline-oriented academic research and put the issue of relevance higher on the agenda. Many peer evaluations indicate the emergence of internationally highly visible research groups. The impact study lists a large number of new inter-firm collaborations with relevant results and notes changing intra-firm innovation behaviour. In some cases, firms like VOLVO or ABB[44] which became parts of international conglomerates, were able to defend or modify Swedish in-house research capacities owing to successful innovation networks within the competence centres. Output of PhDs, patents, publications or spin-offs (over 20) is generally high, and "knowledge", "people", "mindsets" and "infrastructures" are key words.

The first impact study on the Austrian *K plus* competence centre programme, which includes an assessment (Edler *et al.*, 2004) and measures additionality effects in participating firms compared to a CIS3 sample, leads to similar results.

A new wave of "VINN excellence centres" (VINNOVA, 2004) is about to be launched, building on Sweden's success. They will be strongly oriented towards public sector missions and problem-oriented research.

Sources: Arnold *et al*. (2004*a*, 2004*b*); VINNOVA (2004); MAP-TN (2004); *www.vinnova.se*. See also OECD (forthcoming).

Given international experience as well as the current Swiss situation, a specific initiative concerning industry-science relationships might consist of:

- A programme aimed at long-term and strategic R&D co-operation between a number of firms and research groups. Such a programme, similar to the science-driven NCCRs regarding networks and similar to CTI funding regarding the applied character of research, would include the active financial involvement of firms and could be developed as a joint activity of SNF and CTI. There is a wealth of experience with applied R&D competence centres available in several OECD countries which can be used to devise an initiative geared to Switzerland's specific needs.

44. VOLVO headquarters are now in the United States, while Swedish ABB units report to Switzerland.

6.4 The services sector

6.4.1 Innovation in the services sector

Compared to the manufacturing sector, the services sector of most OECD countries is characterised by a moderate level of R&D activity. This is strongly related to differences in innovation processes in services and manufacturing. According to the European Community Innovation Survey (CIS3) the services sector is more likely to introduce new products on the market than the manufacturing sector, which concentrates much more on improving production processes, as well as delivery and design of products. Service firms innovate in marketing but not very much in product or process innovation.[45] Thus, while manufacturing firms foster and draw on internal R&D activities, service firms are more likely to rely on R&D provided by external sources and make use of other sources of knowledge and technology via patents, licences or training. As innovation in services mostly results from external R&D activities, firms often face the problem of gaining sufficient access to the knowledge needed to innovate and to make proper use of the knowledge provided, which may require investment in training and organisational change. There is often a rather weak relationship between service firms and knowledge providers in the public sector (governments, universities, public research institutes, etc.). Further, owing to their small size, service firms often lack the financial base that would allow them to engage in cost-intensive and risky R&D activities to develop innovations. In addition, the services sector is largely regional or national in nature, although the internationalisation of markets is fostering innovative practices.

The services sector also makes several indirect contributions to innovation. On the one hand, service firms demand knowledge and knowledge-intensive products from the manufacturing sector and thus induce R&D activities in the manufacturing sector. On the other hand, service firms provide knowledge that complements the goods and services provided by manufacturing and thus enrich the economy's knowledge base. Since the services sector is labour-intensive, service firms need to emphasise human resource development and ensure the upgrading of the skills and human capital that are important drivers of innovation in knowledge-based economies. Entrepreneurship also drives innovation and productivity growth

45. The process of innovation in services has thus been described as a "reverse product cycle" (Barras, 1986; OECD, 2001*a*, cited in OECD, 2005*b*). Firms first adopt new technologies (*e.g.* ICT). By using them they can offer improved services, and eventually the new technology provides the basis for an entirely new service.

in services. New firms entering the market adopt new technologies and subsequently bundle resources in units with higher productivity (Tamura *et al.*, 2005; Wölfl, 2005).

