Innovative Activities in Switzerland - Strengths and Weaknesses. Background Report for the Midterm-assessment of the "Governmental Guidelines for the Promotion of Education, Research and Technology 2004-2007"

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Innovative Activities in Switzerland – Strengths and Weaknesses

Background Report for the
Midterm-assessment of the „Governmental Guidelines for the Promotion of Education, Research and Technology 2004-2007"

Spyros Arvanitis, Heinz Hollenstein and David Marmet

Study on behalf of the Swiss Federal Office for Professional Education and Technology (OPET)

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Contents

1 Introduction

Every fourth year, the Federal Government formulates guidelines for the policy of the Federal state in the fields of education, research and technology. The last policy paper dealing with the planned policy measures and the allocation of funds for the period 2004 to 2007, for the first time, integrated all three policy area in one single strategy document submitted to the Parliament. A second, even more important novelty, is the initiative to more systematically monitor the outcomes of the policy as decided by the Parliament. A mid-term assessment of the policy, taking place early 2006, should serve this objective and, at the same time, should prepare the ground for the formulation of the policy referring to the next planning period, i.e. 2008 to 2011.

Against this background, the present study, commissioned by The Swiss Federal Office for Professional Education and Technology, aims at describing and analysing structure and evolution of the innovative activities of the Swiss business sector in an international perspective (comparisons with other countries). The study is not policy-oriented; it is designed rather as a report presenting the most important features of the environment which the policy maker has to take into account.

More specifically, the analysis covers selected themes that are considered as highly relevant in this setting. The selection of the topics is the outcome of a dialogue between the contracting parties. Among other things, it was decided that "education" should not be part of the analysis, although it is a core area of the Swiss Innovation System.

In a first part (Chapter 2 to 4) of the study, we analyse to what extent the Swiss economy has progressed towards a "Knowledge-based economy". To this end, in addition to a more general investigation of the change of the industrial structure, we analyse in some detail the process of the foundation of new firms as a one of the means to renew economic structures. Moreover, it is investigated to what extent Switzerland is present in some leading-edge technologies which may shape the industrial structure in the future. A second part (Chapter 4 and 5) is devoted to business R&D. It aims at identifying specific strength and weaknesses of R&D activities, with special emphasis, on the one hand, on R&D networking (R&D contracts, R&D co-operation) and, on the other hand, on the outward- and inward dimension of the internationalisation of R&D. In Chapter 7, we study the functioning of the science/industry interface based on detailed data stemming from a recent KOF survey. Finally, taking as starting point the unfavourable evolution of the innovative activities of private firms in the course of the nineties, we analyse whether the Swiss economy is suffering from a structural innovation gap.

2 Structural Change: Towards a Knowledge-based Economy

2.1 Introduction

In this chapter we define structural change as the change of the value added and/or employment share of sectors and industries respectively in the period 1990-2002. Such changes reflect the dynamics of different parts of the economy; growing sectors increase their value added and/or employment share, shrinking ones show decreasing shares of value added and employment. Particularly, we are interested in changes of the shares of sectors which are commonly related to the "knowledge economy", meaning sectors in which technological knowledge is playing an increasingly important role. These are the high-tech sector (HT-sector) of manufacturing (chemicals, plastics, machinery, vehicles, electrical machinery and electronics/instruments)[1] and the sector of modern (knowledge-based) services (MS-sector) (banks, insurance, computer services, other business services – engineering, consulting etc.).[2] The sum of the high-tech sector and the sector of the modern services constitutes the "knowledge-intensive sector" (KI-sector) of the economy whose magnitude can be used as an indicator of the "knowledge intensity" of an economy.

2.2 Structural change 1990-2002

Table 2.1 shows the sector shifts with respect to (nominal) value added which took place in a number of countries in the period 1990-2002. The Swiss knowledge-intensive sector contributed 36.6% of the value added of the business sector in 1990, this share increased to 42.8% in 2002. This was the highest share among the 12 reference countries. Germany (2002: 40.3%), the USA (36.5%) and the UK (35.9%) showed also high shares of value added of the KI-sector. Also in dynamic terms the increase of the value added share of 6.2 percentage points (pp) from 36.6% to 42.8% was the highest among these countries. Finland and Sweden (1990-2002: increase by 4.8 pp), the Netherlands (4.6 pp) and Austria (4.5 pp) also showed a considerable growth of the KI-sector in the period 1990-2002 but the share of value added remained under 35%.

The high Swiss share of value added of the KI-sector is composed of a high share of the HT-sector (2002: 13.9%) as well as a high share of the MS-sector (28.9%) as the comparison with the reference countries shows. However, five countries (Ireland: 26.2%, Germany: 17.5%, Finland: 15.8%, Japan: 14.4% and Sweden: 14.3%) have higher or similar shares of the HT-sector. The Swiss share of high-tech manufacturing remained practically constant in the observation period;

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1 The high-tech sector contains the following 2-digit industries according to the NOGA classification: 23, 24, 25, 29, 30, 31, 32 ,33, 34 and 35. The low-tech sector contains the remaining 2-digit manufacturing industries: 15-22, 26-28, 36, 37. The selection of the high-tech industries is based on the standard OECD classification (sector approach; see Hatzichronoglou 1997) with the exception of plastics (25) which were added to the high-tech sector in this particular case.

2 The sector of modern services contains the following industries according to the NOGA classification: 65-67, 71-74. Due to data problems it was not possible to include telecommunication to the modern services.

whereas the share of low-tech manufacturing fell by 3.5 pp in the same period. On the contrary, the share of the HT-sector increased considerably in countries like Ireland (by 9.0 pp) and Finland (by 3.6 pp) which experienced a kind of "industrial renaissance" in the nineties. Switzerland has the highest share of value added of the MS-sector, followed by the USA (27.3%), the Netherlands (26.3%), the UK (26.1%) and France (25.0%). In dynamic terms, Switzerland, which experienced an increase of the MS-sector by 5.7 pp, ranks fourth after the UK (9.0 p), the Netherlands (8.1 pp) and Italy (6.5 pp; starting with a very low share).

Table 2.2 shows more specifically the structural change at industry level, focusing on the industry composition of the high-tech sector and the sector of modern services. This table makes clear that the Swiss HT-sector is basically a sector of (a) electrical and optical equipment (30.6% of value added of the HT-sector in 2002), chemicals and pharmaceuticals (30.6%) and machinery (25.0%). The share of electrical and optical equipment as well the share of chemicals/ pharmaceuticals (with the exception of Ireland)[3] is the highest among the reference countries. The dominance of the finance sector (banks and insurance: 59.3% in 2002) is the most outstanding trait of the Swiss MS-sector. On the contrary, other business services including such important industries as the software industry, engineering and consulting are rather weak (40.7% of value added of the MS-sector in 2002).

Table 2.3 shows the sector shifts with respect to employment (measured in full-time equivalents) which took place in the period 1990-2002. The changes of employment shares follow more or less the same pattern as the value added shares. However, there are some remarkable exceptions. Germany, France and the Netherlands have lower shares of value added of the KI-sector than Switzerland but the respective employment shares are higher than those of the Swiss KI-sector. This means that the KI-sector in these three countries are more labour-intensive than in Switzerland. A comparison of the figures for the HT-sector and the MS-sector shows that this employment effect can be traced back to the MS-sector. In this sector the employment share has grown in the period 1990-2002 only by 4.2 pp (value added share: 6.2 pp) due to the unfavourable development of employment of the Swiss finance sector in the second half of the nineties. The share of the finance sector fell between 1990 and 2002 from 43.8% to 36.5% of the employment of the MS-sector (see table 2-4).

3 However, the extremely high Irish share is not backed up by intensive R&D.

Table 2.1: Structural change: nominal value added shares by sectors and countries 1990-2002

Value added share in %

	Switzerland		Austria		Denmark		Finland		France		Germany		Ireland	
	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002	1992	2002	1990	2002
High-tech manufacturing	**13.4**	**13.9**	**11.4**	**11.2**	**10.6**	**10.8**	**12.2**	**15.8**	**12.4**	**12.0**	**19.5**	**17.5**	**17.2**	**26.2**
Low-tech manufacturing	12.9	9.4	15.3	13.1	13.4	11.0	17.7	14.7	13.3	11.0	12.6	10.5	18.9	12.4
Manufacturing	*26.3*	*23.3*	*26.7*	*24.3*	*23.9*	*21.8*	*29.9*	*30.5*	*25.7*	*23.0*	*32.1*	*28.0*	*36.1*	*38.5*
Construction	10.2	6.9	9.3	9.6	7.3	7.3	11.6	7.2	7.6	6.6	8.5	5.9	7.6	10.0
Modern Services	**23.2**	**28.9**	**15.1**	**18.8**	**17.3**	**19.3**	**12.9**	**14.2**	**21.6**	**25.0**	**19.9**	**22.8**	na	na
Traditional Services	37.5	37.3	43.1	42.6	47.4	47.3	41.2	44.5	40.7	41.7	35.4	40.0	na	na
Services	*60.7*	*66.3*	*58.1*	*61.5*	*64.7*	*66.6*	*54.1*	*58.7*	*62.3*	*66.7*	*55.3*	*62.8*	*58.9*	*59.3*
Energy	2.9	3.6	5.9	4.6	4.1	4.3	4.4	3.7	4.4	3.7	4.1	3.3	5.0	2.2
Business Sector	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Knowledge-intensive sector	***36.6***	***42.8***	***26.5***	***30.0***	***27.8***	***30.1***	***25.2***	***30.0***	***34.0***	***37.1***	***39.4***	***40.3***	*na*	*na*
Share Business / Total Economy	79.1	79.5	74.6	77.5	68.9	68.4	71.3	74.6	75.4	73.9	77.1	76.8	70.8	80.9

	Switzerland		Italy		Japan		Netherlands		Sweden		United Kingdom		United States	
	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002
High-tech manufacturing	**13.4**	**13.9**	**12.5**	**10.3**	**17.0**	**14.4**	**11.8**	**8.3**	**13.4**	**14.3**	**14.6**	**9.8**	**11.7**	**9.2**
Low-tech manufacturing	12.9	9.4	16.2	13.1	14.5	10.4	14.4	11.6	14.2	13.0	14.2	9.9	11.1	9.0
Manufacturing	*26.3*	*23.3*	*28.8*	*23.5*	*31.5*	*24.8*	*26.2*	*19.9*	*27.6*	*27.3*	*28.8*	*19.7*	*22.9*	*18.2*
Construction	10.2	6.9	8.0	6.4	12.1	8.6	8.6	8.3	9.4	6.1	8.9	7.7	5.8	6.1
Modern Services	**23.2**	**28.9**	**13.9**	**20.4**	**13.8**	**18.6**	**18.2**	**26.3**	**15.5**	**19.3**	**17.1**	**26.1**	**22.9**	**27.3**
Traditional Services	37.5	37.3	44.7	45.1	37.4	42.3	42.8	42.1	42.3	42.9	41.0	43.6	44.4	45.1
Services	*60.7*	*66.3*	*58.6*	*65.5*	*51.2*	*60.9*	*61.1*	*68.5*	*57.8*	*62.3*	*58.2*	*69.7*	*67.3*	*72.4*
Energy	2.9	3.6	4.7	4.6	5.1	5.7	4.1	3.3	5.2	4.3	4.1	2.9	3.9	3.3
Business Sector	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Knowledge-intensive sector	***36.6***	***42.8***	***26.4***	***30.7***	***30.8***	***33.0***	***30.0***	***34.6***	***28.9***	***33.7***	***31.8***	***35.9***	***34.6***	***36.5***
Share Business / Total Economy	79.1	79.5	76.5	77.3	79.1	76.5	69.0	70.9	71.3	72.4	75.0	74.7	73.2	74.4

Knowledge-intensive sector: high-tech manufacturing and modern services. Source: STAN database, OECD; authors' calculations.

Table 2.2: Structural change: employment shares by sectors and countries 1990-2002

Employment share in %

	Switzerland Full-time equivalent		Austria Full-time equivalent		Denmark Persons		Finland Persons		France Full-time equivalent		Germany Persons		Ireland Persons	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
High-tech manufacturing	**15.0**	**14.0**	**11.9**	**10.3**	**12.1**	**11.0**	**11.4**	**13.9**	**12.5**	**10.9**	**21.1**	**16.3**	na	na
Low-tech manufacturing	15.4	13.1	20.9	16.7	19.3	15.7	20.9	18.4	17.9	14.9	18.4	14.0	na	na
Manufacturing	*30.4*	*27.1*	*32.7*	*26.9*	*31.4*	*26.6*	*32.3*	*32.3*	*30.4*	*25.7*	*39.4*	*30.3*	na	na
Construction	13.7	11.4	11.3	11.4	9.3	10.1	12.8	10.6	11.9	10.2	10.4	9.6	na	na
Modern Services	**15.8**	**21.1**	**11.9**	**16.6**	**15.7**	**19.2**	**12.9**	**16.1**	**19.2**	**24.7**	**12.9**	**20.5**	na	na
Traditional Services	39.2	39.5	42.3	43.6	42.6	43.4	40.2	39.8	37.0	38.2	35.7	38.4	na	na
Services	*55.0*	*60.6*	*54.3*	*60.2*	*58.3*	*62.5*	*53.1*	*55.8*	*56.3*	*62.9*	*48.6*	*58.9*	na	na
Energy	0.9	0.9	1.7	1.5	1.0	0.8	1.8	1.2	1.4	1.2	1.6	1.1	na	na
Business Sector	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*na*	*na*
Knowledge-intensive sector	***30.8***	***35.0***	***23.8***	***26.9***	***27.9***	***30.1***	***24.3***	***30.0***	***31.7***	***35.6***	***34.0***	***36.8***	*na*	*na*

	Switzerland Full-time equivalent		Italy Full-time equivalent		Japan Persons		Netherlands Full-time equivalent		Sweden Persons		United Kingdom Persons		United States Full-time equivalent	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
High-tech manufacturing	**15.0**	**14.0**	**11.5**	**10.8**	**14.5**	**12.5**	**10.9**	**8.2**	**13.9**	**14.0**	**na**	**na**	**11.4**	**9.3**
Low-tech manufacturing	15.4	13.1	22.7	20.0	20.5	16.4	17.6	13.5	18.0	15.1	na	na	13.2	10.5
Manufacturing	30.4	27.1	34.2	30.9	35.0	28.9	28.5	21.7	31.9	29.1	na	na	24.6	19.8
Construction	13.7	11.4	10.2	10.1	14.7	15.7	11.2	11.0	11.1	9.1	na	na	8.1	9.3
Modern Services	**16.5**	**22.0**	**na**	**17.5**	**12.8**	**14.0**	**20.8**	**28.1**	**na**	**21.0**	**na**	**na**	**20.2**	**24.2**
Traditional Services	38.5	38.6	na	40.7	36.3	40.1	38.3	38.5	na	39.7	na	na	45.9	45.8
Services	*55.0*	*60.6*	*na*	*58.2*	*49.1*	*54.1*	*59.1*	*66.5*	*na*	*60.6*	*na*	*na*	*66.1*	*70.0*
Energy	0.9	0.9	na	0.9	1.2	1.3	1.2	0.8	na	1.2	na	na	1.3	1.0
Business Sector	*100.0*	*100.0*	*na*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*na*	*100.0*	*na*	*na*	*100.0*	*100.0*
Knowledge-intensive sector	*31.5*	*36.0*	*na*	*28.3*	*27.3*	*26.5*	*31.7*	*36.3*	*na*	*35.0*	*na*	*na*	*31.6*	*33.4*

Knowledge-intensive sector: high-tech manufacturing and modern services. Source: STAN database, OECD; authors' calculations.

