A few adjustments and the future looks bright for the countries of the European Free Trade Association.

Hans Peter Hertig

Bertrand Piccard, a Swiss psychiatrist and balloonist who initiated the Solar Impulse project, waves after the solar-powered aircraft Solar Impulse 2 arrives at Nanjing Lukou International Airport early Wednesday on April 22, 2015 in Nanjing, Jiangsu province of China. Solar Impulse 2, the first aircraft completely sustained by solar power, took off from Myanmar's second biggest city of Mandalay early Monday and after a 20-hour flight, the Solar Impulse 2 airplane touched down in south China's Chongqing Jiangbei International Airport and stayed at Chongqing, the fifth flight of a landmark journey to circumnavigate the globe powered solely by the sun, for twenty days.

Photo: © ChinaFotoPress/Getty Images

11 · European Free Trade Association

Iceland, Liechtenstein, Norway, Switzerland

Hans Peter Hertig

INTRODUCTION

A relatively quick recovery

The four countries which make up the European Free Trade Association (EFTA) are among the wealthiest in the world. Liechtenstein has a strong banking sector and successful companies in machinery and the construction business. Switzerland does very well in the services sector – particularly in banking, insurance and tourism – but also specializes in high-tech fields such as microtechnology, biotechnology and pharmaceuticals. Norway has built up its wealth by exploiting North Sea oil since the 1970s and Iceland's economy is dominated by the fishing industry, which accounts for 40% of exports. In order to reduce their dependency on these traditional sources of income, the two Nordic states have developed capacities in a wide range of knowledge-based sectors, such as software design, biotechnology and environment-related technologies.

This solid base and the resultant high per-capita income didn't prevent the four EFTA countries from being buffeted by the global financial crisis in 2008–2009; however, they suffered to varying degrees, like most countries in the western hemisphere (Figure 11.1). Iceland was particularly shaken, with three of its largest banks collapsing in late 2008; the country's inflation and unemployment rates more than doubled to almost 13% (2008) and 7.6% (2010) respectively, while central government debt almost tripled from 41% (2007) to 113% (2012) of GDP as the country struggled to conjugate the crisis. These same indicators barely budged in Liechtenstein, Norway and Switzerland, which continued to count unemployment levels of just 2–4% on average. Iceland has since put the crisis behind it but recovery has been slower than for its neighbours.

Growth in all four countries has nevertheless stalled recently (Figure 11.1) and there are some question marks regarding the short-term outlook. The strong, overrated Swiss franc[1] may have a negative impact on key sectors of the Swiss economy, such as the export industry and tourism, suggesting that predictions for GDP growth in 2015 will probably need to be lowered. The same may be necessary for Norway as a result of the slump in oil prices since 2014.

Not surprisingly, Europe[2] is EFTA's main trading partner. In 2014, it absorbed 84% of Norway's merchandise exports and 79% of Iceland's but only 57% of Switzerland's own exports, according to the United Nations COMTRADE[3] database. When it comes to imports of European goods, however, Switzerland takes the lead (73% in 2014), ahead of Norway (67%) and Iceland (64%). EFTA began diversifying its trading partners in the 1990s and has since signed free trade agreements[4] with countries on every continent. Similarly global is the EFTA countries' engagement in the field of science and technology (S&T), albeit with a clear focus on Europe and the activities of the European Commission.

Part of Europe but different

EFTA is an intergovernmental organization devoted to promoting free trade and economic integration in Europe. Its headquarters are based in Geneva (Switzerland) but another office in Brussels (Belgium) liaises with the European Commission. Twelve years after EFTA was founded in 1960, it counted nine member states: Austria, Denmark, Finland, Iceland, Norway, Portugal, Sweden, Switzerland and the UK. All but three had joined the European Union (EU) by 1995: Iceland, Norway and Switzerland. Liechtenstein's adhesion since 1991 brings EFTA's current membership to four.

A turning point in EFTA's development came with the signing of an agreement with the EU on the creation of a single European market. The Agreement on the European Economic Area (EEA) was signed by Iceland, Liechtenstein and Norway and entered into force in 1994. It provides the legal framework for the implementation of the four cornerstones of the single market: the free movement of people, goods, services and capital. The agreement established common rules for competition and state aid and promoted co-operation in key policy areas, including research and development (R&D). It is through this agreement that three of the four EFTA members participate in the EU's main R&D activities as associated states on the same footing as the EU member states.

Switzerland, on the other hand, was unable to sign the EEA treaty, even though it had participated actively in drawing it up, owing to a negative vote in a Swiss referendum in November 1992. A bilateral agreement with the EU nevertheless allows Switzerland to take advantage of the main EU instruments in place, including the seven-year framework programmes for research and innovation, the

1. In January 2015, the Swiss franc soared by almost 30% against the euro, after the Swiss National Bank removed the cap it had imposed in 2011 to prevent such a scenario. Since then, the effect has softened to a 15–20% rise.

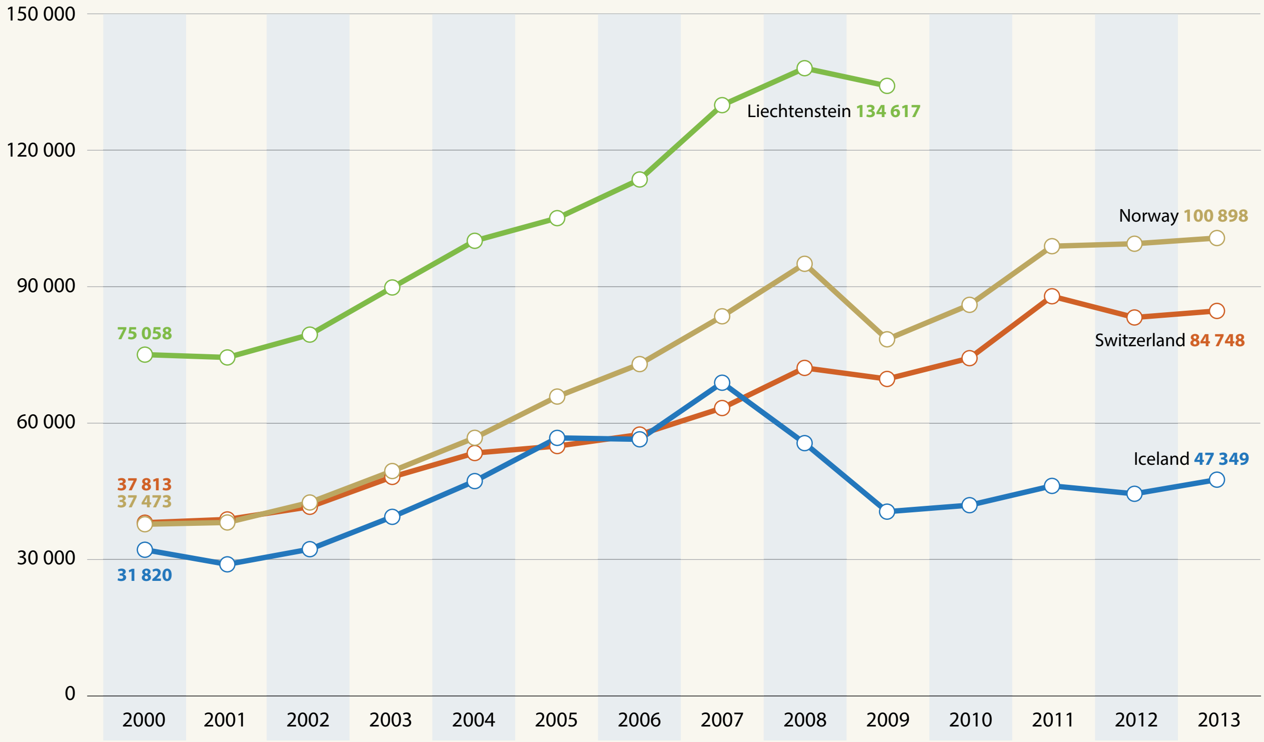
2. Here, Europe encompasses the EU, Southeast Europe and Eastern Europe but not the Russian Federation.