Policy makers need to redesign the measures for fostering innovation, taking account of the services sector's potential to contribute to aggregate productivity growth. Although service firms are generally less innovative than manufacturing firms according to commonly used measures, services such as financial intermediation and business services already show above-average levels of innovation (OECD, 2005*b*).

6.4.2 Some evidence for Switzerland

There is significant evidence of services sector innovation in Switzerland. While the average growth rate of R&D intensity across all services is among the lowest in international comparison – only the United Kingdom (aside from the Czech Republic and the Slovak Republic) has lower growth – the growth rate in telecommunications is the second highest among the countries compared (Tamura *et al.*, p. 146). Hollenstein (2002) used a data set of 880 firms from nine service industries for a cluster analysis designed to group firms into homogeneous categories with respect to 17 indicators of innovation. The indicators cover the input as well as the output side of the innovation process, and the introduction of new products to the market or new processes in the firm. Using this technique, 475 of the firms analysed were classified as innovators and five different modes of innovation were identified:

- Mode 1: *Science-based high-technology firms with full network integration* (21 firms). *Characteristics*: *i)* highly qualified staff; *ii)* intensively engaged in R&D; *iii)* a highly favourable environment in terms of innovation opportunities; and *iv)* good market perspectives. *Structure*: above-average proportion of export-oriented, medium-sized firms. In addition some very large firms heavily concentrated in IT/R&D services and business services (about 70% of the firms in this cluster belong to these industries). In this cluster, 15% of the firms are in banking, insurance and other financial services.

- Mode 2: *IT-oriented network-integrated developers* (19 firms). *Characteristics*: *i)* a highly qualified labour force; *ii)* favourable market perspectives; *iii)* product and process innovations of high technical standard (mostly new). *Structure*: IT/R&D services and business services are once more over-represented in this group along with banking, insurance and other financial services.

- Mode 3: *Market-oriented incremental innovators with weak external links* (99 firms). *Characteristics*: *i)* favourable market prospects; *ii)* supply-side conditions for generating novelties are average; *iii)* rather low level of innovation input; *iv)* product and process innovations primarily incremental in nature; *v)* innovation output of high economic value and marketable; *vi)* rather weak networks; *vii)* use of easily accessible knowledge resources. *Structure*: high share of (very) small firms; industries quite equally represented in this group, with a slight over-representation of business services and wholesale trade and a few firms in transport/telecommunications.
- Mode 4: *Cost-oriented process innovators with strong external links along the value chain* (229 firms). *Characteristics*: *i)* strong price competition; *ii)* (incremental) process innovation aimed at cost reduction; *iii)* innovation strongly benefits from a wide (primarily informal) network from suppliers to users. *Structure*: large firms slightly over-represented, very small ones distinctly under-represented, industry structure close to the sector average.
- Mode 5: *Low-profile innovators with hardly any external links* (107 firms). *Characteristics*: *i)* rather marginal innovations; *ii)* most important form of innovation is adoption of novelties from others. *Structure*: above average share of small firms producing mainly for the domestic market.

As a general trend, the boundaries between manufacturing and services are blurring. One example is ABB Turbochargers, a manufacturer of sophisticated machinery whose business depends largely on well-designed, long-term service contracts based on individualised just-in-time production. The challenge lies in the strong diversification of the products, mainly for shipbuilding (nearly any of tens of thousands of individual parts can be made available within 48 hours worldwide). The worldwide service network is run by the division, which is a profit centre within ABB. The service also operates as a source of inspiration for product and process innovations. Reliable IT services are seen as crucial in such arrangements. Large IT firms and their research nodes seem to take an even more radical approach. In the case, of the IBM research centre Rüschlikon (and IBM in general), for example, the rule is that "if a service is the result, it is kept, if a product results, it is spun out". Better portfolio management, in particular in public research institutions, could help to spur services sector innovations.

International comparisons remain difficult, however, as Switzerland does not provide all the data necessary for a complete OECD-wide comparison of individual service sub-sectors. Overall, R&D growth in the Swiss services sector tends to be nil; this differs from many small European economies such as Ireland, Sweden, Finland or Austria, which report considerable growth in this area (OECD, 2004, p. 130).