Table 2.3: Structural change: shares of nominal value added of selected industries 2002

Share of value added in %

	CH	AUT	DNK	FIN	FRA	GER	IRL	ITA	JPN	NLD	SWE	UK	USA
Chemical, rubber, plastics and fuel products	36.0	26.2	38.9	21.1	38.3	26.8	69.6	32.5	30.5	46.7	31.7	37.9	36.1
thereof:													
Rubber and plastics products	*5.4*	*9.9*	*11.9*	*6.9*	*8.9*	*8.3*	*1.8*	*10.1*	*2.2*	*8.0*	*5.9*	*10.8*	*9.2*
Chemicals and chemical products	*30.6*	*12.9*	*26.4*	*11.0*	*22.3*	*16.6*	*67.8*	*20.2*	*15.8*	*31.9*	*24.6*	*23.5*	*23.3*
Machinery and equipment	25.0	28.4	29.5	21.7	13.6	25.3	2.6	30.2	15.5	20.0	26.4	16.4	13.6
Transport equipment	3.3	17.2	6.2	8.1	27.2	25.5	1.5	15.3	24.0	12.3	25.3	21.9	25.7
Electrical and optical equipment	35.7	28.2	25.3	49.2	21.0	22.4	26.3	22.0	29.9	20.9	16.5	23.8	24.6
Thereof:													
Office, accounting and computing machinery	*na*	*0.9*	*1.0*	*0.1*	*1.3*	*1.2*	*6.0*	*0.7*	*2.9*	*na*	*1.1*	*3.5*	*na*
Electrical machinery and apparatus, nec	*7.9*	*10.5*	*9.6*	*4.9*	*8.3*	*11.2*	*3.8*	*10.1*	*8.5*	*na*	*6.5*	*7.1*	*na*
Radio, television and communication equipment	*5.3*	*11.8*	*5.1*	*39.0*	*4.0*	*3.6*	*7.0*	*5.2*	*15.8*	*na*	*1.6*	*5.8*	*na*
Medical, precision and optical instruments, watches and clocks	*22.6*	*4.9*	*9.6*	*5.3*	*7.4*	*6.4*	*9.5*	*6.0*	*2.6*	*na*	*7.3*	*7.5*	*na*
High-tech manufacturing	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

	CH	AUT	DNK	FIN	FRA	GER	IRL	ITA	JPN	NLD	SWE	UK	USA
Financial intermediation total	59.3	38.5	39.3	35.2	25.8	22.3	na	37.0	46.1	33.8	25.7	32.7	38.4
Thereof: Financial intermediation except insurance and pension funds	*40.1*	*24.5*	*29.0*	*21.2*	*18.2*	*15.0*	*na*	*27.0*	*na*	*20.5*	*na*	*18.9*	*17.9*
Other business activities (incl. renting of machinery and equipment)	40.7	61.5	60.7	64.8	74.2	77.7	na	63.0	53.9	66.2	74.3	67.3	61.6
Thereof:													
Renting of machinery and equipment	*na*	*8.4*	*3.1*	*2.7*	*5.4*	*9.3*	*na*	*na*	*na*	*5.9*	*3.3*	*5.4*	*4.8*
Computer and related activities	*8.3*	*10.2*	*11.1*	*17.6*	*11.4*	*11.1*	*na*	*12.5*	*na*	*9.9*	*18.0*	*13.3*	*7.9*
Research and development	*1.8*	*1.6*	*2.5*	*4.6*	*7.1*	*2.2*	*na*	*na*	*na*	*2.3*	*na*	*2.1*	*na*
Other business activities	*30.6*	*41.3*	*44.0*	*39.9*	*50.4*	*55.1*	*na*	*50.5*	*na*	*48.1*	*53.0*	*46.4*	*48.9*
Modern Services	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**na**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: STAN database, OECD; authors' calculations.

Table 2.4: Structural change: employment shares of selected industries 1991-2001

Employment share in %

	Switzerland FTE		Austria FTE		Denmark Persons		Finland Persons		France FTE		Germany Persons		Ireland Persons	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
Chemical, rubber, plastics and fuel products	25.1	25.1	23.5	22.9	24.4	26.9	23.6	20.5	29.3	29.1	22.0	22.2	29.8	27.6
thereof:														
Rubber and plastics products	*6.1*	*7.1*	*11.8*	*10.5*	*13.3*	*14.5*	*12.5*	*9.6*	*14.6*	*13.7*	*13.2*	*11.9*	*19.2*	*19.8*
Chemicals and chemical products	*19.0*	*18.0*	*10.3*	*11.5*	*10.7*	*12.1*	*8.9*	*9.2*	*11.6*	*13.4*	*8.0*	*9.8*	*10.6*	*7.8*
Machinery and equipment	34.9	30.4	30.7	32.7	40.4	37.0	36.5	31.9	20.3	19.6	29.6	27.3	16.2	11.4
Transport equipment	2.6	5.4	12.4	13.5	10.9	9.2	16.3	12.5	24.3	24.2	19.6	24.5	11.6	8.1
Electrical and optical equipment	37.5	39.2	33.5	30.9	24.4	26.9	23.7	35.1	26.1	27.1	28.8	26.0	42.4	52.8
thereof:														
Office, accounting and computing machinery	*na*	*na*	*0.2*	*0.5*	*1.3*	*1.0*	*1.6*	*0.3*	*1.3*	*1.5*	*2.5*	*1.2*	*10.5*	*15.9*
Electrical machinery and apparatus, nec	*12.3*	*11.1*	*13.1*	*11.9*	*9.0*	*10.5*	*10.4*	*8.8*	*9.4*	*10.1*	*13.2*	*13.2*	*13.5*	*10.6*
Radio, television and communication equipment	*na*	*na*	*13.8*	*11.7*	*5.9*	*6.9*	*7.2*	*19.5*	*7.2*	*7.4*	*5.4*	*4.0*	*6.4*	*10.4*
Medical, precision and optical instruments, watches and clocks	*na*	*na*	*6.5*	*6.7*	*8.2*	*8.5*	*4.5*	*6.5*	*8.2*	*8.1*	*7.7*	*7.6*	*12.1*	*16.0*
High-tech manufacturing	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

	Switzerland FTE		Austria FTE		Denmark Persons		Finland Persons		France FTE		Germany Persons		Ireland Persons	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
Financial intermediation total	43.8	36.5	41.4	27.2	32.7	23.4	33.9	17.7	28.2	21.1	34.6	23.3	na	na
thereof: Financial intermediation except insurance and pension funds	*na*	*na*	*27.6*	*18.0*	*24.4*	*16.9*	*27.3*	*12.0*	*16.4*	*11.3*	*21.6*	*14.3*	*na*	*na*
Other business activities (incl. renting of machinery and equipment)	56.2	63.5	58.6	72.8	67.3	76.6	66.1	82.3	71.8	78.9	65.4	76.7	na	na
thereof:														
Renting of machinery and equipment	*na*	*na*	*2.4*	*2.0*	*2.6*	*2.2*	*2.0*	*1.9*	*2.1*	*2.5*	*1.7*	*1.6*	*na*	*na*
Computer and related activities	*na*	*na*	*4.8*	*10.3*	*9.0*	*13.1*	*9.4*	*19.3*	*6.9*	*9.6*	*5.9*	*8.5*	*na*	*na*
Research and development	*na*	*na*	*1.2*	*1.4*	*4.4*	*2.6*	*5.7*	*5.8*	*9.8*	*7.8*	*2.9*	*2.5*	*na*	*na*
Other business activities	*47.6*	*49.1*	*50.1*	*59.1*	*51.3*	*58.7*	*49.1*	*55.4*	*52.9*	*59.0*	*54.8*	*64.2*	*na*	*na*
Modern Services	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**na**	**na**

Employment share in %

	Switzerland FTE		Italy FTE		Japan Persons		Netherlands FTE		Sweden Persons		United Kingdom Persons		United States FTE	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
Chemical, rubber, plastics and fuel products	25.1	25.1	24.9	26.1	12.6	12.7	33.0	30.7	18.1	18.5	27.2	29.0	24.4	na
thereof:														
Rubber and plastics products	*6.1*	*7.1*	*13.5*	*13.4*	*8.0*	*8.8*	*22.7*	*19.9*	*10.4*	*10.8*	*14.8*	*13.8*	*12.6*	*na*
Chemicals and chemical products	*19.0*	*18.0*	*10.0*	*11.3*	*3.9*	*3.2*	*8.4*	*8.9*	*7.0*	*6.9*	*10.7*	*13.3*	*10.0*	*na*
Machinery and equipment	34.9	30.4	30.3	31.5	25.5	25.9	21.1	24.7	30.6	27.0	24.1	20.6	21.0	na
Transport equipment	2.6	5.4	18.5	15.6	18.3	20.8	16.7	16.7	27.0	26.6	23.1	22.9	22.1	na
Electrical and optical equipment	37.5	39.2	26.3	26.8	43.7	40.6	29.2	27.9	24.3	28.0	25.6	27.5	32.5	na
thereof:														
Office, accounting and computing machinery	*na*	*na*	*1.1*	*1.0*	*5.2*	*4.7*	*na*	*2.2*	*na*	*1.0*	*na*	*na*	*3.5*	*na*
Electrical machinery and apparatus, nec	*na*	*na*	*12.5*	*12.8*	*14.7*	*12.9*	*na*	*6.5*	*na*	*8.2*	*na*	*na*	*7.0*	*na*
Radio, television and communication equipment	*na*	*na*	*6.1*	*6.3*	*18.6*	*18.6*	*na*	*12.3*	*na*	*12.2*	*na*	*na*	*10.7*	*na*
Medical, precision and optical instruments, watches and clocks	*na*	*na*	*6.5*	*6.7*	*5.2*	*4.3*	*na*	*7.0*	*na*	*6.5*	*na*	*na*	*11.2*	*na*
High-tech manufacturing	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**na**

	Switzerland FTE		Italy FTE		Japan Persons		Netherlands FTE		Sweden Persons		United Kingdom Persons		United States FTE	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
Financial intermediation total	43.8	36.5	na	22.4	38.3	32.7	27.8	21.4	na	17.3	na	na	36.4	28.1
thereof: Financial intermediation except insurance and pension funds	*na*	*na*	*na*	*13.7*	*na*	*na*	*16.9*	*12.5*	*na*	*na*	*na*	*na*	*17.8*	*13.1*
Other business activities (incl. renting of machinery and equipment)	56.2	63.5												
thereof:			*na*	*77.6*	*61.7*	*67.3*	*72.2*	*78.6*	*na*	*82.7*	*na*	*na*	*63.6*	*71.9*
Renting of machinery and equipment	*na*	*na*	*na*	*na*	*na*	*na*	*1.7*	*1.9*	*na*	*1.9*	*na*	*na*	*na*	*na*
Computer and related activities	*na*	*na*	*na*	*14.3*	*na*	*na*	*5.0*	*9.5*	*na*	*18.8*	*na*	*na*	*na*	*na*
Research and development	*na*	*na*	*na*	*na*	*na*	*na*	*2.6*	*2.2*	*na*	*na*	*na*	*na*	*na*	*na*
Other business activities	*47.6*	*49.1*	*na*	*63.3*	*na*	*na*	*62.9*	*65.0*	*na*	*62.0*	*na*	*na*	*na*	*na*
Modern Services	**100.0**	**100.0**	**na**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**na**	**100.0**	**na**	**na**	**100.0**	**100.0**

FTE: full-time equivalents. Source: STAN database, OECD; authors' calculations.

2.3 Assessment

The Swiss business sector has well proceeded on the way to a knowledge-based economy in the last fifteen years. This is demonstrated by the high shares in value added and employment of the KI-sector as well as the large increase of these shares compared to the 12 reference countries in the period 1990-2002. The MS-sector builds the bulk of the KI-sector. The financial sector clearly dominates the sector of modern services. This is a *relative structural strength* of the Swiss business sector. Viewed the other way around, the small share of other business services, particularly computer services, seems to be a *relative structural weakness* of the Swiss economy. The HT-sector builds primarily on pharmaceutical products and scientific instruments, both product groups with a large growth potential. The share of Swiss HT-sector did not grow between 1990 and 2002 as e.g. in Finland because the leading manufacturing industries of the nineties (computers, electronics, aircraft, and aerospace) remained poorly developed in Switzerland, which is a further *relative structural weakness* of Swiss manufacturing (see also Chapter 4).

3 Formation of Knowledge-Based Firms

3.1 Introduction

New firms in high-tech manufacturing and/or knowledge-based services (new knowledge-based firms), particularly new firms which are spin-offs of universities, are considered as an important vehicle for the introduction and diffusion of new technological knowledge. Young innovative firms can be the source of product innovations either through their expansion over a longer period of time (e.g. the famous case of Microsoft) or through the merger with a large incumbent firm which then provides for the further development and diffusion of innovation (e.g. in the area of biotechnology).

3.2 Formation of Firms in Switzerland 1985-2001

In this section we present data on market dynamics by sector based on an analysis of data of the Swiss Plant Census 1985, 1991, 1995, 1998 and 2002. The available information at plant level permits only the identification of one-plant firms entering or exiting a certain industry in a period t_1-t_2. Thus, the new firms identified in this way are not only greenfield start-ups but also management-buyouts, existing firms which changed proprietors and so on. The calculated entry and exit rates in table 3.1 describe the market turbulence between 1985 and 2001 which reflects quite precisely the fluctuation of economic activity at the aggregate level in this period. In order to be able to compare the figures in the four periods of varying length considered in this study we calculated an (approximately) average annual rate of entry/exit by dividing the figures in table 3.1 through the number of years of the respective period.

The average *net* annual entry rate in the business sector was 2.8% in the period 1985-1991, 0.3% in 1991-1995, 2.4% in 1995-1998, and 0.9% in 1998-2001 respectively. By comparing the figures for the entire business sector with those of single sectors we gain an impression about the varying market dynamics among these sectors. In all four periods the net entry rate was considerably higher in high-tech than in low-tech manufacturing. The average net annual entry rate in high-tech manufacturing was 3.7% in the period 1985-1991, -0.1% in 1991-1995, 1.0% in 1995-1998 and 1.4% in 1998-2001. Thus, in boom periods the entry rate of HT-firms was above the aggregate rate, in stagnation or recession periods it remained under the aggregate rate. The sector of modern services showed the most dynamic development. The net entry rate remained high over all four periods, quite above the average rate: 7.9%, 3.3%, 5.2%, and 4.6% respectively. Thus, this sector was the main source of new firms in the economy between 1985 and 2001 reflecting the dynamic development of the entire sector of modern services in this period.

The relative importance of the various sectors with respect to the total number of firms is shown in table 3.2. The share of firms of the HT-sector remained almost constant over the whole period (3.6% to 4.0%), that of the MS-sector rose from 16.0% (1985) to 26.9% (2001). The shares of low-tech manufacturing and traditional services fell considerably in the same period.

Unfortunately international comparisons of the dynamics of the formation of new firms, particularly of new firms in the KI-sector, defined e.g. as rates of entry of new firms in a certain industry over time, are quite difficult to realize due to lack of comparable data. Nevertheless, we achieved to construct such a comparison by combining data from several sources (see table 3.3). If we compare the *gross* entry rates, the Swiss economy ranks quite low, almost at the last position, among the 10 reference countries (7.7%), while countries such as Germany (17.0%), the USA and France show considerably higher entry rates (13.0% to 17.0%). At the same time most of the countries with a gross entry rate higher than that in Switzerland show also a high exit rate. As a consequence, their *net* entry rates are lower than in Switzerland. By comparing the net entry rates Switzerland ranks somewhat in the middle of the 10 countries (0.5%), quite near Italy (0.8%). With the exception of France (11.0%) the net entry rates of the other countries are not far away from that of Switzerland.

What about the market dynamics in the KI-sector? We dispose only of information on the sectoral composition of single cohorts of greenfield start-ups of the years 1996/97, 1999, 2000, 2001, and 2002. As shown in table 3.4 the sector of modern services dominates the formation of start-ups in every year. The share of new firms of the MS-sector varies between 42.5% and 47.9%. About 30% of all new firms belong to other business services, about 10% to computer services. The share of high-tech firms was rather low and remained quite stable over the time at about 2.5%. The share of new firms of the entire KI-sector, i.e. the sum of the two sectors, amounted to about 48%.

Table 3.5 shows that the sectoral composition of new firms was quite similar in various European countries in 2001. It is quite remarkable that Switzerland had the highest share of new software firms in this year (12.2%).

In sum, modern services are the most dynamic sector of the Swiss economy also with respect to the formation of new firms. In manufacturing which has been much less dynamic than modern services in terms of value added and employment growth in the last fifteen years, we observe in the high-tech sector a considerably higher growth potential also for new firms than in the low-tech sector. The international comparison shows that the Swiss rate of new firm formation, defined as a net, effective rate, is at the OECD average. Moreover, the contribution of start-ups in the most dynamic sectors of the economy to new firm formation as a whole is about of the same magnitude as in other European countries.