3. Liechtenstein's trade is covered in Swiss statistics.

4. See: www.efta.int/free-trade/fta-map

Figure 11.1: **Trends in GDP per capita in EFTA countries, 2000–2013**

In PPP$ at current prices



Source: World Bank's World Development Indicators, April 2015

Future and Emerging Technologies programme, the grants of the European Research Council and the Erasmus programme for student exchange, but Switzerland's political ties to the EU are more tenuous than those of the three other EFTA members. Moreover, as we shall see, Switzerland's relations with the EU have been jeopardized recently by yet another referendum.

The four EFTA members do not have a unified legal and political status vis-à-vis the EU and the EFTA group itself is anything but homogeneous. It consists of:

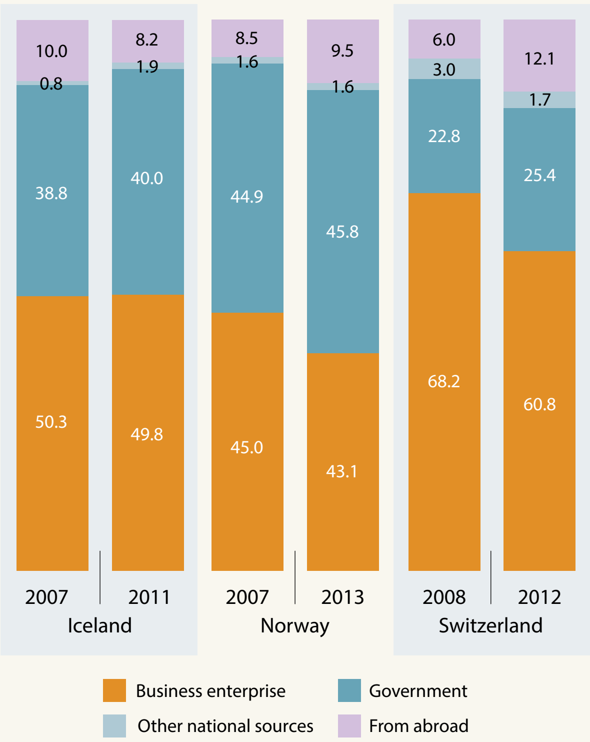
- two geographically remote countries with lengthy sea coasts (Iceland and Norway) and abundant natural resources, versus two inland nations (Liechtenstein and Switzerland) at the heart of Europe which are entirely dependent on the production of high-quality goods and services;
- two small countries (Norway and Switzerland) with a population of 5.1 million and 8.2 million respectively, versus a very small country (Iceland, 333 000 inhabitants) and a mini-state (Liechtenstein, 37 000 inhabitants);
- one country severely hurt by the 2008 financial crisis (Iceland) and another three which were able to digest it relatively painlessly; and
- two countries involved in multinational regional activities in Europe's north – Iceland and Norway are active partners in the Nordic co-operation scheme – and another two, Liechtenstein and Switzerland, which share a common language, maintain close neighbourly co-operation in a multitude of areas and have formed a customs and monetary union since 1924.

The list could be a lot longer but these examples suffice to make the point: the very heterogeneity of the EFTA countries make them interesting case studies for the *UNESCO Science Report*, in which they feature for the first time. There are no R&D activities *per se* within EFTA as, in this area, the EEA treaty has split the small group of four into a group of three plus one. All four are nevertheless involved in most of the European Commission's activities, as well as some other pan-European initiatives such as European Co-operation in Science and Technology (COST) and Eureka, a co-operative scheme providing companies, universities and research institutes with incentives for cross-border market-driven research. They also take part in the Bologna Process, the collective effort of European countries to harmonize and co-ordinate higher education. Norway and Switzerland are also members of the European Organization for Nuclear Research (CERN), which is hosted by the latter on the Franco-Swiss border and attracts thousands of physicists from around the world.

In the following pages, we shall be analysing the ways in which these countries perform individually and as a group in the European context. We shall also analyse the reasons which make Switzerland, in particular, such a high-achiever when it comes to innovation: it topped both the EU's Innovation Scoreboard and the Global Innovation Index in 2014 and belongs to the top three countries for innovation among members of the Organisation for Economic Co-operation and Development (OECD).

Table 11.1 provides key indicators for Iceland, Norway and Switzerland; it doesn't cover Liechtenstein, which is simply too small to have meaningful statistics for this comparative table. Some data are given in the country profile of Liechtenstein (see p. 303). Switzerland belongs to the top three countries in Europe, according to all indicators for science input, science output, innovation and competitiveness in the region, Iceland and Norway rank in the first tier or in the midfield. Norway has considerably increased its gross domestic expenditure on research and development (GERD) but its GERD/GDP ratio remains well below the EFTA and EU28 averages (Table 11.1; see also Figure 11.2). Another weak point is Norway's seeming unattractiveness for foreign students: just 4% of those enrolled in advanced research programmes on Norwegian campuses are international students, against 17% in Iceland and 51% in Switzerland, according to the OECD's *Education at a Glance* (2014); nor can Norway be satisfied with its score in

Figure 11.2: **GERD in EFTA countries by source of funds, 2007 and 2013 or closest years (%)**



Source: OECD (2015) *Main Science and Technology Indicators*

the EU Innovation Union Scoreboard 2014: it is ranked 17th in a field of 35, placing it in the modest group of *moderate innovators*[5] which fall below the EU average (see glossary, p. 738).

All three countries, with some reservations for Norway, have a highly mobile future generation of scientists (Table 11.1) and are strong publishers – Iceland increased its output by 102% between 2005 and 2014 – with a large share of international co–authors (Table 11.1 and Figure 11.3). The country with the highest publication growth rate has also done especially well impact-wise: Iceland ranks fourth for the share of scientific publications among the top most cited (Table 11.1). The clouds on Iceland's horizon are to be found elsewhere; it did not manage to improve its innovation performance between 2008 and 2013. Although it remains in the category of *innovation followers* and above the EU average, Iceland has been overtaken by no fewer than six EU countries and it has lost 11 places in the World Economic Forum's competitiveness index. We shall discuss possible measures Iceland could adopt in order to get back on track later in the chapter.

Before profiling the four nations individually, we shall take a brief look at the common activities Iceland, Norway and Liechtenstein undertake related to R&D within the framework of the EEA agreement.

Common research within the EEA

The EEA agreement affords Iceland, Liechtenstein and Norway the status of fully associated partners in EU research programmes. Iceland and Norway take full advantage of this opportunity; they were among the most successful countries per capita for the obtention of competitive research grants from the Seventh Framework Programme (FP7) over 2007–2013. For its part, Iceland had the best success rate of all European Research Area countries in the FP7–Cooperation programme, which set out to strengthen co-operation in R&D between universities, industry, research centres and public authorities across the EU and the rest of the world. Iceland showed special strengths in environment, social sciences, humanities and health; Norway was one of the leaders in environmental research, as well as in energy and space (DASTI, 2014).