As regards public support (the principle of not funding firms directly does not seem to be strictly followed in the services sector), Tamura *et al.* (2005) mention the following Swiss initiatives as good examples of innovation policies focusing on services:

- Federal programme to foster innovation and co-operation in tourism (CHF 35 million for 2004-07) with the following main objectives: *i)* new products and distribution channels; *ii)* improvement of existing services; *iii)* creation of new organisational structures; *iv)* education and training; *v) R&D* activities.
- Softnet programme (CHF 30 million) to build a software industry of international standards through co-operation between public research institutes and industry and to foster networks of competence and training of ICT professionals (see also OECD, 2004, p. 138).
- New Swiss legislation for digital signatures, domain names, copyright of online services providing legal security for online services.
- New degree programmes and new types of diplomas for professional training in information technologies.

6.4.3 The financial sector

Banking is certainly among the best-known of Swiss service industries, and one of the country's core economic activities. It is very large and has two global players, UBS and Crédit Suisse, a number of other large commercial banks, and a large group of private banks. The sector's history, legal framework, including taxes, image and discretion offer good framework conditions. The banking sector is complemented by the insurance industry, with international actors such as Swiss Re as leading houses. Together, the financial sector accounts for more than 10% of Switzerland's GDP and about 6% of the workforce. Zurich is one of the world's main financial centres, and its regional economy relies strongly on the industry's prosperity. However, this strong position has been deteriorating slowly but steadily. New York and London dominate world financial markets, Frankfurt is becoming more important, and the emergence of new locations such as Dublin or Singapore and the rise of more traditional ones such as Luxembourg have put competitive pressure on Zurich. Important new products and markets seem to emerge elsewhere, outsourcing takes its toll and the active globalisation of the two largest Swiss banks is also leading to a reallocation of decision power, competence centres and resources. While Zurich still places sixth in a global financial ranking, concerns are mounting (AWA, First Tuesday Zurich and ETH Zurich, 2003; First Tuesday Zurich, 2004). These sources indicate that other global financial marketplaces are stronger than Zurich or Switzerland in general.

To counter these developments, experts have made recommendations that are well-established in innovation policy: clustering, human resource development, excellent basic research, intra- and inter-firm innovation, use of ICT. On the surface, there is no difference with fields like biotechnology, the machinery or automotive industry, and it is remarkable how well the three following statements apply. *i)* In this industry, innovation takes place at high speed. New products and processes dominate the market and it is demanding to fully understand, let alone develop them (examples are futures and options). *ii)* For this reason, excellent research institutions in finance, mathematics and related fields are required, preferably on the spot and specifically at universities, not only to produce first-class graduates but also to provide top (basic) research results (examples are mathematics and risk analysis). *iii)* There seem to be economies of scale and agglomeration effects.

Studies compare for example the size of the securities markets, of capitalisation, air transport as a gateway indicator, and general scientific output as a knowledge intensity indicator. In a European comparison, London leads in all four respects, followed by Paris and Frankfurt (the former with higher capitalisation and the latter with more science). According to one study, Zurich ranks fourth, with a strong performance but not in quantitative science. Followers include Amsterdam, Milan and Stockholm (Lakshmanan *et al.*, 2000, p. 68).

The following recommendations are made for the financial industry:

- *Clustering*: Workshops involving key persons in the Zurich financial industry have shown a common understanding of an existing cluster of banks, insurance companies, public institutions (such as regulators or the central bank), business service providers (from accountants and lawyers to management and IT consultancy) and higher education/ research institutions. Actors want some public support, but innovation-friendly framework conditions and excellent universities seem to be the two key factors (AWA, First Tuesday Zurich and ETHZ, 2003; First Tuesday Zurich, 2004).