Table 3.1: Business dynamics: entry and exit rates of one-plant enterprises in the business sector by sector 1985-2001

	Period 1985 – 1991			Period 1991 – 1995			Period 1995 – 1998			Period 1998 – 2001		
	Entry	Exit	Net entry	Entry	Exit	Net entry	Entry	Exit	Net entry	Entry	Exit	Net entry
High-tech Manufacturing	43.1	21.2	21.9	23.7	24.1	-0.4	19.4	16.3	3.2	21.5	17.1	4.3
Low-tech Manufacturing	32.7	25.3	7.4	21.8	27.1	-5.3	18.5	17.8	0.7	18.4	20.2	-1.8
Construction	40.0	22.9	17.1	25.9	26.0	-0.1	24.0	17.5	6.5	22.6	20.5	2.0
Modern Services	77.1	29.6	47.5	46.0	33.0	13.1	38.3	22.6	15.6	39.5	25.7	13.8
Traditional Services	39.2	29.2	9.9	28.0	29.4	-1.4	25.5	20.0	5.5	21.9	23.9	-2.0
Business Sector total	44.6	27.7	16.9	30.4	29.2	1.2	27.0	19.8	7.2	25.8	23.3	2.6

Entry rate t_1-t_2 : number of one-plant firms entering a certain sector in the period t_1-t_2 divided by the total number of firms in this sector in t_1; exit rate t_1-t_2 : number of one-plant firms exiting a certain sector in the period t_1-t_2 divided by the total number of firms in this sector in t_1;

Sources: Swiss Federal Statistical Office, authors' calculations.

Table 3.2: Number of one-plant business enterprises by sector as a percentage of the total number of firms in the Swiss business sector 1985-2001

	1985	1991	1995	1998	2001
High-tech manufacturing	3.8	4.0	3.9	3.6	3.7
Low-tech manufacturing	14.2	12.9	12.4	11.4	11.1
Construction	12.3	12.3	12.7	12.7	12.7
Modern Services	16.0	20.2	22.1	24.1	26.9
Traditional Services	53.5	50.5	48.7	48.1	45.5
Energy	0.1	0.1	0.1	0.1	0.1
Business Sector total	100.0	100.0	100.0	100.0	100.0
Number of firms, total	203'208	237'609	240'436	257'646	264'299

Sources: Swiss Federal Statistical Office, authors' calculations.

Table 3.3: Business dynamics: entry and exit rates of new firms for selected countries 2001

Country	Entry rate (%)	Exit rate (%)
Switzerland	7.7 2)	7.2 2)
Germany	17.0 3)	13.0 3)
France	13.0 3)	2.0 3)
Italy	7.8	7.0
Great Britain	8.9	10.6
USA	15.0 3)	16.0 3)
Japan	na	Na
Finland	7.3	7.3
Sweden	7.0	5.5
Denmark	10.0	9.7
Austria	Na	na
Netherlands	9.4	10.2

Sources: Eurostat; 2) Swiss Federal Statistical Office; 3) Klandt and Brüning (2002); average entry and exit rates of the period 1988-1994.

Table 3.4: Sectoral composition of new firm formation in the Swiss business sector

	1996/97	1999	2000	2001	2002	2003
High-tech manufacturing	2.5	2.6	2.5	2.5	2.4	2.6
Low-tech manufacturing	5.5	4.7	4.9	5.4	4.9	5.1
Construction	8.9	10.1	10.4	11.1	10.6	9.9
Modern Services 1)	42.5	46.2	46.8	47.9	45.2	43.8
thereof:						
Financial Intermediation	*2.1*	*1.9*	*2.5*	*3.3*	*3.3*	*4.5*
Computer Services	*7.6*	*11.2*	*12.9*	*12.9*	*10.5*	*8.6*
Other business services	*31.9*	*31.6*	*30.3*	*30.8*	*30.6*	*29.9*
Traditional Services	40.7	36.4	35.4	33.1	36.9	38.6
Business Sector	100.0	100.0	100.0	100.0	100.0	100.0

1) incl. Telecommunication.

Sources: Swiss Federal Statistical Office, authors' calculations.

Table 3.5: Sectoral composition of new firm formation for selected countries 2001

Country	Manu-facturing	High-tech manu-facturing	Financial Inter-mediation	Computer Services	Other Business Services
Switzerland	7.5	2.3	3.1	12.2	29.2
Denmark	5.9	1.4	0.9	9.7	29.3
Italy	9.0	2.0	2.1	3.6	24.8
Netherlands	5.3	1.4	6.1	6.5	26.7
Finland	8.1	1.7	2.3	4.0	21.1
Sweden	6.7	1.2	0.9	6.4	32.4
United Kingdom 1)	7.2	1.7	1.3	9.9	24.8

1) Year 2000.
Sources: Eurostat, Swiss Federal Statistical Office, authors' calculations.

3.3 Impediments of Formation and Growth of Knowledge-based Firms

We compare the frequency of various categories of impediments of new firm formation for firms of the HT-sector, the MS-sector and all firms of the new firm cohort of 1996/97 (table 3.6). We comment only on deviations from the average of the entire business sector, which could indicate to impediments that are specific to knowledge-based new firms.

Lack of financial resources seem to be the most important category of impediments for new firms of the HT-sector which were founded in 1996/97 and were still operating in 2003. High-tech firms assessed internal finance as insufficient to a considerable larger extent than the average of all firms (36.5% versus 26.6%). 21.7% of HT-firms feared that an expansion of the group of proprietors who could bring new capital to the firm would endanger the firm's autonomy; only 12.0% of all firms found this to be a serious problem. There were almost no differences between the assessment of all firms and HT-firms with respect to venture capital supply and external financing restrictions. Lack of qualified personnel is the second important source of problems for new high-tech firms, also in this case to a larger extent as for all firms (35.% vs. 27.0%). A third relevant impediment of founding activities was for high-tech firms the burden of too high income taxes (30.8% vs. 22.9% of all firms). There were no significant differences between all firms and high-tech firms with respect to the assessment of the relative significance of other important impediments reported in table 3.6.

New firms of the sector of modern services seem to be confronted with the same kind of difficulties as new firms on average. In no single category of impediments of some relevance for at least 20% of firms new MS-firms reported to have more serious problems than all firms on average.

Firms of the HT-sector which ceased to operate in the period 2000-2003 showed a pattern of impediments which diverged considerably from that of firms which survived in this period. These firms did not find insufficient internal financing a considerable restriction but unfavourable credit conditions (external financing) (40.0% vs. 28.2% of all firms). New partners endangering autonomy, too high income tax and too expensive qualified personnel were also for this group of firms serious obstacles, but to a much larger extent than for firms which survived; 40.0% of firms which ceased to operate reported that they were confronted with considerable difficulties in each of these categories. Moreover, 40.0% of them found too high market and technical risks an important impediment of founding activities. On the whole, firms of the HT-sector which did not survive seem to have much more serious financial problems than those which survived. Presumably this is also the reason why they assessed market and technical risks to be more threatening than surviving firms.

Firms of the MS-sector which did not survive in the period 2000-2003 do not seem to have been confronted with more serious problems than survivor firms.

Table 3.6: Impediments of formation of new firms: assessment of firms founded in 1996/97 which were still operating in 2003

	Total	High-tech manufacturing	Modern services
Financial impediments			
Insufficient internal finance	26.6	36.7	21.3
New partners endanger autonomy	12.0	21.7	13.2
No venture capital	9.7	9.2	6.9
Unfavourable credit conditions	21.4	22.5	14.1
Unfavourable credit limits	20.8	16.7	15.0
Lack of information for external finance	12.7	18.3	10.1
Tax burden			
High taxes on earnings and capital	13.8	20.8	13.0
High income tax / tax on assets	22.9	30.8	20.9
High real estate tax	6.3	4.2	4.5
Business risks			
High market risks	15.1	16.7	11.9
High technical risks	8.6	4.2	9.1
Insufficient imitation protection	7.7	9.2	8.0
Information problems			
Lack of information on technological potential	3.3	0.0	2.8
Lack of information on market opportunities	9.5	16.7	9.1
Qualified personnel			
Expensive qualified personnel	19.5	20.8	18.2
Lack of qualified personnel	27.0	35.0	26.0

Percentage of firms reporting values 4 or 5 at a five-point Likert scale (1: "not important"; 5. "very important").
Source: KOF-Survey of start-ups 2000.

Table 3.7: Impediments of formation of new firms: assessments of firms founded in 1996/97 which ceased to operate in the period 2000-2003

	Total	High-tech manufacturing	Modern services
Financial impediments			
Insufficient internal finance	31.6	20.0	27.7
New partners endanger autonomy	10.7	40.0	11.1
No venture capital	12.5	0.0	13.4
Unfavourable credit conditions	28.2	40.0	24.1
Unfavourable credit limit	24.9	0.0	20.1
Lack of information for external finance	18.9	20.0	16.6
Tax burden			
High taxes on earnings and capital	15.5	20.0	17.2
High income tax / tax on assets	27.7	40.0	29.3
High real estate tax	10.0	0.0	6.7
Business risks			
High market risks	21.9	40.0	17.4
High technical risks	13.6	40.0	11.1
Insufficient imitation protection	11.0	20.0	11.2
Information problems			
Lack of information on technological potential	6.5	20.0	5.1
Lack of information on market opportunities	13.1	20.0	10.8
Qualified personnel			
Expensive qualified personnel	28.9	40.0	29.1
Lack of qualified personnel	31.8	20.0	29.5

Percentage of firms reporting values 4 or 5 at a five-point Likert scale (1: “not important”; 5. “very important”).
Source: KOF-Survey of start-ups 2000.

Finally, table 3.8 contains some information on obstacles to newly founded firms in the first six to seven years of operation. Again we focus on the firms in high-tech manufacturing and in modern services. Instead of insufficient internal financing growing firms find the conditions of external crediting unfavourable, to a larger extent than all firms on average (27.5% vs. 22.9%). In this development stage firms still find new partners to be a danger for their autonomy (26.7% vs. 14.0%), and income taxes (34.2% vs. 27.5%) particularly revenue and capital taxes (43.3% vs. 18.6%), to be too high. Moreover problems of availability of qualified personnel (40.0% vs. 31.9%) at wages which can be paid by such firms (47.5% vs. 25.5%) seem to be accentuated. New kinds of problems are added to the old ones: insufficient imitation protection (28.3% vs. 11.8%), technical risks (20.8% vs. 9.4%) and insufficient public promotion of technology (29.2% vs. 10.2%) hamper innovative activities of new HT-firms to a larger extent than other firms. Finally, structural problems such as the regulation of domestic markets (23.2% vs. 13.6%) and the restricted access to EU markets (18.3% vs. 10.6%) built much more considerable obstacles to the development of newly founded firms in the HT-sector than in the rest of the economy.

Once more we could not find any significant differences between the MS-sector and the business sector on average with respect to the impediments of growth listed in table 3.8.

Table 3.8: Impediments of growth of newly founded firms

	Total	High-tech manufacturing	Modern services
Financial problems			
Insufficient internal finance	23.4	22.5	17.5
New partners endanger autonomy	14.0	26.7	13.1
No venture capital	10.6	13.3	9.2
Unfavourable credit conditions	22.9	27.5	17.5
Unfavourable credit limit	19.9	22.5	16.4
Lack of information for external finance	11.9	16.7	8.6
Tax burden			
High taxes on earnings and capital	18.6	43.3	20.5
High income tax / tax on assets	27.5	34.2	27.6
High real estate tax	9.2	13.3	9.5
Business risks			
High market risks	24.5	15.0	22.8
High technical risks	9.4	20.8	10.5
Insufficient imitation protection	11.8	28.3	10.8
Information problems			
Lack of information on technological potential	4.8	0.0	5.4
Lack of information on market opportunities	11.5	22.5	10.9
Qualified personnel			
Expensive qualified personnel	25.5	47.5	22.0
Lack of qualified personnel	31.9	40.0	28.7
Public regulation			
Restricted access to EU markets	10.6	18.3	7.8
Regulation of domestic markets	13.6	23.3	12.5
Restrictive immigration policy	8.4	10.0	8.0
Regulations of environmental protection	5.2	8.3	2.7
Land utilisation and construction regulations	10.3	15.0	9.0
Contact with public authorities	17.4	19.2	18.9
Request for authorisation	14.7	15.0	14.2
Insufficient public promotion of technology	10.2	29.2	8.3

Percentage of firms reporting values 4 or 5 at a five-point Likert scale (1: "not important"; 5. "very important").
Source: KOF-Survey of start-ups 2003.

3.4 Assessment

Modern services are the most dynamic sector of the Swiss economy also with respect to the formation of new firms. In manufacturing which has been much less dynamic than modern services in terms of value added and employment growth in the last fifteen years, we observe in the high-tech sector a considerably higher growth potential also for new firms than in the low-tech sector. The international comparison shows that the Swiss rate of new firm formation, defined as a net, effective rate, is at the OECD average. Moreover, the contribution of start-ups in the most dynamic sectors of the economy to new firm formation as a whole is about of the same magnitude as in other European countries.

New high-tech firms seem to be exposed to considerable financial pressure due either to insufficient internal finance and too high income taxes (at the stage of firm formation), or unfavourable conditions of external financing and too high revenue and capital taxes (at the stage of early growth) which are presumably the main reason why firms cease to exist four years after their foundation. A further important obstacle of firm activities at both stages of development is the availability of qualified personnel. At the early growth stage the survival of new high-tech firms is also endangered by insufficient imitation protection. Finally, more public promotion of technology would enhance the innovation activities of newly founded firms. Start-ups of the modern services seem to be considerably more robust than new firms of high-tech manufacturing. They do not differ in any significant way from all firms on average.

BOX 1: Do newly founded knowledge-based firms generate more jobs than traditional firms?

There are very few Swiss studies dealing with the formation and development of new firms in Switzerland. We report here on some of them, focusing on the survival chances and performance development of *new high-tech firms*.

On the basis of a sample of 63 founders, Kuipers (1990) finds a high mortality risk for firms with a very high or extremely low level of product or service innovation. A moderately high or low innovation level correlates with a high survival rate. Medium innovation levels do not affect the mortality rate of the firm.

Based on a sample of newly founded firms out of the official trade registration, Meyer (2005) points out that new firms with new or improved products are more successful than imitative firms. “Successful” in this context means a higher survival probability. However, new or improved production or distribution methods have no significant effect on survival probability firms. Furthermore, sectors do not seem to differ much concerning their survival probability.

Marmet (2004) used data collected by means of a postal survey of firms of the Swiss founder cohort of 1996/97 as identified by the Federal Statistical Office. His estimations with sample selection show a higher survival probability as well as a higher employment growth for new firms in modern services compared to traditional services. High-tech and low-tech firms in the manufacturing sector do not differ much concerning their survival probability. However, it shows that high-tech firms have a lower employment growth, at least after the first few years of foundation. New or improved products do not affect employment growth, but R&D do has a positive impact on it.

All in all, knowledge-based new firms seem to have a better employment performance compared to traditional new firms. However, the effect might not be as strong as often mentioned in political and academic discussion.

4 Technological Specialization and Leading-edge Technologies

4.1 Introduction

4.1.1 Specialization pattern in high-technology products and knowledge-based services

The share of exports of high-technology products (defined according to the OECD classification, product approach) of total exports of manufacturing goods is a measure of the "technological content" of a country's exports, thus also a measure of its technological competitiveness. The structure of high-technology exports reflects not only a country's production structure but, given the technological "rank" of every product category, also the *technological specialization* of this country.

The share of high-technology exports increased from 15.4% (1994) to 22.9% (2002) of total Swiss exports of manufacturing goods (see table 4.1). In the year 2002, the Swiss share lay above the OECD average of 20.5% for the first time since 1994. This share is lower than that of Japan, the UK or the USA, but it is of the same magnitude as in Finland and the Netherlands and higher than in Sweden, Denmark, Germany or France.

Table 4.1: High-Technology Exports as a Percentage of Exports of Total Exports of Manufacturing Goods („product approach") 1994-2002

Country	1994	1998	2002
Switzerland	15.4	18.4	22.9
Netherlands	16.4	24.8	26.5
Sweden	12.0	18.7	15.4
Finland	11.1	20.2	23.2
Denmark	12.1	14.7	18.0
Austria	8.5	11.0	16.1
Germany	12.7	14.4	16.4
France	16.3	20.1	19.4
Italy	7.9	7.7	8.7
United Kingdom	22.4	27.4	31.1
USA	28.1	32.7	31.9
Japan	25.8	26.6	23.8
OECD	17.3	20.4	20.5

Source: OECD Statistics on International Trade of Commodities, authors' calculations.

This good performance can be traced back to the development of the exports in the following four "main groups" of high-technology products (out of eight "main groups" on the whole according to the OECD classification): pharmaceutical products (technological rank 4), scientific instruments (rank 5), chemical products (rank 7) and non-electrical machinery (rank 8) (see table 4.2). Swiss manufacturing is highly specialised in these product groups. This high specialisation is demonstrated by the shares of these product groups that are considerably higher than on the average in the OECD countries. The degree of specialisation in pharmaceuticals was strongly increased in the nineties, that one for (technologically more traditional) chemical products decreased, even if it remained above average. Thus, there was a shift in Swiss chemical industry from more traditional chemical products (such as dyes, additives etc.) to high-technology pharmaceuticals.