Participation in EU activities is not free, of course. Besides paying a lump sum to each framework programme, the three EEA countries contribute to reducing socio-economic disparities in Europe by promoting social cohesion, via a special programme administered autonomously by the EEA Secretariat: the EEA/Norway grants programme. Although

5. In the opinion of Statistics Norway, the verdict in the European Commission's report is too severe, for it underestimates Norway's innovation potential (see Research Council of Norway, 2013, p. 25).

Table 11.1: **International comparisons for EFTA countries in science, 2014 or closest year**

		Iceland	Norway	Switzerland
Human resources	Human resources in S&T* as a share of the active population, 2013 (%)	53	57	57
	Corresponding ERA** ranking (41 countries)	7	2	2
	Public expenditure on higher education as a share of GDP, 2011 (%)	1.6^{-1}	2.0^{-1}	1.4
GERD	GERD/GDP ratio (2007)	2.9^{-1}	1.6	2.7^{+1}
	GERD/GDP ratio (2013)	1.9	1.7	3.0^{-1}
	Corresponding EU ranking (28 countries)	8	16	3
	Public expenditure on R&D in higher education as a share of GDP (2012)	0.66^{-1}	0.53^{+1}	0.83
Researcher mobility	Share of postdocs having spent more than 3 months abroad in past 10 years (%)	49	43	53
	Corresponding EU ranking (28 countries)	3	10	1
	International students as a percentage of enrolment in advanced research programmes (2012)	17	4	51
	Corresponding OECD ranking (33 countries)	15	25	2
Publication intensity	International scientific co-publications per million inhabitants (2014)	2 594	1 978	3 102
Publication impact	Share of scientific publications in top 10% most cited, 2008–2012	18	13	18
Research excellence	Number of universities in top 200, according to Shanghai Academic Ranking of World Universities, 2014	0	1	7
	Number of universities in top 200, according to QS World University Rankings 2014	0	2	7
	Number of ERC grants per million population 2007–2013	3	8	42
	Corresponding ERA ranking	18	12	1
Patent activity	Number of triadic patent families per million population (2011)	11	23	138
	Corresponding OECD ranking (31 countries)	15	12	2
	RANK IN INTERNATIONAL INDICES			
Innovation potential	Rank in EU's Innovation Union Scoreboard , 2008 (35 countries)	6	16	1
	Rank in EU's Innovation Union Scoreboard 2014 (35 countries)	12	17	1
Competitiveness	Rank in WEF World Competitiveness Index, 2008 (144 countries)	20	15	2
	Rank in WEF World Competitiveness Index, 2013 (144 countries)	30	11	1
	Rank in IMD World Competitiveness Scoreboard, 2008 (57 countries)	not ranked	11	4
	Rank in IMD World Competitiveness Scoreboard, 2013 (60 countries)	25	10	2

-n/+n = data are for *n* years before or after reference year
* individuals who have obtained a tertiary-level qualification in an S&T field and/or are employed in an occupation where such a qualification is required
** ERA comprises the 28 EU members, the four EFTA states, Israel and the EU candidates in the year of the study.

Note: Comparative data are unavailable for Liechtenstein; its patents are covered in Swiss statistics.

Source: Eurostat, 2013; European Commission (2014a) *Researchers' Report; WEF (2014) Global Competitiveness Report 2014–2015;* European Commission (2014b) *ERA Progress Report;* European Commission (2014c) *Innovation Union Scoreboard;* OECD (2015) *Main Science and Technology Indicators;* OECD (2014) *Education at a Glance;* IMD (2014) *World Competitiveness Yearbook;* EU (2013) *Country and Regional Scientific Production Profiles;* IMF (2014) *World Economic Outlook;* UNESCO Institute for Statistics, May 2015; Iceland Statistics this is not really an R&D programme, education, science and technology play a crucial role in the areas covered by the programme, from environmental protection, renewable energy and the development of green industries to human development, better working conditions and the protection of cultural heritage. Between 2008 and 2014, the three EEA donors invested € 1.8 billion in 150 programmes that had been defined jointly with 16 beneficiary countries in central and southern Europe. In relation to climate change, for instance, one of the programme's priority themes, a joint project enabled Portugal to draw on the Icelandic experience to tap its geothermal potential in the Azores. Portugal has also co-operated with the Norwegian Institute for Marine Research to keep its seas healthy. Through another project, Innovation Norway and the Norwegian Water Resource and Energy Administration have helped Bulgaria to improve its energy efficiency and innovate in green industries.

The EEA grants/Norway grants programme will continue in the years to come, albeit with small changes to the programme structure, a likely increase in spending levels and a merger of the two types of grant into a single funding scheme. As in the past, Iceland and Norway will be participating as fully associated members in the new framework programme covering the period from 2014 to 2020, Horizon 2020 (see Chapter 9). Liechtenstein, on the other hand, has decided to refrain from an association with Horizon 2020, in light of the small number of scientists from this country and its resultant low participation level in the two former programmes.

COUNTRY PROFILES

ICELAND

A fragmented university system

Iceland was severely hit by the global financial crisis of 2008. After its three main banks failed, the economy slipped into a deep recession for the next two years (-5.1% in 2009). This hindered ongoing efforts to diversify the economy beyond traditional industries such as fisheries and the production of aluminium, geothermal energy and hydropower into high-knowledge industries and services.

Although most of the figures in Table 11.1 look good, they would have looked even better a few years ago. The country invested 2.9% of GDP in R&D in 2006, making it one of the biggest spenders per capita in Europe, surpassed only by Finland and Sweden. By 2011, this ratio was down to 2.5% and, by 2013, had hit 1.9%, its lowest level since the late 1990s, according to Iceland Statistics.

Iceland has an excellent publication record, both quantitatively and qualitatively (Table 11.1 and Figure 11.3). It has one internationally known university, the University of Iceland, which ranks between 275th and 300th in the *Times Higher Education Supplement*. The country's strong publication record is no doubt largely due the country's highly mobile younger generation of scientists. Most spend at least part of their career abroad; half of all doctorates are awarded in the USA. Moreover, 77% of articles have a foreign co-author. Even if it is true that this high percentage is typical of small countries, it places Iceland in the group of the most internationalized science systems in the world.

Like Norway, Iceland has a solid science base that does not translate into a high innovation potential and competitiveness (see p. 304). Why is this so? Norway can blame this paradox on its economic structure, which encourages specific strengths in areas requiring low research intensity. Restructuring an economy to favour high-tech industries takes time and, if there is steady high income falling in the government's lap from low-tech industries in the meantime, there can be little incentive to put the necessary measures in place.

Unlike Norway, Iceland was well on the way to a more diversified and more knowledge-based economy in the years before the 2008 crisis. When the crisis struck, it had widespread repercussions. Research expenditure at universities and public research institutes slid from 1.3% of GDP in 2009 to 1.1% in 2011. Efforts to complement the foreign training of Icelandic scientists and strengthen their active role in international networks by developing a solid home base with a strong Icelandic research university were stopped in their tracks. This put Iceland in a double bind: it fuelled the brain drain problem while lowering the country's chances of attracting multinational companies in research-intensive domains.

The European Commission produces a series of Erawatch reports for the EU and EEA countries. Iceland's Erawatch report (2013) identified a number of key structural and financial challenges faced by Iceland's STI system. Besides the shortcomings mentioned above, the report cited weaknesses in governance and planning, a low level of competitive funding with an insufficient number of grants that were also too small, inadequate quality control and a fragmented system, with too many players (universities and public laboratories) for a country the size of Iceland. The country has seven universities, three of which are private; the University of Iceland had about 14 000 students in 2010, compared to fewer than 1 500 at most of the other institutions.