- *Human resource development*: Domestic supply is reported to be far from sufficient. This is not necessarily a big problem in an open, advanced economy that can support high wage levels. There is a strong drive to hire people with top qualifications, while medium qualifications are becoming less and less important. This is due in part to an acceleration of the offshoring and internationalisation strategies of large actors. It is reported that some banks have to send their hedge fund managers to Frankfurt or elsewhere to update their knowledge. At least one of the large banks has its own internal business school.

- *Excellent basic research, academic infrastructure*: Large actors increasingly tend to choose Anglo-Saxon universities as partners, owing to the superior quality of their specific education. ETH Zurich and the University of Zurich are seen as strong but not sufficiently advanced in all necessary respects. Policy papers regarding the financial sector map a large number of research groups in Switzerland and emphasise the importance of larger groups and networks such as the NCCR FINRISK, the Geneva-Lausanne-Neufchatel cluster or the common Risklab of the two Zurich universities. At the same time, they rate London, New York and Frankfurt more highly, because the level of research is not in line with the importance of the financial sector. The conclusion is clear: the financial industry crucially needs a much stronger research infrastructure. The public sector should provide more public funding in the budget period 2008-11.

- *Local growth opportunities based on an environment of innovative business firms*. While the availability of financial instruments is critical for the creation and growth of firms, an environment of innovative businesses also provides growth opportunities for financial markets. A study on global gateways states: “Before industrialisation, financial centres were also centres of interregional and international trade. Today and increasingly in the future, there will be a similar synergy between science, high-technology innovations and financial activities. The supply of risk capital will be crucial to the innovation and growth of high-technology production and the reduction of epistemic risks will be the central factor determining the size and growth of regional financial markets. Financial markets like Zurich, Amsterdam, Stockholm or Helsinki depend on the quality and potential applicability of research in medicine and the other pharmaceutical sciences, biotechnology, chemistry, electrical engineering and computer sciences. Small financial markets with their own stock exchange do have a future, but only if surrounded by research-and-development-dependent and innovation-prone industries.” (Andersson, 2000, pp. 38 *ff*)

- *Intra- and inter-firm innovation*: Rapid innovation and sophistication in product markets serve as a starting point. Constantly finding new products and interlinking innovative platforms and customers are reported to be crucial. Anglo-Saxon competitors are seen as early movers for new products. The research portfolio is broad: the large banks employ not only economists but also mathematicians, physicists and other science graduates. In a large bank, hundreds of employees perform research in the strict sense. Hedge funds with their specific morphology and rapid changes in the underlying models are an example of an innovation driver. Open know-how architectures have an important function. It is not possible to develop everything in house. There is much intra-industry co-operation, *e.g.* in process innovation. Offshore software development, *e.g.* to India, seems to play a noteworthy role, with outsourcing partners changing often. For obvious reasons, co-operation by firms in the financial industry is quite rare. High costs, the difficulty of building platforms and the speed of innovation put pressure on smaller market participants.

- *Information and communication technologies*: ICTs are one of banks' major cost factors. Large banks use the best software firms as benchmarks and pursue an early follower policy. Banks such as UBS and Crédit Suisse could well be labelled the "two top Swiss ICT firms", as they provide employment for several thousand IT engineers in Switzerland and worldwide. Rationalisation is a key driver of IT development and use. Typically, a large bank has "megasoftware" mostly developed in house and a large portfolio of active projects at all times (close to headquarters and worldwide). The core business is carried out within the firm, and various (and changing) offshore IT partners in locations such as India or Singapore provide the rest. Nevertheless, stakeholders from the IT sector still see market niches for Swiss ICT firms in the financial sector.

In summary, innovation in the financial sector seems to very important, rapid, comprehensive and – at first glance – not too different from other industries. Swiss experts (AWA, First Tuesday Zurich and ETHZ, 2003; First Tuesday Zurich, 2004) plead for a strengthening of basic research and higher education capabilities. Basic research is seen as central, since this is where innovations are created (First Tuesday Zurich, 2004).