Reflecting weaknesses in its production structure and technological capabilities respectively Switzerland is very weakly represented in the categories aircraft and aerospace (position 1), computer (position 2) and electronics (position 3) which are not only the most technology-intensive product groups but also those with the highest growth rates in the nineties.

Table 4.2: Percentage breakdown of high-technology exports by product groups („product approach")

Product group	Switzerland			OECD		
	1994	1998	2002	1994	1998	2002
1 – Aircraft, aerospace	2.0	3.5	5.6	13.4	15.8	15.7
2 – Computers	5.4	5.9	2.3	25.7	24.2	20.5
3 – Electronics	14.0	12.6	8.7	33.1	34.3	34.6
4 – Pharmaceutical products	16.6	24.4	40.2	4.5	4.6	6.6
5 – Scientific instruments	22.2	19.0	19.9	11.8	10.8	12.0
6 – Electrical machines	2.4	2.7	1.6	2.6	2.6	2.8
7 – Chemicals	21.7	15.6	8.8	4.8	3.6	3.4
8 – Non-electrical machines	15.7	16.3	12.9	4.0	4.0	4.4
High-technology exports as a percentage of total exports of manufacturing goods	15.4	18.4	22.9	17.3	20.4	20.5

Source: OECD Statistics on International Trade of Commodities, authors' calculations.

The Swiss economy is also highly specialised in knowledge-based services. 50.9% of Swiss exports of services in 2001 (OECD: 45.5%; see table 4.3) were exports of knowledge-based services. A very high degree of specialisation is found for financial services, also for insurance services. Rather low specialisation is observed in business services (including computer services). The export share of telecommunication is only slightly larger than in the OECD.

4.1.2 Specialization in biotechnology, information and communication technologies and nanotechnology

We now take a look on the specialization pattern with respect to leading-edge technologies such as biotechnology, information and communications technologies (ICT) and nanotechnology. The

Table 4.3: Exports of ‚knowledge-based' services as a percentage of total service exports

	Switzerland			OECD		
	1992	1998	2001	1992	1998	2001
Financial services	18.9	25.7	27.5	4.2	5.3	6.7
Insurance services	5.7	5.9	3.8	2.2	1.9	1.6
Business services (including computer and information services)	15.4	16.4	16.9	30.3	34.2	35.1
Communications services	2.3	2.3	2.7	1.5	2.1	2.1
Total ‚knowledge-based' services	42.3	50.3	50.9	38.2	43.5	45.5

Source: OECD Statistics on International Trade in Services, authors' calculations.

degree of specialization of Swiss economy in *biotechnology* according to the information on patent registrations at the European Patent Office (EPO) is almost the same as on average in the EU15 countries (see column 3 in table 4.4). A recent study finds a falling tendency of registrations of biotechnology patents particularly for large Swiss firms (see Hotz-Hart and Küchler 2005. p. 61). However, one has to take also into consideration that large Swiss pharmaceutical firms are increasingly inclined to register new biotechnology patents mainly at the US Patent Office. Moreover, due to increasing internationalization of R&D activities during the nineties new patents are more often now registered from research locations outside Switzerland, primarily in the USA. But Switzerland-based R&D is also benefiting from such patents because of the intensive knowledge and technology transfer between headquarters and foreign affiliates of large companies (see also section 4.2 and chapter 6).

In case of *ICT patents* the Swiss specialization again is about at the average level of the EU15 countries (see column 1 in table 4.4). Between 1991 and 1999 there was even a decrease of Swiss ICT patent registrations (see column 2 in table 4.4). This is a domain in which Swiss performance has declined during the nineties. This deficit with respect to ICT patents reflects the increasingly weaker relative position of Swiss manufacturing in developing and producing computers and other electronic products with the exception of scientific instruments during this period.

The Swiss economy is ranking not only in ICT hardware but also in ICT software at rather low position in international comparison. At the time about 5% of all Swiss patent registrations are related to new software products. This is a rather low share as compared with that of the USA or Finland (over 10%; see Hotz-Hart and Küchler 2005, p. 61). But contrary to hardware-related patents software patent registrations showed a significant increase in the period 1998-2003 (see Hotz-Hart and Küchler 2005, p. 61f.). Nevertheless, the specialization of the Swiss economy with respect to the development of new ICT software still lies below the OECD average.

A more favourable picture for Switzerland can be obtained wit respect to the development of nanotechnology at the level of basic research. According to the information in table 4.4 (column 4 and 5 respectively), Switzerland has the highest specialization regarding publications in nanotechnology from all countries listed in table 4.4. The decline of the Swiss share of OECD publications in nanotechnology (see column 5 in table 4.4), which was accompanied by an even larger decrease in other countries, can be traced back to the catching up in the late nineties of some countries such as Finland and Korea and countries from Eastern Europe (Poland, Czech Republic, Slovakia, Hungary).

Table 4.4: Index of spezialization of ICT und biotechnology patents (EPO) and nanotechnology publications

	ICT	ICT	Biotech-nology	Nanotechnology	
	1999	Growth rate 1991-1999 in %	Average share 1995-1999	2000	Change of the number of publications as a percentage of OECD total 1997-2000
Switzerland	0.6	-2.0	0.6	1.7	-5.4
Netherlands	1.2	8.3	1.0	0.9	-3.5
Sweden	0.6	71.0	0.5	1.3	8.5
Finland	1.1	59.2	0.5	0.9	31.0
Denmark	0.3	111.8	2.2	1.0	-17.4
Austria	0.4	29.0	0.6	1.3	-15.6
Ireland	0.9	29.4	1.3	1.0	-29.6
Germany	0.6	15.0	0.5	1.6	-0.6
France	0.9	-0.5	0.7	1.3	0.4
Italy	0.4	3.9	0.3	0.9	12.0
UK	0.8	24.9	1.4	0.8	-2.7
EU	0.7	18.2	0.7	na	na
USA	1.1	3.4	1.7	0.8	-8.2
Japan	1.6	-21.1	0.6	1.3	-9.7

Index of spezialization of country i: share of patents (publications) of a certain category of country i divided by the country's i share of total of OECD patents (publications); Index of specialization of OECD=1.
Source: OECD (2003), p. 27, 33, 45; authors' calculations.

In the following sections of this chapter we are going to take a more detailed look at the two high-tech industries, pharmaceuticals and scientific instruments, in which the Swiss economy shows an above-average specialization.

4.2 Biotechnology; pharmaceutical products

4.2.1 Biotechnology in Switzerland

Biotechnology was introduced in Switzerland already at the beginning of the eighties by the three large pharmaceutical enterprises located in Basle, Ciba, Roche and Sandoz. It took a long breeding time until the first products generated by the new technology could be introduced at the market place. The results of biotechnology-oriented research became economically relevant about ten years after the start (see Arvanitis and Schips 1996).

Biotechnology-oriented R&D of these "pioneering" enterprises received strong impulses from external information sources such patents and licenses of other firms, R&D co-operations, recruitment of groups of researchers and the acquisition of smaller innovative firms. At the beginning the technological contribution of foreign sources, primarily from the USA, was significantly larger than that of domestic sources, inclusive universities and other research organizations. The intensive knowledge and technology transfer taking place between the headquarters and the foreign affiliates of these large firms helped accumulating know-how in biotechnology also in Switzerland. Contrary to the experience in the USA and the UK, newly founded highly specialized "New Biotechnology" firms transferring know-how from the university to the industry did not play an important role in the "pioneer" phase of the introduction and diffusion of biotechnology in Switzerland.

Until the middle of the nineties, Swiss biotechnology was in terms of new products and revenues still of small relevance. Thus, Switzerland was positioned quite behind pioneer countries such as the USA and the UK. In the last ten years Swiss biotechnology has caught up with the pioneers. It could strongly improve its position vis-à-vis important competitors, so that nowadays it belongs internationally to the top-group. This favourable development can be traced back to a great extent to large-scale knowledge appropriation through the acquisition of innovative firms as well as the restructuring of the large enterprises located in Basle (merger of Ciba and Sandoz to Novartis, formation of Actelion through a management buyout, and so on). According to the official R&D statistics, the Swiss biotechnology firms spent 302 Mio. Sfr. for R&D in 2000 (i.e. 3.9% of total private R&D expenditures) and 518 Mio. Sfr. in 2004 (5.4% of the total) respectively. Thus, a significant increase has taken place in this period reflecting the robust state of biotechnology in Switzerland.

Table 4.5 contains information on the R&D intensity (R&D expenditure as a percentage of sales) of the largest Swiss pharmaceutical enterprises, which are also strongly involved in biotechnology. All five firms show an extraordinarily high R&D intensity (9% to 25%). For Novartis, Serono and Actelion more than 50% of investment in R&D is performed in Switzerland. Roche and Vifor are primarily engaged abroad. Compared with the start phase at the beginning of the eighties there is a clear shift in favour of foreign R&D locations, primarily in the USA.

Table 4.5: Biotechnology in Switzerland: large pharmaceutical corporations; firms belonging to the Interpharma 2003

R&D Intensity	Novartis	Roche	Serono	Actelion	Vifor
Sales (in Million SFr.)	21523	19781	2506	300	196
R&D expenditure (in Million SFr.)	4136	3946	631	79	18
as a percentage of sales	*19.2*	*18.3*	*25.2*	*26.2*	*9.1*
R&D expenditure in Switzerland (in Million SFr.)	2155	914	354	65	5
as percentage of total R&D expenditures	*52.1*	*23.2*	*56.1*	*82.3*	*27.8*

Source: Pharma-Markt Schweiz, 2004, authors' calculations.

Meanwhile, there exists also in Switzerland a wide know-how in biotechnology outside the large enterprises in smaller firms that undertake the role of suppliers of specialized knowledge in form of intermediate products and services, labor equipment etc. for the R&D departments of the large firms. This network of suppliers was built through university spin-offs, management buyouts of divisions of large firms focussing on core competencies, start-ups supported by venture capital firms, which in many cases were belonging themselves to large firms, e.g. the Novartis Venture Fund. Table 4.6 contains information on small biotech firms. 48.4% of the 355 firms existing in 2001 were developer of new processes, analytical instruments, labor equipment etc. Further 37.6% of them were producers of gentech products such as medicaments, food, chemical reagents, bio-materials etc. Only one fourth of this category, i.e. 9.6% of all biotech firms, was pure developers and producers of medicaments.

Table 4.6: Biotechnology in Switzerland: SME by activity fields 2001

Activity fields	Number of firms
Processes:	*162*
Labor equipment	56
Equipment for biological processes	36
Instruments for chemical analysis (purification, separation of biological molecules)	15
Controlling apparatus, apparatus for chemical analysis	13
Platform technologies	18
Bio-informatics	11
Environmental technology/disposal of waste	8
Medical technology	5
Products:	*126*
Medicaments	32
Reagents for labors	31
Cell cultures	8
Specialities chemistry, basic chemistry	7
Food chemistry	7
Agriculture	6
Bio-materials	5
Cosmetics, hygiene	3
Veterinary medicine	3
Diagnostics	24
R&D services	22
Consulting	25
Total	*335*

Source: Swiss Biotechnology Industry Guide; CS Economic & Policy Consulting 2003; authors' calculations.

The Swiss pharmaceutical firms are not only highly R&D intensive but also quite successful in developing and introducing new products. In the year 2002 79 pharmaceutical products were on their pipeline, 34 of them already in clinical testing (see table 4.7). Only the UK enterprises Kingdom had absolutely more products on the pipeline than the Swiss firms.

Tabelle 4.7: Produkt pipeline in biotechnology in selected European countries 2002

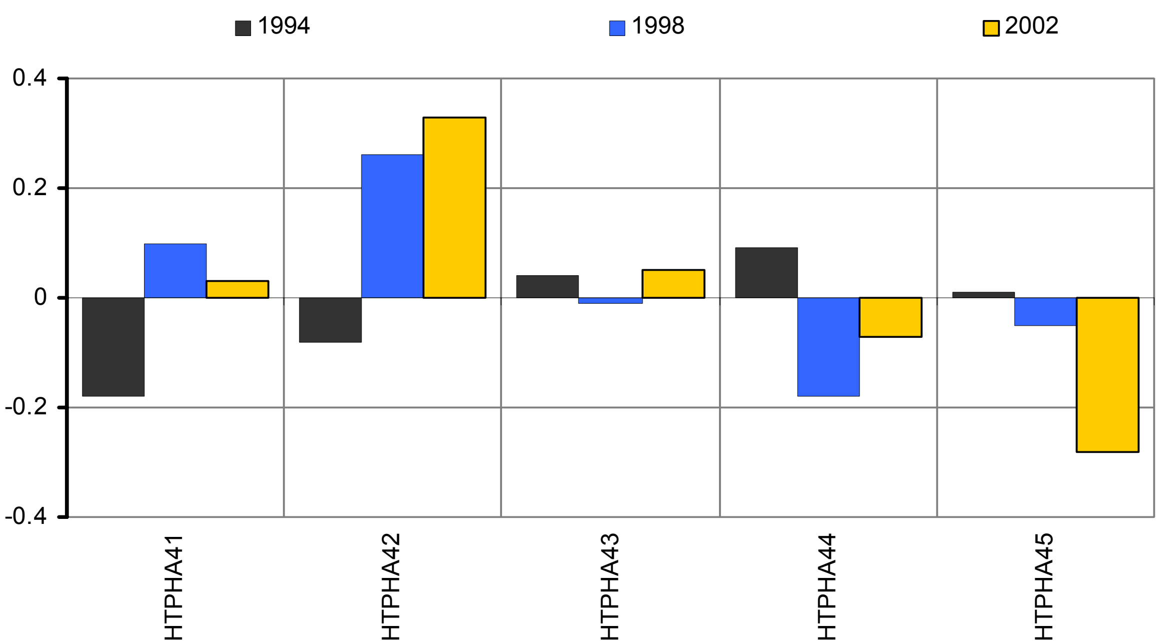
Land	Pre-clinical development	Phase I	Phase II	Phase III	Total
Switzerland	45	12	11	11	79
Sweden	14	8	10	0	32
Denmark	14	5	5	4	28
Germany	7	4	3	1	15
France	16	8	6	1	31
United Kingdom	65	50	56	23	194
Italy	9	0	4	3	16

Source: Ernst & Young, CS Economic & Policy Consulting 2003.

4.2.2 Pharmaceutical products

The pharmaceutical industry has performed economically quite satisfactorily in the last fifteen years raising significantly its exports, revenues and as a consequence employment in Switzerland. Employment in this industry grew up from 20'200 employees (in full-time equivalents) in 1995 to 24'970 in 1998 and 28'120 in 2001 respectively. Thus, the employment growth between 1995 and 2001 was about 40%.