At least some of these weaknesses are addressed in the first policy paper published by the government-elect in 2013. Its *Science and Technology Policy and Action Plan 2014–2016* advocates:

Figure 11.3: **Scientific publication trends in EFTA countries, 2005–2014**

Growth has slowed in Iceland since 2010 and remained steady in Norway and Switzerland

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Iceland	427	458	490	575	623	753	716	810	866	864
Liechtenstein	33	36	37	46	41	50	41	55	48	52
Norway	6 090	6 700	7 057	7 543	8 110	8 499	9 327	9 451	9 947	10 070
Switzerland	16 397	17 809	18 341	19 131	20 336	21 361	22 894	23 205	25 051	25 308

2 594

Publications per million inhabitants in Iceland in 2014

1 978

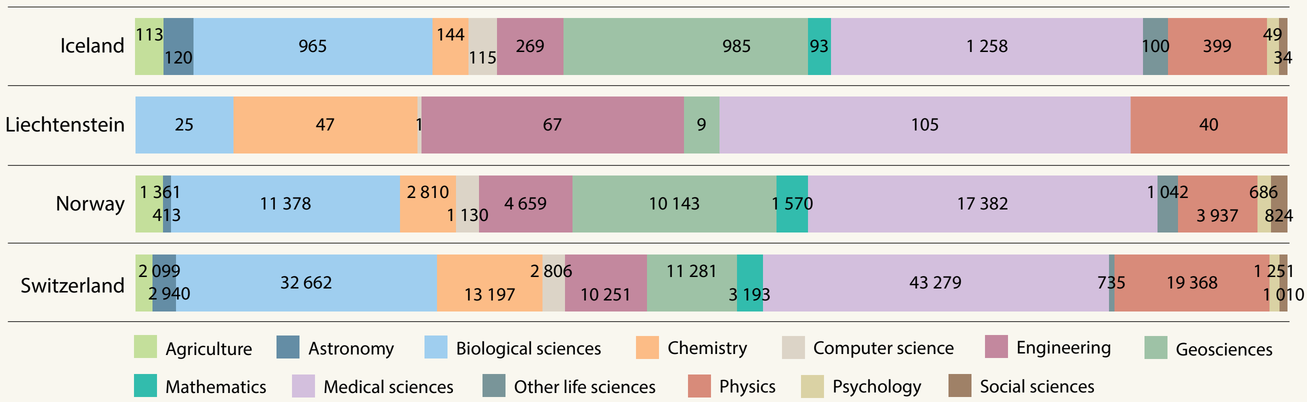
Norwegian publications per million inhabitants in 2014

3 102

Swiss publications per million inhabitants in 2014

Countries specialize in medical sciences, Switzerland stands out in physics

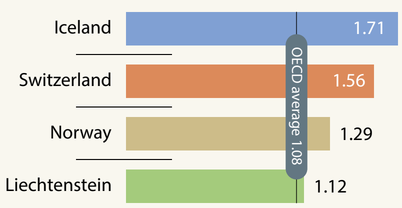
Cumulative totals by field, 2008–2014



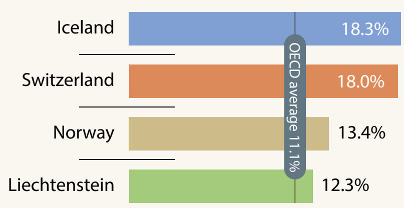
Note: The totals by field do not include unclassified publications, which are quite numerous for Switzerland (13 214), Norway (5 612) and Iceland (563). See the methodological note on p. 792.

All countries surpass the OECD average by far for key indicators

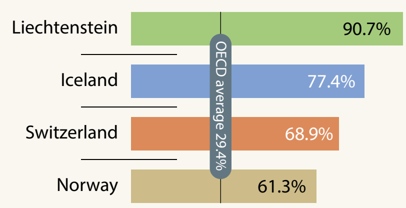
Average citation rate for publications 2008–2012



Share of papers among 10% most-cited 2008–2012



Share of papers with foreign co-authors, 2008–2014



The main partners are in Europe or the USA

Main foreign partners between 2008 and 2014 (number of papers)

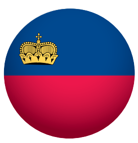
	1st collaborator	2nd collaborator	3rd collaborator	4th collaborator	5th collaborator
Iceland	USA (1 514)	UK (1 095)	Sweden (1 078)	Denmark (750)	Germany (703)
Liechtenstein	Austria (121)	Germany (107)	Switzerland (100)	USA (68)	France (19)
Norway	USA (10 774)	UK (8 854)	Sweden (7 540)	Germany (7 034)	France (5 418)
Switzerland	Germany (34 164)	USA (33 638)	UK (20 732)	France (19 832)	Italy (15 618)

Source: Thomson Reuters' Web of Science, Science Citation Index Expanded; data treatment by Science–Metrix

- a higher contribution to tertiary education in order to reach the level of other Nordic countries;
- restoration of the pre-2008 target of raising the GERD/GDP ratio to 3% by 2016;
- measures to increase Iceland's participation in international research programmes;
- the definition of long-term funding projects and the research infrastructure they call for;
- strengthening competitive funding at the cost of fixed contributions;
- a better use of the tax system to encourage the private sector to invest in R&D and innovation; and, lastly,
- a better system for evaluating the quality of domestic research and innovation.

Unfortunately, these recommendations hardly touch on the problem of fragmentation pinpointed by the Erawatch country report in 2013. Iceland counts one university for every 50 000 inhabitants! Of course, prioritizing some institutions over others is a politically difficult manoeuvre; it impinges on STI but also has regional, social and cultural dimensions. Notwithstanding this, channelling available resources to a single strong university likely to impress the international scientific community and attract students and faculty from abroad is an absolute must. This institution would then be able to take the lead in Iceland's most promising research fields – health, information and communication technologies (ICTs), environment and energy – and perhaps develop others. The brilliant young Icelanders living abroad would be more willing to return home with their new ideas. Maybe it will take this young generation to heed the message from an independent expert group that recently reviewed Iceland's STI system commissioned by the European Commission. If Iceland wishes to put an end to institutional fragmentation, they said, to improve co-ordination of the main players, foster co-operation and develop an efficient evaluation and quality assessment system, the way forward can be summed up in two words: pull together.

LIECHTENSTEIN



Innovation drives Liechtenstein's economy

Liechtenstein is a special case in many respects. It is one of Europe's few remaining principalities, a constitutional democracy combining a parliament with a hereditary monarchy. One-third of inhabitants are foreigners, mainly Swiss, German and Austrian. Its tiny size – 37 000 inhabitants in 2013 – excludes it from most comparative S&T statistics and rankings. Its public expenditure on R&D amounts to less than the budget of a small university and its publication output represents a couple of hundred citable documents per year. The EEA agreement links it closely to Iceland and Norway but its geographical location on Switzerland's eastern border, national language (German) and the long tradition of close collaboration in many policy fields with the Swiss make joint ventures with Switzerland a much more evident and pragmatic solution. Science and technology are no exception. Liechtenstein is fully associated with the Swiss National Science Foundation, giving its researchers the right to participate in the foundation's activities. Moreover, Liechtenstein enjoys the same privilege with the Austrian Science Fund, the Austrian equivalent of the Swiss National Science Foundation.

Liechtenstein boasts an impressive GERD/GDP ratio of 8 %, according to the national education authority, but this is of limited meaning in international comparisons on account of the extremely small number of actors and nominal figures. Nevertheless, this ratio reflects the high level of R&D undertaken by some of Liechtenstein's internationally competitive companies in machinery, construction and medical technology, such as Hilti, Oerlikon-Balzers or Ivoclar Vivadent AG; the latter develops products for dentists, employs 130 people in Liechtenstein and about 3 200 people worldwide in 24 countries.