6.4.4 The tourism sector

Tourism is another strong sector of the Swiss economy. As in some other fields, there is stagnation at a traditionally high level or some erosion. In 2004 about CHF 22.6 billion were earned in tourism, more than half of it accounted for by to foreign visitors. The overall share of tourism in GDP in that year was in the range of 5%, and about 3% for foreigner tourists. Tourism represents about 9% (CHF 12.9 billion) of overall exports and is the third largest source of export income following the metal/machinery and the chemical industries. The tourism balance of payment 2003 was positive (about CHF 2 billion). With about 216 000 employees, tourism is one of the largest employers in Switzerland. In addition, it creates employment indirectly by absorbing other services. With about one tourism enterprise per 250 inhabitants density is very high and competition severe (BFS, 2005*d*; BFS *et al*., 2005). Further, the rise of many attractive tourism regions worldwide, changes in customer preferences and behaviour, and relatively high price levels led to a decline in terms of nights spent (CHF 78 million in 1991; CHF 65 million today). Some peripheral Swiss regions depend almost entirely on tourism. Regions and communities receive support from the Confederation, albeit at a decreasing scale.

Challenges include quality assurance, the relation of cost to quality, better advertising and, in general, attracting more tourists. Switzerland's early success in high-end tourism led to a high share of what are now perceived as old-fashioned four- or five-star hotels with their specific problems. The federal and the cantonal level interact in supporting Swiss tourism, and interest groups are reportedly strong.

Innovation in the tourism industry involves new and better quality services, new attractions, new forms of co-operation, and of, course, intensive use of new ICT applications for booking, travel and "info-tainment". The concept of innovation has a different meaning than in other industries. The sector is supported, as mentioned, by a dedicated innovation funding scheme: InnoTour is a federal programme designed to foster innovation and co-operation in tourism which makes state aid available to SMEs directly. It has a strong infrastructure component and includes funding of R&D activities. Co-operation is seen as crucial in this programme. In the period 1997-2002, CHF 25 million was available for the programme, and CHF 35 million was earmarked for 2004-07 (compared to more than CHF 50 million annually for federal tourism promotion). Part of the project costs must be covered by participants. The projects are reported by stakeholders to be often of a "low-tech" character, centred on "new markets", "new products" and "new distribution channels". They range from new alpine cycling roads to ICT booking systems, quality assurance or distribution channels.

6.4.5 The construction industry

The image of Switzerland includes good, solid buildings, the *Glacier Express*, the *Alpine Transversal* and perfectly designed mountain roads. Owing to rigorous standards and a demanding topography, the quality of Swiss construction is high. At the same time, competition in the Swiss construction sector seems to be restricted, placing the industry in the partly protected part of the economy. New and foreign entrants encounter a number of obstacles. Stakeholders describe investment behaviour as conservative and the bias towards long-proven solutions as stronger than in other sectors. Public transport authorities are reported to be hesitant to use new solutions in construction and "not invented here" appears to be a dominant attitude towards such solutions. On the other hand, the Swiss method of building tunnels has won international acclaim. There are indications, however, that innovation could be spurred in the industry. This would require new forms of financing large construction ventures, including contractual models in public-private partnerships.

6.4.6 The creative industries

Like the financial sector, creative industries seem to be mostly an issue for regional policy making in urban areas such as Greater Zurich. Cluster structures in creative industries provide opportunities for metropolitan areas to gain specific location advantages. Authors like Richard Florida (2002) have spurred the debate and linked the degree of creativity to technological innovation, social tolerance, well-being and change. Cities like London and Vienna[46] actively promote their creative industry sector, which includes music, fashion, architecture, design, multimedia, print, film and others. In many cities this is a growing area. Lifestyle, image, small firms, fluctuating jobs, links to tourism and culture are associated catchwords.

In a study by Held *et al.* (2005) the creative industries of the City and Canton of Zurich was recently mapped. The study found 8 000 firms with more than 30 000 employees (full-time equivalent[47]) for the canton with a

46. For the Vienna Creative Industries, see *www.creativeindustries.at; www.departure.at; www.wwtf.at* for a rich set of data and public funding activities.