Figure 4.1: Export specialisation; pharmaceutical products



Pharmaceutical products		*Share of Swiss exports (1)*		
Abbrevation	*Description*	*1994*	*1998*	*2002*
HTPHA41	Antibiotics	15.0	22.4	14.6
HTPHA42	Hormones and their derivatives	7.5	13.8	18.5
HTPHA43	Glycosides, glands, antisera, vaccines	32.2	28.2	35.7
HTPHA44	Medicaments containing antibiotics or derivatives thereof	26.3	15.8	17.7
HTPHA45	Medicaments containing hormones or other products of heading 5415-	19.1	19.7	13.5

(1) Pharmaceutical products

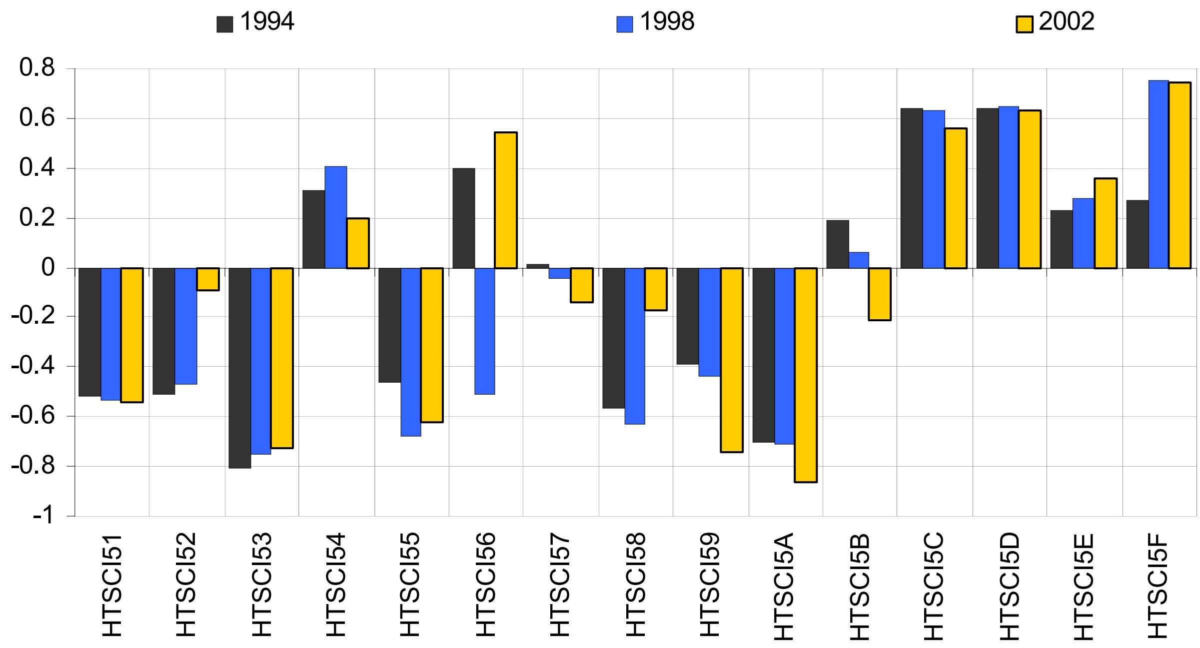
The Swiss exports of pharmaceutical products show with one exception almost the same specialization pattern as the exports of total OECD. In figure 4.1 most of the RSCA values lie around the zero line.[4] With respect to sub-groups of pharmaceutical products, the Swiss industry is over-specialized in "hormones and their derivatives" (product group 2 in figure4.1), rather under-specialized in "medicaments containing hormones etc." (product group 5 in figure 4.1). The product group "glycoside, anti-sera, vaccines" is the most important single product group (36% of total exports of pharmaceutical products; see data table in figure 4.1). The other four product groups vary between 14% and 19% of total exports. Between 1994 and 2002 the share of "hormones and their derivatives" increased from 8% to 19% of total exports of pharmaceutical products, while the share of medicaments containing antibiotics or hormones decreased from 45% to 31%. It seems that since 1994 with respect to the fabrication and export of pharmaceutical products a shift has taken place from products to intermediate products. This means that according to a typical strategy of multinational firms, final products are being increasingly fabricated near the consumer markets.

4.3 Medical technology; scientific instruments

The product category "scientific instruments" is composed of 15 product groups of varying importance (measured by the corresponding share of total exports of "scientific instruments") and degree of specialization (see figure 4.2 and the corresponding data table). Six of these product groups are "measuring instruments" (positions 1 to 5; 7; see the data table in figure 4.6), i.e. about 50% of the exports of the overall category "scientific instruments" in 2002. Six further product groups build the specific category "products of medical technology" (positions 6 and 10; 12 to 15), i.e. 45% o the exports of scientific instruments. In each of these main groups the export are concentrated primarily in the following three product groups: "measuring instruments" (41.2% in 2002), "pacemakers for stimulating heart muscles" (21.3%) and "orthopaedic appliances" (21.3%). With respect to measuring instruments the specialization of Swiss industry lies near the OECD average. Switzerland shows above-average specialization in five out of six product groups belonging to medical technology; the sixth one, "contact lenses", for which the specialization is quite low, has a share of exports of scientific instruments of only 0.1%. The industry of products of medical technology showed also a significant employment growth in the period 1995-2001. The number of employees in full-time equivalents increased from 11'720 to 16060, i.e. by about 37%.

4 RCSA=(share of exports of country i divided by the country's i share of total of OECD exports)-1; RCSA=0 is the OECD baseline.

Figure 4.2: Export specialisation; scientific instruments



		Share of Swiss exports (1)		
Abbreviation	*Description*	*1994*	*1998*	*2002*
HTSCI51	Electro-diagnostic apparatus for medicine or surgery and radiological apparatus	6.2	5.4	5.4
HTSCI52	Binoculars, astronomical instruments and optical telescopes	0.2	0.2	0.5
HTSCI53	Microscopes (other than optical microscopes)	0.1	0.1	0.1
HTSCI54	Compound optical microscopes	2.0	2.2	1.4
HTSCI55	Liquid crystal devices, lasers and other optical instruments	1.4	1.0	1.5
HTSCI56	Dental drill engines	0.9	0.1	0.7
HTSCI57	Measuring instruments and apparatus	60.9	53.5	41.2
HTSCI58	Photographic cameras	1.2	0.8	1.3
HTSCI59	Cinematographic cameras	0.1	0.1	0.0
HTSCI5A	Contact lenses	0.2	0.2	0.1
HTSCI5B	Optical fibres other than those of heading 7731-	3.4	4.5	3.4
HTSCI5C	Hearing aids	3.3	3.4	3.0
HTSCI5D	Orthopaedic appliances	15.2	16.7	16.6
HTSCI5E	Ocular prosthesis	2.6	2.7	3.4
HTSCI5F	Pacemakers for stimulating heart muscles	2.4	9.2	21.3

(1) Scientific instruments

4.4 Assessment

Is there enough growth potential in the existing technological specialisation of the Swiss economy? With respect to three leading technologies information and communication technologies (ICT), biotechnology and nanotechnology we obtain the following picture for Switzerland:

- The Swiss presence in the R&D and production of *hardware ICT* is *weak*. The Swiss manufacturing could not participate as a supplier to the fast-growing markets for computer and electronics in the nineties. Nevertheless, the Swiss economy is a very intensive *user* of ICT (see *Hollenstein et al. 2003*).
- The Swiss specialisation in *software ICT* is *weak* compared to the OECD average. Contrary to the hardware sector, the development of the software industry was quite promising in the nineties; this quite knowledge-intensive industry, starting at a rather low level, has noticeably grown in the last ten years.
- Switzerland has a rather *strong* presence in *nanotechnology*, particularly in research in this new technology field. Being highly specialised in the development and production of precision machinery and scientific instruments Swiss manufacturing is endowed with capabilities that could be of great use in the development of applications of nanotechnology. This is a field in which the *relative advantage* in research today could be transformed to a *relative strength* at the market place in the future.
- The Swiss position in the *biotech sector* is quite *strong*. As we have already discussed, Swiss research is highly specialised in Life Science. Besides the enormous potential of the large firms around Basle both at home and abroad, there is meanwhile also a sector of smaller biotech firms, many of them highly specialised suppliers of intermediate biotech products and sophisticated equipment.
- In the service sector a *relative strength* is the high specialisation in the *financial* and i*nsurance services*.

Is there a technological "lock-in" problem for the Swiss economy? Only partly. The high specialisation in "old", mature industries without a large potential in the future such as non-electrical machinery and chemicals could be considered as a potential disadvantage. An expansion of activities in the direction of computer and electronics industry has not taken place. But the existing capabilities were successfully used to focus activities in market "niches" for high-technology products such as scientific instruments and medical technology products. Moreover, a transformation from traditional chemicals to high-technology pharmaceuticals has taken place also in the chemical industry in the nineties. Both transformation processes were performed without subsidies and caused only moderate social costs. Both the industry for pharmaceutical products and that products of medical technology showed an extraordinarily high employment growth in the period 1995-2001 of about 40%.

5 R&D Activities and Networking

5.1 Pattern and evolution of R&D

In this section we briefly describe intensity and evolution of R&D activities of the Swiss economy, as well as its main characteristics as compared with twelve OECD countries. To this end, we consider the following dimensions of R&D: intensity and growth of R&D expenditures, breakdown by performing sector, relative importance of basic and applied research, R&D expenditures by industry and firm size classes, and, finally, R&D subsidies by size of the receiving firms.

Table 5.1: Evolution of R&D expenditures 1995-2001

	R&D expenditures as a percentage of GDP 2001	Average annual growth rate of R&D expenditures 1995-2001	Business R&D expenditures as a percentage of value added in industry 2001	Average annual growth rate of business R&D expenditures 1995-2001	Average annual growth rate of government R&D expenditures 1997-2001
Switzerland	2.63	1.3	3.11	2.4	-2.3
Netherlands	1.94	2.9	1.61	3.8	-0.7
Sweden	4.27	7.2	5.20	8.0	3.0
Finland	3.40	11.3	3.54	13.5	4.7
Denmark	2.19	7.2	2.31	10.6	5.1
Austria	1.90	5.9	1.62	9.2	5.0
Ireland	1.17	7.5	1.06	7.1	4.8
Germany	2.49	3.3	2.50	4.3	0.6
France	2.20	2.4	2.01	2.8	0.2
Italy	1.07	2.7	0.79	2.8	5.5
UK	1.90	2.3	1.87	2.0	2.7
USA	2.82	5.4	2.85	6.1	1.5
Japan	3.09	2.8	3.33	3.6	2.7
EU	1.93	3.7	1.79	4.4	-
OECD	2.33	4.7	2.27	5.3	2.6

Column 1: Switzerland, Netherlands: 2000, Denmark: 1999; column 2: Switzerland, Netherlands 1996-2000, Denmark: 1995-1999; column 3: Switzerland: 2000, Denmark: 1999, Austria: 1998; column 4: Switzerland: 1996-2000, Netherlands: 1996-2001, Austria: 1993-1998; column 5, 6 and 7: Switzerland, Netherlands, Italy, France, USA: 2000; Germany, Denmark: 1999, Austria: 1998; column 9: Switzerland: 1996-2000.

Source: OECD (2003), CEST (2003), authors‘ calculations.

In terms of the R&D intensity (i.e. R&D expenditures as a share of GDP), Switzerland traditionally belongs to the top performers among the OECD countries. Among the countries listed in Table 5.1, it takes rank 5 (whole economy) and rank 4 respectively (business sector). However, in the second half of the nineties, the growth of R&D in all countries listed in Table 5.1 has been higher than in Switzerland. Therefore, some countries got ahead of Switzerland (Sweden, Finland), others strongly reduced the gap (Denmark, Ireland, Austria). The increase of R&D expenditures of 1.3% p.a. in nominal terms implies a stagnation of R&D outlays in real terms. Not much better is the tendency we observe for the private sector; given a nominal increase of only 2.4% p.a., real growth of expenditures was very low. Government R&D outlays decreased even in nominal terms, in strong contrast to many countries where public R&D grew at a yearly rate of 3% to 5%; only three countries (Germany, France, Netherlands) did not much better than Switzerland.

However, some recently released data point to a rebound of Business R&D expenditures (BFS 2005). In the period 2000-2004, they increased, in nominal terms, by about 5% p.a. As a result, Business R&D as a share of GDP significantly increased, while this proportion remained unchanged in almost all countries listed in Table 5.1

To sum up, R&D expenditures in Switzerland stagnated in the nineties at a high level, with public spending even decreasing. Since many of the other countries strongly increased their R&D outlays, Switzerland, lost quite a lot of its previously excellent position in relative terms. We hypothesise that the bad macroeconomic performance of the nineties, leading to a decrease of internal funds of firms and a cut of public expenditures (in order to keep the fiscal balance manageable), was the primary cause of the unfavourable evolution of R&D spending. Private R&D expenditures picked-up again since the year 2000. Whether the proposition of a causal link between macroeconomic conditions and private R&D outlays holds true, will be analysed in Chapter 8.

In Switzerland, R&D activity is to a large extent performed by the private sector (76%); only the USA, Japan and Sweden show similar shares, although in almost all countries the relative importance of private R&D increased in the nineties. Among public R&D, the balance between R&D at institutions of higher education and government R&D is strongly tilted towards the first one; in Switzerland, the university sector performs 23% of overall R&D, with only 1% invested directed by government itself (private non-profit organisations included). This pattern is unique, Sweden being the only other country showing the same tendency to a certain extent (19% vs. 3%).

Against this background, it is not surprising that R&D expenditures are concentrated on basic research much stronger than in any other country (28% of total R&D). In the USA, this share is only 21%, a fact that may be astonishing at least at a first glance. The well-known impressive basic research performance of this country probably reflects the absolute size of this type of research activities (scale effect) rather than its importance relative to other R&D components. In contrast, a small country like Switzerland can achieve an outstanding performance in basic research only if it devotes a large portion of its public R&D funds to this type of activities; otherwise, research would remain below the required “critical mass”. It is further surprising that in the USA almost 60% of R&D is allocated to experimental development, a share which is matched only by Japan (what is not very surprising). In Switzerland, the corresponding share only amounts to 36%, one of

Table 5.2: Intramural R&D expenditures per employee in 1999 (US-$, PPP)

	Switzerland	Germany	Finland	France	Netherlands	Italy	Japan	Sweden	UK)	USA
Total manufacturing	4665	3849	4822	3900	3273	1237	4322	6605	2286	6432
Food	3138	189	1109	546	1429	200	925	803	581	874
Textiles, clothing	216	773	569	352	321	32	340	511	95	245
Wood products	62	151	446	135	-	36	648	143	-	-
Paper, printing	202	47	1147	160	209	55	493	1450	-	1237
Chemicals, pharmaceutical	20408	11392	10011	14369	11459	4451	19947	26007	12181	19588
Rubber, plastics	972	1374	2570	2364	1203	674	7882	1613	397	1814
Non-metallic minerals	243	1147	1119	1227	497	66	2384	686	488	1058
Metals, metalworking	886	692	1329	833	844	511	1691	1207	398	970
Non-electrical machinery	5468	3081	4033	2516	5766	745	3460	5178	1731	3184
Electrical machinery, electronics, instruments	7615	6127	20761	11012	8830	4671	11106	18805	3417	18658
Vehicles	1388	11798	1116	11333	1690	6549	6518	12462	5066	17878
Other industries	375	714	1091	1643	-	203	704	383	8	1277

Switzerland 2000, France and Japan 1998, Netherlands and UK 1996. In case of the Netherlands, non-electrical machinery includes office machinery as well.

Sources: OECD (2001), Swiss Federal Office of Statistics (unpublished data), own calculations.

the lowest of all countries. This pattern seems to be consistent with the observation of both countries being strong with respect to scientific output (e.g. publications), with the USA having a lead over Switzerland in terms of the generation of radical innovations.

Table 5.2 shows an international comparison of R&D expenditures for manufacturing as a whole and twelve single manufacturing industries (outlays normalised by the number of employees). In total manufacturing, Switzerland ranks fourth out of the ten OECD countries included in the table. In Sweden and the USA R&D expenditures are by far at highest, whereas R&D outlays in Finland are only slightly higher than in Switzerland. The distance to the countries following next in the ranking, i.e. Japan, France and Germany, is quite substantial.

Switzerland ranks first in the food industry and the production of non-electrical machinery; it takes the second position in chemicals/pharmaceuticals, and the fifth one in the metal industry (if only metalworking would be considered, Switzerland presumably would score very high in this industry as well). The Swiss performance is low in all other industries, perhaps with the exception of electrical machinery, which is classified in the same industry as computers/electronics/instruments where Switzerland is underrepresented. According to these results, industrial specialisation of R&D is quite favourable, since R&D expenditures are concentrated on high-tech- and medium-high-tech industries, with the exception of the food industry; in this case, the top position of Switzerland probably reflects primarily the R&D activity of one big multinational enterprise (Nestlé).

R&D expenditures are less concentrated on large firms than in most other OECD countries. The share of R&D expenditures of larger firms is lower than in Switzerland only in Ireland and Italy, and it is about the same in the UK (see Table 5.3). This result is somewhat surprising in view of the large number of multinational having their headquarters and doing R&D in Switzerland. The more even distribution of R&D activities reduces, on the one hand side, innovation risks (advantages of diversification); on the other hand, and more importantly, it strengthens the capacity to absorb external knowledge and to profit from knowledge spillovers. The high R&D intensity of SME's is thus a significant advantage of the Swiss System of Innovation.

The same table shows that subsidies for private R&D (which are low in quantitative terms) are heavily geared to SME's, much more than in any other OECD country. Thua, policy seems to contribute to the strong knowledge base of Swiss SME's. However, this is not the only conclusion that can be drawn: on the one hand side, subsidies favour innovative activities of small firms, i.e. those firms suffering most from financial restrictions reflecting capital market imperfections; on the other hand, since scale effects are important in R&D, the allocation of public funds may be not very efficient. Therefore, a stronger targeting towards medium-sized companies (including firms with 250 to 400 employees which are classified as "large" in Table 5.3) may perhaps be quite sensible.