Liechtenstein's public funding of R&D – roughly 0.2% of GDP – goes mainly to the country's sole public university, the University of Liechtenstein. Founded in its present form in 2005 and formally accredited in 2011, the university concentrates on areas of special relevance for the national economy: finance, management and entrepreneurship, and, to a lesser degree, architecture and planning. The school has got off to a good start; it is attracting a growing number of students from beyond its German-speaking neighbours, not least because of a highly attractive faculty/student ratio. A large proportion of the country's youth nevertheless studies abroad, mainly in Switzerland, Austria and Germany (Office of Statistics, 2014).

Whether Liechtenstein will continue to flourish and earn the international reputation and status it covets remains to be seen. Liechtenstein's development will, in any case, determine the future of its public R&D sector. If the University of Liechtenstein lives up to expectations in terms of growth and quality, this may incite parliament to rethink its recent decision to drop out of the EU's Horizon 2020 programme. Innovation is the key element behind Liechtenstein's strong economy and supportive R&D measures by the public sector could well prove a useful complement to private R&D investment for preserving the country's advantages in the long run.

NORWAY

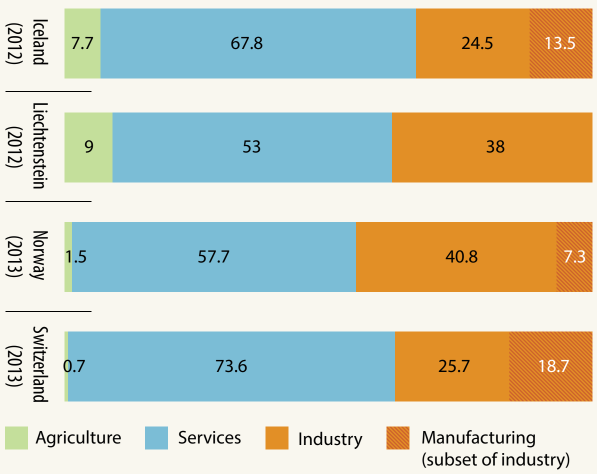
Knowledge not translating into innovation

Norway has one of the highest income levels in the world (PPP$ 64 406 per capita in current prices in 2013). Despite this, the country's strong science base contributes less to national wealth than its traditional economic assets: crude oil extraction from the North Sea (41% of GDP in 2013); high productivity in manufacturing; and an efficient services sector (Figure 11.4).

As shown in Table 11.1, the first links in the added value chain are promising. The share of the adult population with tertiary qualifications and/or engaged in the STI sector is one of the highest in Europe. Norway did have a traditional weakness in the relatively low number of PhD students and graduates but the government has managed to remove this bottleneck; since 2000, the number of PhD students has doubled to match those of other northern European countries. Together with public R&D expenditure above the OECD median and a large pool of researchers in the business enterprise sector, this makes for solid input to the S&T system (Figure 11.5).

It is at this point that the clouds appear: output is not what the level of input would suggest. Norway ranks third in Europe for the number of scientific publications per capita but the share of Norwegian-authored articles in top-ranked journals is only just above the ERA average (Table 11.1). Similarly, Norway's performance in the first seven calls by the ERC for research proposals is good but not excellent and the same is true for the international prestige of its universities:

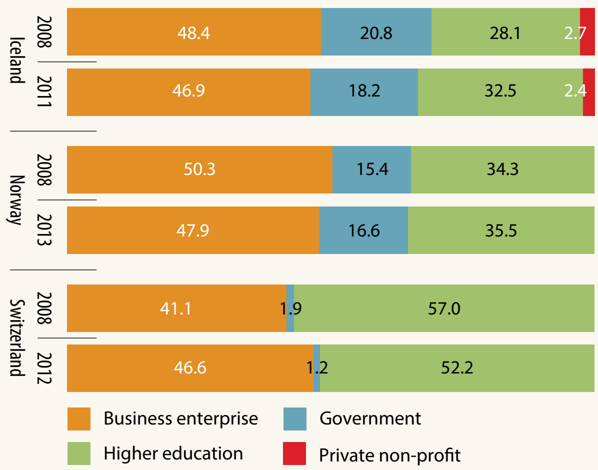
Figure 11.4: **GDP in EFTA countries by economic sector, 2013 or closest year (%)**



Note: For Liechtenstein, manufacturing is included in other industry; 'agriculture' includes households and corresponds mainly to the rental activities of real estate agencies.

Source: World Bank's World Development Indicators, April 2015; for Liechtenstein: Office of Statistics (2014)

Figure 11.5: **Researchers (FTE) in EFTA countries by sector of employment, 2008 and 2013 or closest years (%)**



Note: The category of 'other researchers' includes private non-profit and not elsewhere classified, reported only in Iceland. For Switzerland, federal and central government researchers only are classified as 'government'.

Source: UNESCO Institute for Statistics, April, 2015

Norway's leading institution, the University of Oslo, ranks 63rd in the Shanghai Academic Ranking of World Universities, a sign of world-class research. However, if we look at rankings that consider criteria other than research quality, an obvious problem emerges. Two Norwegian universities figure among the top 200 in the QS World University Rankings: the University of Oslo (101st) and the University of Bergen (155th) [Table 11.1]. Both do well citation-wise but disappoint when it comes to the internationalization count. This reflects a Norwegian pattern. Also disappointing is the small proportion of international students enrolled in advanced research programmes (Table 11.1);[6] Switzerland, Iceland and other small European countries such as Austria, Belgium or Denmark do much better for this indicator. Clearly, Norwegian universities face a vicious circle: the main asset for attracting high-performing international students and faculty members is a university's reputation, the number one reputation-maker in globalized higher education is the rankings and a key criterion for good positions in the league tables is having adequate percentages of international students and faculty members. Whether one likes it or not, rankings are the signposts on the avenues of international talent circulation.[7]

How can Norway break this circle and better brand itself as an attractive destination for study[8] and research? Norway

6. The OECD figures for Norway may have a tendency to underestimate the percentage because of the specificities of Norwegian statistics and/or because a large share of foreign students have either obtained resident status or are EU citizens.

7. For a discussion of the relationship between universities, rankings, regional context and globalized higher education, see UNESCO (2013) and Hertig (in press).

8. Canada is asking itself the same question. See Chapter 4.

faces two severe handicaps for the internationalization of its science system, of course: location and language. To overcome these handicaps, it could remove legal and logistical barriers to cross-border mobility, undertake campus upgrades, reform study programmes so that they better suit the needs of a foreign clientele and extend PhD and postdoctoral programmes abroad, including special measures to reintegrate students afterwards – but this may not be enough. Another measure is probably necessary to make a visible difference: the establishment of additional research flagship programmes that shine on the international scene like that for arctic science (Box 11.1).

One such flagship programme has recently caught the attention of the scientific community beyond the immediate circle of neuroscientists, after the director of the Kavli Institute for Systems Neuroscience was awarded the Nobel Prize in Physiology or Medicine in 2014 for discovering that the human brain has its own positioning system. Edvard Moser shares the prize with fellow Norwegian, May-Britt Moser, Director of the Centre for Neural Computation in Trondheim, and John O'Keefe from University College London. The Kavli Institute for Systems Neuroscience is hosted by the Norwegian University of Science and Technology in Trondheim and is part of Norway's centres of excellence scheme. The first 13 of these centres of excellence were established in 2003. Twenty-one additional centres were established in two separate rounds in 2007 (8) and 2013 (13). These centres receive stable public funding over a period of ten years to the tune of € 1 million per centre per year. This sum is rather low; similar centres in Switzerland and the USA receive two to three times more. Allocating a higher sum to a couple of institutions that Norway is bent on profiling internationally may warrant further reflection. Investing more in such centres would also lead to more balanced support for the different types of research. Basic research is not Norway's top priority; few other European countries have a portfolio more oriented towards applied science and experimental development (Figure 11.6).