47. This is roughly equivalent to three-quarters of the Zurich banking sector. For comparison, Vienna, which is larger than Zurich, has more than 100 000 employees in this sector.

turnover of more than CHF 8 billion. The predominance of small firms is typical of creative industries in nearly every city. The study identified the following success factors: proximity and co-operation, cheap and flexible office space, hot spots for identification, better links between public, private and intermediary actors. There are some ideas for better networking, but a major conclusion of the study is: "Actors are already co-operating, but common platforms and interests and goals are still missing widely. On the other hand the Zurich creative industries are still part of the sheltered economy, and therefore weakly developed, undercapitalised, and not enough internationally linked" (Held *et al.*, 2005, p. 6). A strong cluster management is proposed (p. 24).

The regional authorities acknowledge these developments and support raising awareness and coalitions. The strong role of government as a large content provider should be used more actively, but direct support for the creative industries would be difficult and is not a priority.

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Acronyms

ARE	Federal Office for Spatial Development
BAG	Federal Office for Public Health
BBT/OPET	Federal Office for Professional Education and Technology
BERD	Business enterprise expenditure on research and development
BFE	Federal Office for Energy
BFS	Swiss Federal Statistical Office
BLW	Federal Office for Agriculture
BSV	Federal Social Insurance Office
BUWAL	Agency for Environment, Forests and Landscape
CASS	Council of the Swiss Scientific Academies
CERN	European Organization for Nuclear Research
CEST	Centre for Science and Technology Studies
CHF	Swiss franc
CIM	Computer-integrated manufacturing
CRUS	Rectors’ conference of the universities
CTI	Commission for Technology and Innovation (Innovation Promotion Agency)
DSP	Directorate for Security Policy
EAWAG	Swiss Federal Institute for Environmental Science and Technology
EDA	Federal Department of Foreign Affairs
EDI	Federal Department of Home Affairs
EDK	Swiss Conference of Cantonal Ministers of Education
EMPA	Swiss Federal Laboratories for Materials Testing and Research
EPFL	École Polytechnique Fédérale de Lausanne

ERT Message	Message concerning the Promotion of Education, Research and Technology issued by the Federal Council and transmitted to Parliament for discussion and decision
ESA	European Space Agency
ETH	Swiss Federal Institute of Technology
ETHZ	Swiss Federal Institute of Technology Zurich
EuroHORCs	European Heads of Research Councils
EVD	Federal Department of Economic Affairs
FP	(European Union) Framework Programme (for Research and Technological Development)
GDP	Gross domestic product
GERD	Gross expenditure on research and development
ILL	Institute Laue-Langevin
IMS	Intelligent Manufacturing Systems
IPR	Intellectual property rights
KOF	Swiss Institute of Business Cycle Research at the ETH Zurich
NCCR	National Centres of Competence in Research
NRP	National Research Programmes
OAQ	Centre for Accreditation and Quality Assurance of the Swiss Universities
OFS	Swiss Federal Statistical Office
PSI	Paul Scherrer Institute
R&D	Research and development
RDT	Research and technological development
S&T	Science and technology
SBF	State Secretariat for Education and Research
SECO	State Secretariat for Economic Affairs
SMEs	Small and medium-sized enterprises
SNF	Swiss National Science Foundation
SUK	Swiss University Conference

SWTR	Swiss Science and Technology Council
UAS	Universities of applied sciences
UVEK	Federal Department of Environment, Transport, Energy and Communications
VBS	Federal Department of Defence, Civil Protection and Sports
WSL	Swiss Federal Institute for Forest, Snow, and Landscape Research

OECD PUBLICATIONS, 2, rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(92 2006 09 1 P) ISBN 92-64-02974-5 – No. 55351 2006

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ISBN 92-64-02974-5
92 2006 09 1 P

9 789264 029743