Table 5.3: Breakdown of R&D expenditures and R&D subsidies by firm size in 2001

	Percentage share of R&D expenditures by firm size class			Percentage share of R&D subsidies by firm size class		
	< 50 employees	50 – 250 employees	> 250 employees	<50 employees	50-250 employees	> 250 employees
Switzerland	10.6	19.6	69.8	47.9	26.7	25.4
Netherlands	5.9	13.2	80.9	-	-	-
Sweden	-	13.1	-	-	17.2	-
Finland	10.0	12.6	77.4	34.6	21.5	43.9
Denmark	12.7	17.8	69.5	21.6	27.0	51.4
Austria	5.5	12.3	82.2	14.9	13.7	71.4
Ireland	20.5	28.7	50.8	-	-	-
Germany	5.8	9.3	84.9	4.9	7.3	87.8
France	4.2	9.2	86.6	5.4	4.0	90.6
Italy	5.9	59.6	34.5	8.4	58.1	33.5
UK	14.4	20.5	65.1	7.7	4.7	87.6
USA	5.9	8.2	85.9	5.2	6.2	88.6
Japan	-	7.0	-	-	-	-
EU	7.4	17.0	75.6	7.3	13.1	79.6
OECD	5.3	11.4	83.3	6.7	10.7	82.6

The reported figures underestimate the effective R&D expenditures in the USA (only federal expenditures with military R&D excluded). Switzerland, Netherlands, France, Italy, USA: 2000; Denmark, Germany: 1999; Austria: 1998.
Source: OECD (2003), authors' calculations.

To sum up, the Swiss performance in R&D is high in terms of the level of expenditures. Moreover, the structure of R&D activity is advantageous in several respects: R&D, to a large extent, is performed in the private sector. Public R&D is concentrated on basic research at universities. The R&D intensity (and thus absorptive capacity) of SMEs is high. The industrial specialisation of R&D in manufacturing is as favourable as that of the most important competing countries.[1] Under-investment in public and private R&D in the course of the nineties is the most important weakness. The negative impact of the sluggish evolution of innovation inputs is visible: the increase of innovation output such as publications, patents, etc. slowed down as well (see Chapter 8). However, there are signs of a rebound of private R&D expenditures since the year 2000, which, hopefully, will prevent negative permanent effects of the unfavourable development in the nineties (long time lags in the R&D process).

[1] It is worth mentioning that, in the service sector Switzerland is the most innovative country in Europe (see Chapter 8). Therefore, the industrial structure of R&D of the economy as a whole is more favourable than for manufacturing only.

5.2 R&D networks of firms

5.2.1 Internal vs. external R&D strategies

Competition based on innovative products and/or processes has intensified in recent years, since, among other things, the length of product cycles is shrinking, technological innovations become more complex and expensive, etc. Under these circumstances, it is not surprising that a growing number of firms are coming under pressure to use their R&D funds more efficiently by concentrating R&D on very specific fields of activities and combining internal R&D with external R&D related to contract-R&D and/or R&D co-operations. Earlier work shows that the pressure for using external R&D is at strongest in high-tech and knowledge-intensive activities (Arvanitis and Hollenstein 2001; Hollenstein 2005).

Table 5.4 shows that in 2002 almost 50% of Swiss firms followed R&D strategies which involved a combination of internal and some form of external R&D ("external R&D strategies"). As expected, the highest proportion of firms following external R&D strategies is found in high-tech manufacturing and knowledge-intensive services. Most industries for which external R&D is particularly important are highly innovative; in other words, less innovative industries concentrate

Table 5.4: Importance of internal and external R&D strategies in 2000/02
(Percentage share of R&D performing firms)

	Internal R&D-strategy	External R&D-strategies		
		Type 1	Type 2	Type 3
	Internal R&D only	Internal R&D and contract-R&D	Internal R&D and R&D co-operation	Internal R&D, contract-R&D and R&D co-operation
Total	52.3	26.0	8.5	13.2
Sector				
Manufacturing	48.9	26.1	9.2	15.9
- High-tech	40.3	36.2	9.4	14.0
- Low-tech	52.0	22.4	9.1	16.5
Services	55.2	26.5	7.9	10.4
- Knowledge-intensive	44.3	18.4	17.6	19.7
- Other	61.3	31.0	2.5	5.30
Industries with the highest share of external R&D				
Banking/Insurance	27.6	32.8	12.9	26.7
Energy	28.0	32.4	0.0	39.6
Electronics/instruments	28.0	32.4	0.0	39.6
Chemicals/Pharmaceuticals	38.7	18.2	28.1	15.1
Machinery	40.1	40.0	7.6	12.3
Firm size (employees)				
1-99	54.2	24.9	8.4	12.6
100-249	45.4	30.2	8.8	15.6
250+	22.4	43.6	11.1	22.9

Source: KOF Innovation Survey 2002, see Scherrer (2005).

more on purely internal R&D strategies. Large firms more often make use of external R&D than small ones; however, even among small firms, a substantial segment adheres to an external R&D strategy. We conclude from these results that the knowledge network in the Swiss economy, in particular in the most innovative segments, is very tight.

The combination of internal R&D and external R&D contracts (external strategy type 1) is most widespread (26% of all firms); "only" 13% of firms rely on both forms of external R&D, i.e. contract-R&D and R&D co-operations (external strategy type 3). Over the last few years, contract R&D strongly gained in importance at the expense of the most comprehensive networking strategy (type 3), with only a few exceptions (e.g. banking/insurance, energy, electronics/instruments).

Whether this shift from strategy type 3 to type 1 indicates some weakening of the (very tight) R&D network, is an open question. We rather presume that it reflects a further optimisation of the firm's R&D process in terms of cost efficiency, access to complementary knowledge, speed of knowledge creation, etc. In order to answer the question raised above, we need an in-depth (econometric) analysis of the relative advantages of the various elements of a firm's R&R strategy (internal R&D, contract-R&D, R&D co-operation). Some descriptive information is shown in subsection 5.2.3.

5.2.2 International dimension of external R&D

Table 5.5 shows the extent to which firms are engaged in domestic and international R&D contracts and R&D co-operations. Since a firm can maintain such relationships with partners from several regions, the row totals are higher than 100%, i.e. 130% and 197% for R&D contracts and R&D co-operations respectively. Hence, the geographical scope of external R&D is large, in particular in case of R&D co-operations.

Tabelle 5.5: External R&D by partner region in 2000/02
(Percentage share of firms with R&D partners in a specific region; multiple answers)

	Contract-R&D	R&D co-operation
Switzerland	84.3	88.7
EU	34.8	67.0
USA	7.5	20.7
Japan	0.8	8.0
Other countries	2.2	12.7

Source: KOF Innovation Survey 2002, see Scherrer (2005).

Not surprisingly, the frequency of both forms of external R&D is negatively correlated with distance. Almost all firms engaged in external R&D choose domestic partners. However, foreign partners are important as well, particularly in case of R&D co-operation. Despite the geographical distance, this also holds true to a remarkable degree for US partners (21% of firms) pointing to the importance of this country as a source of knowledge (see also Chapter 6). Since only highly "qualified" firms are attractive as partners of a technological leader like the USA, this result also is an indication of the high innovation performance of Swiss firms.

We conclude that the R&D network of Swiss firms not only is very tight but also highly international. In this respect, Switzerland is in a strong position as compared to other countries as will be shown in Section 5.2.5.

5.2.3 Contract-R&D

The share of firms out-contracting R&D (solely or in combination with R&D co-operations) strongly increased between the mid-nineties until the turn of the century (from 25% to 43%); afterwards it remained constant at about this level.

Firms out-contract R&D most frequently to other firms (68% of all out-contracting firms), 44% to the university sector and 33% to other research institutions (specialised laboratories, etc.), which is a sector not so well-developed than in other countries like, for example, Germany (Frauenhofer Gesellschaft, etc.). The frequency of contracts with other firms is about the same for small and for large firms, whereas contractual relationships with universities and other research institutions are more prevalent in case of large firms. Nevertheless, it is quite remarkable that more than a third of out-contracting small firms (less than 100 employees) award mandates to university partners.

Some quantitative data on R&D contracts are presented in the BOX 2. Not much is known about the motives for and determinants of out-contracting R&D, the relationship between internal R&D and R&D out-contracting as well as the impact of out-contracting on R&D outcomes. At this stage, we are able to present some descriptive results with respect to the motives of out-contracting and the important question, whether in-house R&D and contract-R&D are substitutes or complements.

The Innovation Survey 1999 yielded data on the firms' assessments of four motives for out-contracting R&D.[5]

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

5 We did not collect such data in the Innovation Survey 2002.

- Knowledge-oriented complementarity: Out-contracting of R&D to complement efficiently internal R&D (whose level is not reduced) with knowledge in fields of technology which are completely new for the firm.

BOX 2: Quantitative data on extramural R&D expenditures of the business sector

The proportion of firms out-contracting R&D indicates to what extent firms draw on this type of measure in the frame of their R&D strategy. However, it does not tell us anything on the amount of R&D invested through this channel. Some quantitative data, disaggregated by destination and receiving institutions, are shown in the table below. This information complements our detailed characterisation of external R&D strategies presented in the main text.

R&D contracts by destination and receiving institution 1992 - 2004

	Mio. SFr				% of total contract-R&D			
Destination	1992	1996	2000	2004	1992	1996	2000	2004
Domestic	*255*	*580*	*575*	*1407*	*40*	*58*	*33*	*35*
- firms	198	370	410	1053	31	37	23	26
- universities	44	150	125	259	7	15	7	6
- other	13	60	40	95	2	6	2	5
Foreign	*287*	*350*	*1135*	*2428*	*45*	*35*	*64*	*60*
Patents, etc.	*96*	*50*	*50*	*211*	*15*	*7*	*3*	*5*
TOTAL	638	1000	1760	4046	100	100	100	100

Source: Federal Office of Statistics.

The main messages we draw from the table are the following:

- R&D out-contracting increased, in quantitative terms, at an extraordinary rate since 1992 (factor 6). The increase strongly accelerated over time.
- The amount destined to foreign institutions increased at a significantly higher rate than that received by domestic institutions. Consequently, the share of foreign investment strongly increased (average 2000/04: 60% vs. 40% in 1992/96). This development does not reflect necessarily a weakness of Switzerland as a location for performing R&D; it rather is the result of the globalisation of knowledge production and acquisition (part of an "asset augmenting" foreign R&D strategy; see Chapter 6).
- In Switzerland, the amount of contract-R&D received by the business sector is much higher than that of universities (what is not surprising since universities primarily perform basic research).
- Structure and evolution of extramural R&D is dominated, in the same way as (intramural) R&D investments in foreign affiliates (see Chapter 6), by the pharmaceutical industry (77% of total R&D contracts in 2004, of which 2/3 to foreign partners). This industry is the real driver of the process of internationalisation of business R&D in quantitative terms.

Table 5.6 shows that, on balance, about 40% of firms substitute contract-R&D for own R&D, whereas for more than 60% of firms internal R&D and out-contracting are complementary (col. 3

vs. col. 6). Complementarity is more important than substitution in all industries and firm size classes, although to a different extent. The dominance of complementarity is particularly strong for large firms. The main driver behind complementary as well as substitutional out-contracting is not the anticipation of lower costs (efficiency-orientation) but rather the opportunity to source new (specialised) knowledge (col. 1 vs. 2 and col. 4 vs. 5 resp.). This again holds true for all industries and size classes, and is more accentuated for large firms, in particular in case of complementary out-contracting.

Table 5.6: Motives for R&D out-contracting in 1997/99
(Percentage share of firms for which a certain strategy of out-contracting is highly important; multiple answers)

	Substitution			Complementarity		
	Efficiency-oriented	Knowledge-oriented	All	Efficiency-oriented	Knowledge-oriented	All
Total	12.9	39.5	40.9	29.7	54.0	59.1
Manufacturing						
Chemicals/pharma	10.3	34.5	34.5	20.7	51.7	58.6
Machinery	9.8	35.4	39.0	26.8	54.9	61.0
Electrical machinery	25.0	55.0	65.0	40.0	60.0	75.0
Electronics/instruments	9.6	36.5	38.5	32.7	59.6	71.2
Services						
Banking/insurance	10.5	31.6	36.8	31.6	73.7	73.4
R&D-/ICT services	16.7	50.0	50.0	33.3	83.3	83.3
Business services	19.0	33.3	38.1	38.1	23.8	42.9
Firm size						
6-19	14.9	40.4	40.3	34.0	38.3	44.3
20-49	18.5	46.2	42.3	27.7	47.7	50.7
50-99	11.3	40.8	41.3	28.2	47.9	48.8
100-199	19.1	44.9	46.8	34.8	53.9	61.7
200-499	8.1	37.4	40.2	22.2	57.6	61.8
500-999	7.3	24.4	26.8	31.7	75.6	82.3
1000+	7.1	28.6	27.3	35.7	64.3	60.1

Source: KOF Innovation Survey 1999, see Arvanitis et al. (2001).

In sum, out-contracting of R&D is a widely diffused practice, independent of industry and firm size (with some “advantage” of large firms). The relevance of contract-R&D strongly increased over time in terms of the numbers of companies involved as well as size of the funds invested in this practice. Contract-R&D is highly and increasingly international. Both contracts with business partners and with research institutions are very important; whereas the first type of partnership probably indicates a high potential for a two-way co-operation, the second one underlines the importance of an optimal design of science-industry relationships (see Chapter 7).

5.2.4 R&D co-operation

In 2000/02 about 22% of R&D-performing firms co-operated with other companies or with research institutions. Although this share is lower than in 1997/99, R&D co-operation is a core element of the Swiss Innovation System.

R&D co-operations can take different forms, which range from informal technology-related information exchange as the loosest form of engagement up to equity-based joint ventures with a majority stake as the tightest one. The most frequent form of co-operation are contract-based agreements to execute common research projects, and, not surprisingly, informal information exchange (in both cases about 60% of co-operating firms; see Arvanitis et al. 2004, Ch.7). Nevertheless, more than 20% are engaged in equity-based co-operations (majority or minority stakes).

Furthermore, we distinguish three categories of co-operations by the type of partner: vertical co-operation (partnership with suppliers, users, consulting firms or members of the same enterprise group), horizontal co-operation (competitors), and, finally, co-operation with research institutions (universities, other public or private research institutes). As shown in Table 5.7, vertical co-operation is the most frequent type of co-operation (more than 90% of co-operating firms), followed by science-related partnerships (62%) and horizontal relations (33%). Vertical co-operation is more or less of the same importance in all industries and firm size classes. However, for the other two categories of co-operations, we observe quite strong differences. Services firms are clearly more often engaged in horizontal co-operation than manufacturing firms. Large firms are strongly over-represented in science-oriented relationships, but – remarkably – almost half of the (co-operating)

Table 5.7: R&D co-operation by type of partner in 2000/02
(Percentage share of co-operating firms; multiple answers)

	Vertical co-operation	Horizontal co-ooperation	Co-operation with research institutions
Total	93.4	32.9	61.7
Manufacturing			
Chemicals/pharma	94.1	14.7	52.9
Machinery	100.0	25.6	69.8
Electrical machinery	84.6	30.8	92.3
Elektronics/instruments	90.3	22.6	61.3
Services			
Banking/insurance	91.7	75.0	66.7
R&D-/ICT services	90.9	45.5	81.8
Business services	87.5	75.0	37.5
Firm size			
1-99	94.5	34.3	46.6
100-249	89.7	23.1	61.5
250+	94.6	38.2	81.8

Source: Scherrer (2005) based on KOF Innovation Survey 2002.

small firms are active in this type of partnership as well. Moreover, co-operation with research institutions quite strongly vary by industry as well: some manufacturing branches (mechanical and electrical machinery) and some service industries (banking/insurance, R&D/ICT-services) are over-represented.

Information about the motives for engaging in R&D co-operations allow some insight into the importance of specific R&D strategies. Table 5.8 shows the relevance of seven categories of motives according to the firms' assessments. The motives "building know-how in new fields of technologies" and "access to specific knowledge" aim at an enhancement of a firms' knowledge base; to some extent this holds true for "pooling together complementary knowledge" as well. The second and the third of these three motives are, by far, the most important ones, whereas the "classical" motives aiming at internalising the benefits of new knowledge (risk and cost sharing) are of minor relevance. This also is true for the motive "profiting from public support", which is not surprising in view of the low intensity of technology policy (although policy measures mostly require a co-operation with a research institution). We conclude that R&D co-operation is related overwhelmingly to a strategy of enhancing a firm's knowledge base.