Measures like the above would help Norway to fix some of the weak spots in its generally very good public science system. However, as mentioned above, Norway's main weakness is its performance in the later stages of the added value chain. Scientific knowledge is not being efficiently transformed into innovative products. Norway's most negative STI indicator in the OECD's 2014 country report concerns the number of patents filed by universities and public laboratories; the lowest per capita figure within the OECD. It does not suffice to blame academia for this predicament. The problem goes deeper; patents are the result of an active relationship between the producers of basic knowledge and the private companies using, transforming and applying it. If the business side is not

Box 11.1: Arctic research in Svalbard

Svalbard (Spitsbergen) is a Norwegian archipelago situated midway between continental Norway and the North Pole. Its natural environment and unique research facilities at a high latitude make it an ideal location for arctic and environmental research.

The Norwegian government actively supports and promotes Svalbard as a central platform for international research collaboration. Institutions from around the world have established their own research stations there, most of them in Ny-Ålesund. The first two polar institutes were established by Poland in 1957 and Norway in 1968. Norway has since set up four other research stations: in 1988 (shared with Sweden), 1992, 1997 and 2005. The most recent addition was the Centre for Polar Ecology in 2014, which is part of the University of South Bohemia in the Czech Republic. Other research stations have been set up by China (2003), France (1999), Germany (1990 and 2001), India (2008), Italy (1997), Japan (1991), the Republic of Korea (2002), the Netherlands (1995) and the UK (1992).

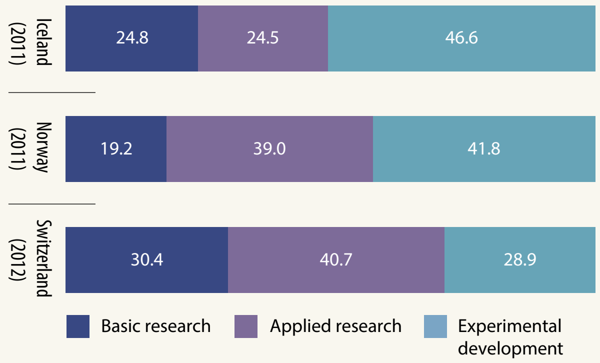
Longyearbyen, the world's most northerly city, hosts research bodies and infrastructure such as the:

- European Incoherent Scatter Scientific Association (est. 1975), which conducts research on the lower, middle and upper atmosphere and ionosphere using the incoherent scatter radar technique;
- Kjell Henriksen Auroral Observatory (est. 1978); and the
- University Centre in Svalbard (est. 1993), a joint initiative of several Norwegian universities. It undertakes arctic and environmental research, such as studying the impact of climate change on glaciers; it also offers high-quality courses at under-graduate and postgraduate levels in arctic biology, arctic geology, arctic geophysics and arctic technology.

Svalbard has been linked with the rest of the digital world since 2004 through a fibre optic cable. Norway is committed to developing Svalbard further as a 'science spot' and to improving the access of the international research community to its infrastructure and scientific data.

Source: Norwegian Ministry of Education and Research and Ministry of Foreign Affairs

Figure 11.6: **GERD in EFTA countries by type of research, 2012 or nearest year (%)**



Note: For Iceland, the data do not add up to 100%, as 4% of research is unclassified. For Norway, data are based on current costs only, not total expenditure, and thus exclude both current and capital expenditure.

Source: UNESCO Institute for Statistics, April, 2015

well developed, publicly funded science will also falter. This is what is happening in Norway. Despite having a productive, prosperous economy, Norway only has a small proportion of high-tech companies that conduct in-house R&D and creaking bridges to publicly funded research.

Moreover, it has only a handful of home-grown multinational companies implanted in top research hubs around the globe. Few other OECD countries have lower private R&D expenditure per capita than Norway, despite its generous tax incentives for R&D since 2002. Less than half of Norwegian companies have reported being engaged in innovation activity in the past couple of years, compared to almost 80% in Germany; Norwegian companies also score poorly for the percentage of turnover from innovative products. Some hurdles are external to the national innovation system, the most important among these being high tax rates and restrictive labour regulations, according to the 2014 WEF *Global Competitiveness Report*.

Not easy to intensify R&D in a low-growth period

One of the goals proclaimed by Norway's incoming government in 2013 in its strategy for future co-operation with the EU was to 'make Norway one of the most innovative countries in Europe' (Government of Norway, 2014). The 2014 budget consequently allocates more funds to instruments that support business R&D. Although the amount and growth rate may be too timid to make a real difference, it is certainly a step in the right direction. Norway needs to do more, though, to smooth its path to innovation paradise. It needs to strengthen basic science and the main actors in charge of it, research universities, through the measures proposed above. It also needs to strengthen existing programmes and invent powerful new ones to forge alliances between enterprises and research groups in academia.

All this will come at a cost, of course. Quite uncharacteristically for Norway, finding sufficient public funds may present the most important challenge of all in the years to come. With the plunge in the Brent crude oil price to just half its value between July 2014 and January 2015, it looks like the long period of unbroken high annual GDP growth has become a thing of the past. Consequently, optimistic long-term goals like that fixed by the previous government in a white paper of doubling the country's GERD/GDP ratio to 3% by 2015 no longer seem very realistic. Like many other European countries, Norway will have no choice but to diversify into more innovative economic sectors by intensifying R&D. In the current times of low economic growth, the task will be anything but easy (Charrel, 2015).

SWITZERLAND

Can Switzerland keep its place in the sun?

For the sixth year running, Switzerland led the list of 144 countries analysed in the 2014 WEF *Global Competitiveness Report*. It performs particularly well in higher education, training and innovation. It is also an unrivalled hotspot for innovation, according to the European Commission's 2014 Innovation Union Scoreboard, ahead of all the EU countries, its fellow EFTA members and key world players such as Japan, the Republic of Korea and USA. What is the secret behind this striking performance and what are the chances that Switzerland will be able to keep its place in the sun?

For one thing, Switzerland has a remarkably strong science base. Seven of its 12 universities figure among the top 200 in the Shanghai ranking, a league table mainly focusing on research output. Switzerland is among the top three countries in most global rankings for the impact of its scientific publications and is by far the most successful country per capita in the calls for project proposals issued by the European Research Council, a grant-funding scheme that has become the most prestigious instrument for the support of basic science in Europe (see Box 9.1).

Obviously, in a small country, world-class performance and internationalism are closely linked. More than half of all PhD-holders at the 12 Swiss universities and close to half of the R&D personnel in the private sector are non-Swiss. Two-thirds of faculty members of the two Federal Institutes of Technology (ETH), the Eidgenössische Technische Hochschule (ETHZ) in the German-speaking city of Zürich and the École polytechnique fédérale de Lausanne (EPFL) in the French-speaking part of Switzerland, are non-Swiss.

Complementing the excellent performance of its publicly funded universities and a couple of the institutes attached to the ETH domain is a research-intensive private sector, led by globally active world leaders in engineering (ABB), the food industry (Nestlé), agriculture and biotechnology (Syngenta) and pharmaceuticals (Novartis, Roche), the pharmaceutical industry accounting for one-third of all Swiss in-house R&D spending. These companies share a striking characteristic with Swiss academia: the ability to attract leading researchers from all over the world to engage in Swiss research efforts at home and in their laboratories around the world.

Scientific strength is one thing, turning it into innovative, competitive products is another, as Norway knows only too well. The following characteristics of the Swiss system are key factors in its success:

- First and foremost is the combination of world-class universities working in high-tech fields in tandem with research-intensive multinationals, sophisticated companies that themselves operate at the high end of the value chain within a small geographical area.
- Secondly, Swiss universities and companies have essential research strengths for the development of competitive products for the global market; more than 50% of publications are in biological and medical sciences, other top fields being engineering, physics and chemistry (Figure 11.3).
- Thirdly, more than half of the labour force is qualified to do demanding jobs in science and engineering (Table 11.1); Switzerland leads all other European countries for this indicator. This results less from having a high percentage of people with university degrees – Switzerland doesn't particularly shine in this regard – than from having a labour force that has obtained the requisite qualifications through other means: on the one hand, there is the excellent vocational curriculum provided through apprenticeships and universities specialized in applied research and vocational training (Fachhhochschulen/Hautes écoles spécialisées); on the other, the hiring of top professionals from abroad.
- Fourthly, there is a clear working division between the public and private sectors. Almost two-thirds of Switzerland's R&D is funded by industry (Figure 11.2). This not only guarantees efficient technology transfer – the shortest route from scientific breakthroughs to competitive products are in-house channels – but also allows the public sector to concentrate on non-oriented basic research.
- Fifthly, there has been no break in the high levels of investment in R&D, which has been managed in a stable political system with stable policy priorities. Like most countries in the western hemisphere, Switzerland was hit by the 2008 financial crisis but not only was its GDP rapidly back on track, the impact on R&D spending was also minimal. Even in the private sector, investment in R&D only shrank marginally, from 1.9% to 1.8% of GDP. The universities were particularly spoiled, as, in just four years, their budgets grew by one-third.
- Last but not least, Switzerland has a swath of local advantages for business, in general, and high-tech companies, in particular: excellent research infrastructure and good connectivity (87% of the population had access to internet[9] in 2013), low taxes, a lightly regulated job market, few barriers to founding companies, high salaries and an excellent quality of life. What an asset, too, to be situated at the heart of Europe, unlike Iceland and Norway.

Switzerland could become a lone(ly) wolf in Europe

Switzerland has built its recipe for success in STI on developing a sturdy international network. It is ironic that the fallout from the referendum of 2014 may jeopardize this proud achievement.

The adoption of a popular initiative restricting immigration to Switzerland in February 2014 offends one of the guiding principles of the EU, the free movement of persons (Box 11.2). Shortly after the vote, the Swiss government informed the EU and Croatia that it was unable to sign a protocol to its agreement with the European Commission that would have automatically extended this agreement to the new EU member state. Giving Croatian citizens unrestricted access to the Swiss job market would have been incompatible with the 'yes' vote of the Swiss on the 'stop mass immigration' initiative (Box 11.2).

The EU reacted without delay. The European Commission excluded Switzerland from research programmes potentially worth hundreds of millions of euros for its universities and suspended negotiations on Switzerland's participation as a full member in the world's largest and best-funded research and innovation programme, the € 77 billion Horizon 2020. The European Commission also suspended Switzerland from the Erasmus student exchange programme. According to the ATS news agency, some 2 600 Swiss students took advantage of Erasmus in 2011 and Switzerland played host that same year to about 2 900 foreign students within the same EU-funded programme.

Thanks to intense diplomatic activity behind the scenes and fruitful bilateral discussions, the situation was looking less dramatic by mid-2015. In the end, Switzerland will be able to participate in Excellent Science, the central pillar of Horizon 2020. This means that its universities will be entitled to benefit from grants offered by the European Research Council and by the Future and Emerging Technologies programme, among other instruments. This is welcome news for the École

9. The ratio is even higher in Liechtenstein (94%), Norway (95%) and Iceland (97%).

polytechnique fédérale de Lausanne (EPFL), which is leading one of the two flagship projects[10] of the Future and Emerging Technologies Programme, the Human Brain Project, which seeks to deepen our understanding of how the brain functions.

So far, so good, you might say, but the Sword of Damocles is hanging over the Swiss government. The current agreement is limited in time and will expire in December 2016. If Switzerland doesn't come up with an immigration policy in accord with the principle of the free movement of persons by then, it will lose its status as a fully associated member of Horizon 2020 and retain the status of a third party in Erasmus+. Should that happen, even though it won't affect Swiss engagement in Europe (such as CERN) beyond EU projects, Switzerland will still become a very lonely wolf in Europe's S&T landscape.

10. The other flagship project is developing the new materials of the future, such as graphene.

Disappointing economic growth could affect R&D targets

Remaining part of the European Research Area is crucial but it is not the only challenge Switzerland faces, if it wishes to stay in the lead. The country will also need to maintain the current heady levels of R&D spending. In the financial plan for 2013–2016, education, research and innovation all enjoy exceptionally high annual growth rates in the range of 4%. However, that was before the Swiss franc gained so much value against the euro in January 2015, undermining exports and tourism. Targets that looked like a piece of cake in early 2015 have become a gamble: as in Norway, albeit for different reasons, economic growth is in trouble; since growth is a prerequisite for higher public spending, R&D, like many other policy areas, may suffer.

Overdependent on a handful of multinationals

Another bottleneck is the recruitment of highly qualified R&D personnel. In just three years, Switzerland dropped from 14th to 24th position in the WEF *Global Competitiveness Report*

Box 11.2: A vote on immigration ricochets on Swiss science

Assessing public attitudes to science and technology from informal opinion polls is one thing, making decisions on scientific topics through legally binding referenda is quite another.

Popular referenda are part of the political routine in Switzerland's direct democracy. The Swiss vote on literally everything, from new opening hours for retail stores and bonus ceilings for top managers to multinational treaties. Now and then, they also vote on science and technology.

If one eliminates the many votes in which attitudes to specific technologies were not necessarily the main argument for a 'yes' or a 'no' vote, such as on issues related to nuclear energy, there have been four referenda at the federal level in the past 20 years on legal provisions that would severely restrict research; each of these referenda has asked citizens to vote on a highly complex issue, questioning vivisection, stem cells, genetic modification of agricultural products and reproductive technologies. Is there a voting pattern? Yes, clearly so. In each of these four referenda, the great majority voted against measures that would have restricted or hindered scientific research.

Considering the very positive attitude of the Swiss towards science and technology, why then, in 1992, did they vote against the Agreement on the European Economic Area, which would have automatically given them access to the European Research Area? Even more critically, why did they vote in favour of an initiative in February 2014 limiting the number of immigrants to Switzerland that severely endangers the country's co-operation with the EU in science and technology? One in four Swiss residents was born abroad and about 80 000 immigrants move to Switzerland each year, most of whom are EU citizens.

There were two main reasons for the rejection. The first is evident: in both cases, science and technology were just one part of the package and, as shown in post-voting polls, the fact that voting against one of the four principles of the EU – the free movement of persons – would also weaken Swiss science was either not understood by voters or judged less important than other considerations.

This, of course, leads directly to the second reason. The Swiss political elite, who favoured the European Economic Area agreement and were opposed to strict immigration controls, missed an opportunity to put science and technology on the campaign agenda. Would it have changed the outcome? Yes, probably, since the outcome of both referenda was extremely tight. The initiative 'against massive immigration' in February 2014 was adopted by 1 463 854 votes to 1 444 552. Had the heads of Swiss universities and other important actors of the Swiss science scene thought to pen a couple of enlightening articles in major newspapers in the weeks prior to the referendum highlighting the potential cost of a 'yes' vote in terms of the loss of access to EU research and student exchanges (Erasmus), this would most likely have turned the outcome around.