Table 5.8 also shows that, to some extent, the three categories of partnerships differ with respect to the role played by the various motives. Vertical co-operation shows a pattern very similar to the average, reflecting the high frequency of this type of co-operation. In case of horizontal co-operations, "cost sharing" is clearly more important than on average (perhaps reflecting a common interest for some (key) technology in the pre-competitive stage), whereas the opposite is true for "access to specific technologies", which might be a sensitive parameter of (horizontal) innovation competition. For science/industry partnerships, all motives are more important than on average, in three cases quite distinctly, in the other four only by a thin margin. Correspondingly, the sum over the seven columns is at highest in this case; it seems that this type of partnership is compatible with a broader array of objectives than the other two. The motives "access to specific knowledge" and "building know-how in new fields of technologies" are by far more important than in case of vertical or horizontal co-operation. In other words, universities and other research institutions are seen as particularly suitable partners for enhancing the firm's knowledge base. This result underlines the importance of an optimal design of the interface between science and industry. Finally, it is not surprising that "profiting from public support" is a more important motive for R&D co-operation with research institutions than for vertical and horizontal co-operation, since fostering this type of partnership is an important objective of technology policy.

R&D co-operation is of growing importance; however, is it also successful? In order to answer this question, it is often investigated whether economic performance is higher in case of firms co-operating in R&D as compared to those exclusively relying on internal R&D. However, since R&D

Table 5.8: Motives for R&D co-operation by type of partner in 2000/02
(Percentage share of firms for which a specific motive is highly important; multiple answers)

Partner	Motive						
	Risk sharing	Cost sharing	Speeding-up R&D projects	Access to specific technology	Pooling together complementary knowledge	Building of know-how in new technology fields	Profit from public support
Vertical co-operation	21.2	29.6	43.4	62.8	69.0	46.0	11.7
Horizontal co-operation	22.8	36.8	40.4	56.1	71.1	47.4	13.2
Co-operation with research institutions	23.0	29.2	42.4	69.6	71.4	52.2	15.5
Total	20.0	28.0	42.3	61.0	69.0	45.3	11.0

Source: Scherrer (2005) based on KOF Innovation Survey 2002.

co-operation is only one, and certainly not the most important factor determining economic performance, it may be more sensible to look at some "intermediate goal variable" that is directly linked to R&D co-operation. In this vein, we collected information on various components of "co-operation output", ranging from science-related outcomes (publications) up to market-oriented results in terms of new products to be introduced on the market or production techniques to be adopted by the firm (see Table 5.9).

Table 5.9: Output of R&D co-operation by type of partner in 2000/02
(Percentage share of firms with co-operations leading to a specific type of outputs)

Partner	Publications	Patents	Prototypes, test versions	New products	New processes
Vertical co-operation	23.7	36.5	61.3	86.1	44.5
Horizontal co-operation	19.3	24.6	52.6	85.1	42.1
Co-operation with research institutions	34.8	46.0	64.0	83.2	51.6
Total	23.7	36.3	60.3	85.0	44.0

Source: Scherrer (2005) based on KOF Innovation Survey 2002.

In general, R&D co-operations seem to be very successful (at least according to the view of the surveyed firms), with a very high percentage of firms having realised new products (less often new processes). It is not surprising that the share of co-operating firms that generated patents is relatively low (36%), since appropriation of knowledge often is based on other strategies than patenting (e.g. time lead). Similarly, only a small proportion of firms produces publications, which is "natural" since publications usually are not an objective of a co-operation among firms that are not science-based.

The "productivity" of R&D co-operation differs among the three types of partnerships shown in Table 5.9. Horizontal co-operation is less productive than the other two forms of partnerships with regard to four out of the five types of output. Co-operation with research institutes clearly is the most "productive" type of partnership. Remarkably, this does not hold only for publications and patents (what is not surprising), but also for prototypes/test versions and process innovations; moreover science-related co-operations keep up with the other two types of co-operation in terms of product innovations. These results indicate that the interface between science and industry works quite well, and that research may immediately contribute to market success (see Chapter 7 for a more detailed analysis of the working of this interface).

5.2.5 International comparison of R&D co-operation

Table 5.10 shows a comparison of some aspects of R&D co-operation with selected EU countries; there is no such information for the USA and for Japan. The data for Switzerland differ somewhat from those presented in the previous sections since we had to bring in line our statistical analysis to the EU standards (e.g. threshold of ten employees as against five in the Swiss Innovation Survey). As a result, the proportion of firms co-operating in R&D with other firms or with research institutions is 27% as against 22% according to the results presented in Table 5.4 (sum of column 3 and 4).

In no other country is R&D co-operation nearly as prevalent as in Finland, where every second firm co-operates with other organisations. Sweden takes the second position, followed by France and Switzerland, whereas the other countries – perhaps with the exception of the Netherlands – lie well behind; the same holds true for those EU countries we did not include in the table). We observe that Finland, Sweden and Switzerland also are the leading countries in terms of innovation performance (see Chapter 8), indicating a positive correlation between R&D co-operation and innovation performance.

In addition to the frequency of R&D co-operation , Table 5.10 presents information on co-operation by five types of partners (firms of the same enterprise group, suppliers, users, competitors and other firms, research institutions) with separate information for three origin regions of the partners (Switzerland, EU, USA). It turns out that the country ranking in case of the five types of partners more or less corresponds to the overall ranking. Compared to the other countries, Swiss firms co-operate more with competitors/other firms and research institutions, whereas co-operation within the same company group is quite rare; co-operation with suppliers and users take an intermediate position. Finland and Sweden, the only two countries with a tighter R&D network than Switzerland, show a somewhat different pattern. Finland, attaining the lead in four out of the five types of partner relationships shows the largest advantage in case of co-operation with research institutions and is in the weakest position with regard to partnerships with competitors/other firms. In Sweden, in relative terms, firms co-operate most frequently with companies of the same group and with research institutions.

In general, firms prefer domestic partnerships. Quite surprisingly, this pattern is more or less independent of country size. Nevertheless, geographical distance is a relevant factor, since firms significantly co-operate more often with partners from EU countries than with US companies/institutions. The data show that the degree of internationalisation of R&D co-operation (measured by the frequency of EU- and/or US-partnerships in relation to that of domestic co-operations) is at highest in Sweden, both in case of co-operation with EU and with US institutions. Switzerland takes the second position, whereas in Finland R&D co-operation is , in relative terms more inward-oriented than in the other two countries. Finally, we find that in case of co-operation with research institutions Switzerland is most strongly internationalised, with a particularly high orientation towards the USA. In this country, R&D co-operation with suppliers also is very international, in this case clearly focused on EU countries.

Table 5.10: International comparison: R&D co-operation by partner and partner region (multiple answers)

	Share of co-operating firms (%)							
	CH	DE	FRA	ITA	SWE	FIN	A	NED
Total	27.4	17.4	28.4	9.3	31.8	50.6	21.1	24.0
Type of partner								
Same group								
National	5.1	5.0	8.0	1.3	8.4	17.0	4.9	7.2
EU	3.7	1.7	4.8	0.7	7.4	9.0	5.2	4.3
USA	0.9	1.1	2.2	0.3	3.7	3.2	0.9	2.3
Suppliers								
National	12.5	6.2	10.4	3.7	15.6	32.3	8.4	8.1
EU	11.6	1.5	5.2	1.2	9.5	14.9	6.8	5.6
USA	2.5	.7	1.3	0.4	4.7	4.2	0.7	1.8
Users								
National	15.1	7.4	8.1	2.5	15.7	33.9	6.3	9.2
EU	7.7	1.7	3.7	1.0	9.3	11.4	6.6	6.3
USA	2.1	1.0	1.3	0.4	3.9	5.4	1.5	2.0
Otherfirms, competitors								
National	15.6	6.7	4.5	2.0	3.5	15.4	7.2	6.3
EU	8.9	1.2	1.7	0.7	2.0	4.3	5.0	3.8
USA	0.6	0.6	0.6	0.2	0.7	2.4	0.2	0.9
Research institutions								
National	10.7	7.8	7.7	2.3	13.5	28.2	8.6	5.2
EU	4.1	1.2	2.1	0.8	2.6	5.0	3.5	1.9
USA	1.7	0.4	0.7	0.1	1.4	0.8	0.8	0.4

Reference period: 1998-2000 (EU countries), 2000-2002 (Switzerland).

Source: Third Community Innovation Survey, KOF Innovation Survey 2002, Arvanitis et al. (2004).

To sum up, Switzerland belongs to the leading countries in terms of the frequency of R&D co-operation, with Finland by far outperforming all other countries. The R&D network of Swiss firms is highly internationalised, particularly with regard to co-operation with suppliers and universities; in the latter case, US partners play a very important role.

5.3 Co-operation in basic research

As shown in Section 5.1, the share of basic research in total R&D is significantly higher in Switzerland than in any other country. This type of R&D primarily is performed in the university sector, although private institutions/firms are involved to a higher extent than in other countries. In recent years, however, basic research undertaken by private firms is decreasing (CEST 2003), to some extent compensated for by supporting this type of research at universities (e.g. R&D contracts).

Over the last years, co-operation in basic research has become more prevalent. In order to compare internationally the importance of co-operation in this field of activity, we rely on the proportion of publications with at least one foreign co-author. By excluding purely domestic co-publications we tentatively concentrate on high-end publications. Table 5.11 shows that the share of co-publications is about the same in Switzerland and the USA as well as in Italy; it is much higher than in other small European countries with intensive publication activity (Sweden, Finland, the Netherlands). In Switzerland, the intensity of international co-publication is particularly high in Life Sciences and Clinical Medicine.

Table 5.11 International co-operation of researchers: co-publications 1998-2002

	Percentage share of all publications
Switzerland	15.2
Netherlands	3.2
Sweden	1.0
Finland	1.1
Denmark	-
Austria	0.8
Ireland	-
Germany	10.5
France	9.7
Italy	16.1
UK	4.8
USA	15.1
Japan	1.7

At least one foreign co-author; Source: CEST (2004).

5.4 Assessment

Switzerland belongs to the leading countries in terms of R&D intensity and R&D networking. The structure of R&D is advantageous as compared to other countries in several respects. Firstly, the share of private R&D is high, implying that R&D investments are allocated according to market demand. Secondly, SME's are heavily involved in R&D activities, what is supportive to the economy's absorptive capacity for external knowledge. Thirdly, the structure of public R&D is favourable since it is to a very large extent allocated to basic research performed at universities.

Worrying, however, is the sluggish evolution of R&D expenditures in the nineties: R&D outlays more or less stagnated, with public R&D even decreasing. As a result, Switzerland lost some of its previously excellent position. This unfavourable trend may negatively impact the long term growth potential of the economy (long lags in the R&D process). However, there are signs of a rebound of private R&D expenditures since the year 2000. A reversal of the trend also is necessary in case of public spending for R&D (and education), which must be prioritised among public expenditures.

Networking of R&D activities is indispensable in a world characterised by intensive and increasing international competition based on product and process innovations. It turned out that every second firm follows an R&D strategy involving some form of external R&D, i.e. out-contracting of R&D and/or R&D co-operation. We found that contract-R&D more often complements internal R&D than it substitutes for it. Similarly, R&D co-operation serves, in the first instance, to enhance a firm's knowledge base. Moreover, R&D co-operation is highly "productive" in terms of publications, patents, prototypes as well as product and process innovations. Co-operation with research institutes seem to be particular productive, even with regard to outcomes readily applicable on the market (new products) and within the own firm (new processes). In sum, R&D networking is a means to concentrate internal R&D on core competencies and to use external R&D to strengthen the firm's overall knowledge base. A strong international orientation is another feature of R&D networking in the business sector; this holds true for contract-R&D, but even more for R&D co-operation, with special emphasis on partnerships with suppliers and universities. In addition, (international) co-operation in basic research also is very intensive in the Swiss case.

6 Internationalisation of R&D Activities

6.1 Basic trends and core questions

The Swiss economy is highly internationalised in terms of foreign trade and FDI since decades. In the mid-eighties, foreign investment started to increase significantly stronger than foreign trade for reasons such as the liberalisation of capital markets, the economic integration of Europe, North America and other regions, the transition to world market-oriented development strategies in Asia and South America, technical change leading to lower communication and transport costs, etc. As a consequence, total foreign capital stock increased from 6% to 23% of world GDP in the period 1980 and 2003. Switzerland, with a ratio of 111% was the most highly internationalised economy in 2003, followed by the Netherlands, Sweden and the UK. In addition, the degree of internationalisation of the Swiss economy increased between 1980 and 2003 by factor 4.5, although the initial level already was very high (UNCTAD, 2004).

Moreover, foreign investment changed, to some extent, its character. Traditionally, strengthening direct presence on large and fast-growing markets was the primary objective of foreign investments. This motivation may still be the most important one, but other objectives such as exploiting lower labour costs or gaining access to leading-edge knowledge increasingly become relevant as well. It is against this background that the analysis of the internationalisation of R&D activities is an important element of assessing the technology position of the Swiss economy.

It is quite difficult to trace the development of R&D activities over time at the international level. However, there is no doubt that they strongly increased in the last decades, with an accelerated pace since the eighties (see e.g. Narula and Zanfei, 2004). Swiss data, as will be shown below, are in line with this trend.

As a reaction to these developments, there is increasing concern in the public in Switzerland (and in other countries as well) that foreign R&D activities may substitute for domestic ones ("relocation of R&D"), thereby reducing the long-term growth potential of the economy. However, it is also argued that the internationalisation of R&D is a natural further step in the ongoing process of globalisation. In this view, foreign R&D is considered as a means to tap into the worldwide pool of knowledge ("technology-sourcing") in order to complement and augment the domestic knowledge base. This strategy is successful only if the knowledge transfer from foreign affiliates to the (domestic) headquarter works sufficiently well. In the following subsection we shall assess which of the two competing hypotheses regarding the relationship between foreign and domestic R&D is more appropriate ("substitution" vs. "complementarity").

Internationalisation is not a one-way process. Not only are Swiss firms investing in R&D at foreign locations but foreign companies do the same in Switzerland. Based on a set of indicators, we shall analyse the innovative activities of foreign-owned firms in Switzerland in order to assess their contribution to the domestic innovation performance (subsection 6.3).

6.2 Outward-investments in R&D activities

6.2.1 Pattern and evolution of Swiss R&D at foreign locations

Total R&D expenditures of Swiss-based firms strongly increased between the mid-seventies and the mid-eighties, with domestic and foreign investments growing at about the same rate implying a more or less stable ratio of foreign to total R&D expenditures (see Table 6.1). In the next ten years, foreign R&D expenditures increased much stronger than domestic ones. Consequently, the share of foreign R&D expenditures reached 54% in 1996 and remained unchanged until the turn of the century. According to data recently released by BFS (2005), the share of foreign R&D slightly declined in the period 2000-2004 to 50%, what corresponds to the level of 1992. In other words: since 1992, Swiss firms invest abroad about the same amount as in Switzerland. This result also holds true if the (strongly increasing) extramural R&D expenditures are taken into account.

About half of total R&D is spent by the chemicals and pharmaceuticals industry and another third by a broad category containing the industries metals/metalworking, mechanical and electrical machinery, electronics as well as scientific instruments. The share of foreign R&D expenditures is higher and increased more rapidly than on average in chemicals/pharmaceuticals and electrical machinery/electronics/instruments (but not in metals/metalworking and non-electrical machinery). R&D expenditures of (private) research labs and institutions increased faster than in any other industry, with a particular strong growth of the share of foreign R&D.

Table 6.1: Evolution of R&D expenditure of Swiss firms outside Switzerland (Mio. CHF)

	Chemicals		Metal/Machinery, electrical machinery/electronics		Total	
	Total R&D expenditures	Share of R&D expenditures abroad (%)	Total R&D expenditures	Share of R&D expenditures abroad (%)	Total R&D expenditures	Share of R&D expenditures abroad (%)
2000	7200	66	6175	47	16740	54
1996	6190	59	5990	59	14830	54
1992	6033	52	6170	53	14098	50
1989	4881	50	5471	39	12001	44
1986	4290	49	3193	28	7969	38
1983	3404	44	2230	32	5824	38
1980	2449	39	1837	39	4454	38
1975	1918	35	1396	33	3484	32

Source: Swiss Federal Office of Statistics, authors‘ calculations.

Another way to describe the trend in R&D activities abroad is to focus on the firms' first-time location of R&D outside of Switzerland (see Table 6.2). 51% of firms with R&D activities abroad reported in 2002 that they started these activities between 1991 and 2000, 38% even between 1996 and 2000. This trend is traced back primarily to small and medium-sized firms, with 61% and 54%

respectively having become active abroad in the period 1991-2000. The same holds true for only 26% of large firms; 44% of them were present abroad already before 1970. In order to assess the results based on this second indicator, one has to remind that it does not imply anything about the magnitude of foreign investment. In other words: there is a growing tendency even for small firms to locate some of their R&D activities abroad, but, for obvious reasons, the large firms are primarily the economic actors shaping the trend in terms of investment volumes.