Source: compiled by author

2014 for its capacity to find and hire the talent it needs to preserve its advantages with respect to innovation. There are also the more structural dangers, such as the economy's distinct dependence on the performance of a handful of R&D-intensive multinational companies. What if they falter? The latest OECD and EU reports show that the proportion of Swiss firms investing in innovation has fallen and that Swiss small and medium-sized enterprises are exploiting their innovation potential less effectively than in the past.

In view of this, the Swiss government may have to become more interventionist (Box 11.3). It has already taken a step in this direction. In 2013, the government transferred responsibility for R&D from the Department for Internal Affairs to the Department for Economic Affairs. Of course, the transfer is not without risk but, as long as the new political environment acknowledges the key role of basic research in the added value chain and supports science to the same extent as the former ministry, the greater proximity to publicly funded applied research may prove beneficial. There are a number of initiatives in the pipeline which go in this direction. One is the creation of two regional innovation parks around the two Federal Institutes of Technology, ETHZ in Zürich and EPFL in the Lake Geneva area, a region known as western Switzerland's Health Valley.[11] A second initiative in the pipeline is the funding of a set of technology competence centres as a 'technology' complement to the highly successful National Centres of Competence in Research run by the Swiss National Science Foundation since 2001. A third initiative foresees the establishment of a network of energy research centres piloted by the Commission for Technology and Innovation that will be reorganized and better funded, to help them perform this and other technology-driven tasks. Also in preparation is a package of measures designed to improve the career prospects of the up and coming generation of scientists which include better working conditions for PhD students, positive discrimination to increase the share of women in senior academic positions and, in a mid-term perspective, the introduction of a nation-wide tenure track system (Government of Switzerland, 2014).

11. on account of the presence of numerous biotech and medical-cum technical companies, the excellent clinical research conducted by several hospitals and world-class life science at top universities

Box 11.3: **Swissnex: a Swiss formula for science diplomacy**

Among the factors that may explain Switzerland's success in STI, one element resurfaces regularly: Switzerland's global presence. The country manages to attract top people from abroad and to be present where it counts. Swiss institutions of higher learning are extremely well connected (Table 11.1); the same is true for Swiss companies in research-intensive fields. They act globally and have established companies and research laboratories close to other centres of world-class science, such as the Boston area or parts of California in the USA. Around 39% of their patented discoveries are joint ventures with research groups from abroad, the highest percentage in the world.

Moreover, when it comes to helping the Swiss 'seduce' foreign territories, even the anything-but-interventionist Swiss government likes to mingle: Switzerland may have the busiest and most entrepreneurial science diplomacy in the world. In addition to the classic network of science attachés maintained by most industrialized countries in their key embassies around the world, it has begun establishing specialized hubs in specific hotspots for science and technology, the so-called 'Swissnex.' Swissnex are joint ventures between two ministries; although they are formally annexed to Swiss consulates and embassies and thus part and parcel of the diplomatic complex, strategically and in terms of content, they fall under the State Secretariat for Education, Research and Innovation.

A first Swissnex opened midway between Harvard University and the Massachusetts Institute of Technology in the USA in 2000. Five others have since been established in San Francisco (USA), Singapore, Shanghai (China), Bangalore (India) and Rio de Janeiro (Brazil).

Swissnex is a unique construct: a small enterprise located in the grounds of a diplomatic mission that is financed jointly by the Swiss government and private sponsors and shares a common mission at all locations: to diversify Switzerland's image from that of the land of chocolate, watches and beautiful alpine scenery to that of a leading nation in STI.

A parallel goal is to facilitate co-operation between the public and private R&D constituency at home and in the host country by adapting the portfolio to the local context. Obviously, building bridges between Switzerland and the USA calls for a different approach to that adopted in China. Whereas the USA has an open science system and is home to a host of branches of high-tech Swiss companies, the Swiss science scene is still little-known in China and the country has a much more political way of doing things. The Swissnex approach fits the bill and it is one of the many assets helping Switzerland to stay on top.

Source: compiled by the author, including from Schlegel (2014)

Taken together, all these measures may enable Switzerland to defend its position at the top but, importantly, none of them suggests ways in which Switzerland could play an active role in Europe. There is some hope that this oversight may be remedied in the near future. At least, another referendum proposing to restrict immigration even further was strongly defeated in November 2014 – and this time Swiss science made its voice heard prior to the vote.[12]

CONCLUSION

A few adjustments and the future looks bright

There is no doubt about it: the four small and micro-states that make up EFTA are well positioned economically, with GDP per capita well above the EU average and strikingly low unemployment rates. Even if added value chains are anything but linear, the excellent quality of higher education and R&D output are certainly key factors in their success.

Switzerland either tops international rankings, or figures in the top three, for R&D performance, innovation potential and competitiveness. Its main challenge in the years to come will be to defend its primacy, maintain high investment in basic research in order to preserve the exceptional quality of its universities and inject fresh public funds reserved for national and regional initiatives into more applied, technology-oriented fields of research. Switzerland will also need to resolve its political problems with the EU before the end of 2016 in order to ensure full participation in Horizon 2020, the world's most comprehensive and best-funded multinational R&D programme.

For Norway, the challenge will be to reduce its strong economic dependence on the not particularly R&D-intensive petroleum industry by diversifying the economy with the help of innovative high-tech companies and linking them to the public R&D sector. Neither public nor private investment in R&D does justice to a country with such a high level of income; both will need a push.

Iceland's prime challenge will be to heal the remaining open wounds from the 2008 financial crisis and to recover lost ground; less than a decade ago, it was an astonishingly strong player in the research field, considering its size and remote geographical location, with world-class figures for its GERD/GDP ratio, scientific publications per capita and publication impact.

Last but not least, tiny Liechtenstein faces no obvious challenges in the field of R&D, apart from ensuring a solid financial base for its higher education flagship, the University of Liechtenstein, established in its present form a decade ago. The government will also need to maintain a political framework that allows the country's prosperous industries to continue investing in R&D at the traditionally heady levels.

The future looks bright, for if there is one common feature which characterizes the four EFTA countries and explains their strength within Europe and beyond, it is their political stability.

KEY TARGETS FOR EFTA COUNTRIES

- Raise Iceland's GERD/GDP ratio to 3% by 2016;
- Iceland to introduce tax incentives to foster investment in innovative enterprises;
- Norway to invest US$ 250 million between 2013 and 2023 in funding research conducted by its 13 new centres of excellence;
- Switzerland to set up two innovation parks in the vicinity of ETHZ and EPFL, sponsored by the host cantons, the private sector and institutions of higher education;
- Switzerland has until the end of 2016 to resolve the current political problem with the EU regarding the free movement of persons, if it is to preserve its status of associated partner in Horizon 2020.

12. See for instance the editorial by EPFL President Patrick Aebischer, in EPFL's campus newspaper, *Flash*, in the days before the referendum.

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Hans Peter Hertig (b.1945: Switzerland) is a professor emeritus of the École polytechnique fédérale de Lausanne in Switzerland. He obtained a PhD in Political Science from the University of Berne in 1978. He has held positions at universities in Switzerland and the USA and is a former director of the Swiss National Science Foundation (1993–2005). He also established the Swiss science hub (Swissnex) in Shanghai (China). Hans Peter Hertig is an expert in cross-disciplinary programming, cultural exchange and science policy.