Despite the increasing internationalisation the vast majority of R&D performing firms (still) follows predominantly domestically oriented R&D strategies, even among the larger companies. Foreign R&D is located to a very high extent in other highly industrialised countries offering large markets and disposing of a high-quality knowledge base.

Table 6.2: First-time location of R&D outside Switzerland 2002
(percentage share of firms starting foreign R&D activities in a certain time period)

	Firm size			
	5 - 99	100 – 499	500 and more	Total
Until 1970	6.8	10.2	44.4	15.1
1971-1980	10.2	18.6	7.5	13.0
1981-1990	13.5	13.6	14.8	13.7
1991-2000	61.0	54.2	25.9	51.4
1991-1995	15.2	13.6	11.1	13.7
1996-2000	45.8	40.6	14.8	37.6
2001-2002	8.5	3.4	7.4	6.8
Entire time period	100	100	100	100

Source: Swiss Innovation Survey 2002.

6.2.2 Domestic ownership of foreign R&D output

Data on domestic ownership of research output generated in other countries may also be used as an indicator of outward R&D-investment. Table 6.3 shows the share of domestically controlled patent based on foreign R&D as a percentage of all domestic patents filed at the European Patent Office (EPO). It turns out that this share is much higher in Switzerland than in any other country included in the table. In the period 1999/2000, almost half of all Swiss-owned patents reflect R&D activities at foreign locations, what impressively underlines the high importance of outward R&D activities of Swiss companies. Over the nineties, Sweden, Finland and Switzerland, i.e. three highly innovative countries, showed the strongest increase (percentage points) of the ownership of foreign inventions. In sum, data on international patenting confirm the high and growing importance of foreign R&D activity of Swiss firms.

Table 6.3: Domestic ownership of inventions made abroad
(share of foreign inventions controlled by domestic residents as a percentage of all patent applications filed at EPO)

	1991/92	1999/00
Switzerland	35.9	47.1
Netherlands	40.7	32.4
Sweden	12.7	26.6
Finland	10.2	22.7
Denmark	17.2	14.4
Austria	16.9	23.3
Ireland	45.5	36.4
Germany	8.5	11.8
France	10.4	17.2
Italy	4.8	5.7
UK	18.5	18.3
EU	5.6	7.9
USA	11.6	17.3
Japan	3.1	3.8

Source: OECD, Patent Database, September 2004

6.2.3 Motives, strategies and determinants of foreign R&D investments

Why do firms engage in foreign R&D or increase their foreign R&D investments? Dunning (1993, 2000) distinguishes several categories of motives for locating R&D in foreign countries. Firstly, there are market-seeking motives which reflect "asset exploiting" R&D strategies that correspond to the product cycle model of international trade and investment (Vernon 1966). In this case, foreign R&D is a means to support local production or sales, mainly by adjusting and modifying products according to local market needs. Secondly, there are knowledge-seeking (asset-seeking) motives which are part of strategies based on complementing and augmenting the domestic knowledge base of a firm by tapping into knowledge sources available at foreign locations. Such strategies have become more important in recent years (see, among others, Kuemmerle 1999, Patel and Vega 1999, Le Bas and Sierra 2002). In principle, the development of these competencies would be feasible at home as well; however, it would take more time and resources since knowledge production is path-dependent (Criscuolo et al. 2005). Knowledge-seeking motives such as exploiting proximity to leading universities and firms (networks) in certain technology fields[6] reflect "asset augmenting" strategies only if the knowledge transfer to a firm's domestic headquarter works sufficiently well. Thirdly, foreign R&D may be attractive if R&D costs are significantly lower than at home; in this

6 The importance of geographical proximity giving rise to knowledge spillovers (externalities) has been stressed in the "innovation literature" since many years (see Jaffe et al. 1993). The high relevance of this aspect for the present topic is shown in some recent econometric studies (e.g. Cantwell and Piscitello 2005a,b),

case, internationalisation of R&D may increase the efficiency of a firm's R&D organisation (efficiency-seeking R&D). However, since international co-ordination of R&D is costly, low R&D costs at foreign locations do not "automatically" lead to a relocation of domestic R&D activities (see e.g. Gassmann and von Zedtwitz 1999 or Grünfeld and Sanna-Randaccio 2005). Finally, resource-seeking motives are relevant in the present context if a foreign location offers a (particularly) ample supply of R&D personnel. In these circumstances, resource-seeking motives may be related to efficiency-seeking (cost-reducing) motives as well as to knowledge-seeking (foreign R&D personnel incorporating knowledge in specific technology fields).

Table 6.4: Motives for performing R&D at foreign locations 2002
(percentage share of firms performing foreign R&D that assess a specific motive as important (value 4 or 5 on a 5-point Likert scale)

Motives	Firm size (number of employees)			
	5 - 99	100 – 499	500 and more	Total
Individual motives				
Market-seeking				
(1) Supporting local production and sales	29.5	39.7	61.3	39.7
Knowledge/asset-seeking				
(2) Proximity to leading edge universities	24.6	27.0	25.8	25.6
(3) Proximity to highly innovative firms (local networks of excellence)	45.9	23.8	35.5	35.3
(4) Transfer of knowledge/technology to the Swiss headquarter	24.6	20.7	35.5	25.6
Cost-reducing/efficiency-seeking				
(5) Low R&D costs	36.1	23.8	9.7	26.3
(6) Higher government support for R&D investments	13.1	12.7	6.5	11.5
Resource-seeking				
(7) Ample supply of R&D personnel	39.3	36.5	35.5	37.8
Group of motives (averages)				
Market-seeking (1)	29.5	39.7	61.3	39.7
Knowledge/asset-seeking (2, 3, 4)	31.7	23.8	32.3	28.8
Cost-reducing/efficiency-seeking (5, 6)	24.6	18.3	8.1	18.9
Resource-seeking (7)	39.3	36.5	35.5	37.8
Overall average (1 – 7)	*28.6*	*27.3*	*33.9*	*29.1*

Source: KOF Innovation Survey 2002

Table 6.4 presents some information on the relevance of several motives for locating R&D in foreign countries. It turns out that market-seeking (item 1) and resource-seeking motives (item 7) are the most important drivers of foreign R&D. Knowledge-seeking motives (average of items 2, 3 and 4) are of intermediate relevance; however, "proximity to highly innovative firms" also is one of the most relevant motives when all seven items are considered. Efficiency-seeking motives (average of items 5 and 6) are less important than the other three categories; this holds true in particular for item 6 ("higher government support for R&D investments").

The table also shows that the pattern of motives quite strongly differs by firm size. In case of large firms, market-seeking is clearly the most important motive for locating R&D in foreign countries, resource-seeking and knowledge-seeking motives coming next; efficiency-seeking motives seem to be almost irrelevant. Moreover, the transfer of knowledge and technology to the Swiss headquarter is an important motive in case of large firms. The results for medium-sized firms apparently hardly differ from the overall pattern. This is not the case for small companies. Market-seeking motives are significantly less important than for the other two size classes, whereas efficiency-seeking motives are more important for small firms than for medium-sized and, in particular, for large firms.

The relative importance of the different (categories) of motives implies that the strategies of "asset-exploiting" (market-seeking motives) and "asset-augmenting" (knowledge-seeking motives, to some extent, resource-seeking motives as well) are the most prominent ones. Efficiency-seeking is not very important, in particular in case of large firms, which dominate the volume of R&D expenditures.

The data on the motives for performing foreign R&D presented in Table 6.4 reflect ("subjective") assessments of the surveyed firms with respect to the importance of several (potential) drivers of foreign R&D. In the following we present results of descriptive cross-country studies based on "objective" indicators (data on patents and foreign investments) and findings of econometric work dealing with the determinants of Swiss firms' R&D activities at foreign locations. Both types of studies yield insights that complement those of the descriptive analysis of the motives of foreign R&D activities.

Table 6.5: R&D strategies of MNE's by home country
(percentage share of firms following a specific strategy)

Home country	Strategy			
	Asset-exploiting	Asset-augmenting	Technology-seeking	Market-seeking
Switzerland	19.6	57.6	14.5	8.4
Sweden	41.3	44.7	10.1	3.9
Finland	53.7	43.0	2.7	0.6
Norway	8.5	69.3	16.9	5.4
Denmark	24.7	70.9	1.2	3.3
Netherlands	28.7	34.0	20.2	17.1
Belgium	21.1	36.2	26.8	15.4
France	51.5	33.7	7.7	..7.1
Germany	25.3	54.6	9.2	10.9
Italy	6.0	24.3	65.0	4.6
UK	23.6	60.7	10.2	5.6
USA	33.8	51.0	8.7	6.6
Japan	32.1	35.3	20.0	12.6
All countries	30.1	47.4	13.1	9.5

Quelle: Le Bas and Sierra (2002.

There are a few international cross-country studies where Switzerland is included, which deal *directly* with the relative importance of several R&D strategies. Patel and Vega (1999) and Le Bas and Sierra (2002) using the same approach (see *upper part* of the BOX 3), found that, in the Swiss case, "asset exploiting" and "asset augmenting" are the most prominent strategies, whereas the proportion of Swiss MNE's characterised by "(pure) technology sourcing" (i.e. high importance of foreign technology sourcing combined with a small domestic knowledge base) is low. According to both studies, "asset augmenting" is the most widespread international R&D strategy of Swiss (large) MNE's. The results of Le Bas and Sierra (2002) are summarised in Table 6.5. These findings are confirmed by two further studies referred to in the *lower part* of the BOX 3.

Econometric studies for Switzerland dealing with the determinants of a firm's R&D activities at foreign locations yielded additional insights. Arvanitis and Hollenstein (2001), using the well-known OLI framework (Dunning 2000; Cantwell and Narula 2001), found that "ownership-specific advantages" (O) of a firm and "internalising advantages" (I) are the dominant factors explaining whether a firm performs foreign R&D or whether it is only active at home. O-advantages represent firm-specific characteristics and capabilities (mainly intangible assets) that make a company superior to local competitors irrespective of general locational characteristics. I-advantages can be realised by internalising market transactions through, for example, the acquisition of a foreign

BOX 3: The relative importance of foreign R&D strategies
(Le Bas and Sierra 2002)

Technologic performance in the *home* country	Technological performance in the *host* country Strong	Weak
Weak	*Technology-sourcing* (13.1%) Home RTA < 1 Host RTA > 1	*Market-seeking* Home RTA < 1 Host RTA < 1
Strong	*Asset-augmenting* Home RTA > 1 Host RTA > 1	*Asset-exploiting* Home RTA > 1 Host RTA < 1

The definition of the four strategies is based on the firms' relative strengths or weaknesses in thirty technological fields (patent classification). Strengths and weaknesses are measured in relative terms (relative technological advantages RTA). For each technological field, home RTA (host RTA) is defined as the firm's share in that field of EPO patents invented in the home (host) country relative to its overall share (all fields) of EPO patents invented at home. For each country, the firms are allocated to one of the four strategies according to their specific relative patent position in all technological fields.

Cantwell and Janne (1999) found that "asset augmenting" strategies are dominating in the Swiss pharmaceutical and chemical industry, whereas "asset exploiting" is characteristic for the Swiss metal and machinery sector (and probably the rest of the manufacturing sector). Driffield and Love (2003) find that countries whose firms invested in the UK benefited from the knowledge-base of this host country. The effect is particularly large in case of technologically leading countries such as Switzerland, Sweden or the USA. If such investments are oriented towards spatially-clustered R&D intensive firms, the advantages are even higher. This result is confirmed by Cantwell and Piscitello (2005b). Since "proximity to highly innovative firms" is a very important motive of outward-R&D of Swiss firms (see Table 6.4), these findings are favourable from the Swiss point of view.

(R&D performing) firm. In this way, search and transaction costs can be reduced, the technology transfer between foreign and home country facilitated, etc. In contrast, the authors did not find any evidence for "location-specific disadvantages" (L) of Switzerland driving Swiss firms to invest in R&D abroad. L-disadvantages refer to higher R&D costs, deficient supply of researcher, unfavourable regulatory framework, etc. as compared to foreign locations. Other econometric studies for Switzerland confirm these findings (see BOX 4).

BOX 4: Econometric studies dealing with the determinants of Swiss firms' R&D activities at foreign locations

Arvanitis and Hollenstein (2005) also applied the OLI approach, on the one hand in order to explain whether or not a firm performs foreign R&D, on the other hand to identify the factors determining the extent of foreign R&D investments. The empirical analysis, first of all, confirmed the main results of the earlier study of the two authors (see the text); in addition, it is shown that the internationalisation of R&D is a cumulative and path-dependent process. Hollenstein (2005) investigated whether strategies of internationalisation differ by firm size. He found some (weak) evidence for L-disadvantages of Switzerland as variables explaining internationalisation strategies that involve, in addition to other business functions, foreign R&D activities. However, O-advantages again turn out to be the dominant explanatory factors.

6.2.4 Substitution vs. complementarity

In Section 6.1 we raised the question whether foreign and domestic R&D activities are substitutes or complements, or in other words, whether foreign R&D goes at the expense of the domestic knowledge base. Since foreign R&D expenditures are strongly increasing, although in recent years not more than domestic R&D outlays (see subsection 6.2.1), it would be quite alarming when the "substitution hypothesis" would hold true.

The findings presented in the previous subsection dealing with the motives of foreign R&D, the relative importance of various R&D strategies and the relevance of O-, L- and I-advantages in explaining foreign R&D activities enables us to assess the relative merits of the two competing hypotheses (substitution vs. complementarity). Anticipating our conclusion we can already at this place that, independent of the type of analysis, it turns out that foreign and domestic R&D activities are complements.

Firstly, efficiency-seeking motives are of minor importance, and there is hardly any evidence of disadvantages of Switzerland as a location for performing R&D (insignificance of L-disadvantages in the econometric analysis). Secondly, knowledge-related O-advantages are the dominant driver of foreign R&D. Thirdly, "asset exploiting" and "asset augmenting" R&D strategies (in both cases the domestic knowledge base is strong) are much more important than (pure) "technology seeking" where foreign R&D aims at compensating domestic weaknesses. Fourthly, the transfer of knowledge acquired through foreign R&D to (domestic) headquarters works quite well. Fifthly, technologically leading countries like Switzerland benefit most from outward-investments in countries with a large knowledge base (reflecting its high absorptive capacity); this particularly holds true for investments directed towards spatially clustered firms (geographical "proximity" as an important motive of foreign R&D).

6.3 Inward-investments in R&D activities

6.3.1 Core questions

In this section we mainly address two topics. Firstly, we describe level and evolution of innovative activities performed by foreign firms in Switzerland and shortly deal with potential obstacles to the growth of inward-FDI. Secondly, and most importantly, we aim at assessing the contribution of foreign firms to the innovation performance of the Swiss economy.

6.3.2 Extent and evolution of foreign presence in Switzerland

Information on overall inward-investments yield some indication of the importance of foreign presence in innovation-related activities, assuming that, given the high knowledge-intensity of the Swiss economy, inward-investments are to a significant extent related to knowledge creation and innovation. According to UNCTAD (2004), inward-capital stock, although not as high as outward-capital stock (see subsection 6.1), amounted to 50% of GDP in 2003; in that year, this ratio was higher only in Ireland and the Netherlands. In addition, the degree of penetration of the Swiss economy with foreign capital increased since the early eighties by factor 6, with an initial level in 1980 of 8%. Among the countries characterised by a strong foreign penetration in 2003, the increase was higher over the last two decades only in Sweden and Finland who experienced an "explosion" of foreign inward-investments (Sweden: from 2% to 48%, Finland: from 1% to 29% of GDP). According to this crude indicator, Switzerland seems to be attractive and, over time, has become even more attractive as a location for foreign direct investments.

Table 6.6 shows for Switzerland and twelve other countries the extent of domestically generated research output (patents) that is owned by foreign firms. Foreign ownership is measured as the share of patent applications owned by foreign residents based on domestic R&D as a percentage of all domestic patent applications filed at the European Patent Office (EPO). There are two interpretations of a high percentage share. Firstly, it may indicate that R&D of the host country is primarily performed by foreign MNE's, what is true for countries that still lag in technological terms (e.g. Ireland and, to some extent, Austria). Secondly, it may reflect a strong knowledge base of the host country (e.g. Switzerland, Denmark) and/or a tradition of very low barriers to inward-investments (e.g. UK; see Table 6.7). Foreign ownership of research output is low in Finland and Sweden where the obstacles to inward-investments have been high until recent years (see Table 6.7). The fact that foreign ownership of research output generated in Switzerland is very high, although the barriers to inward-inward investments are restrictive (see the next subsection), is an indication for the strong knowledge base of this country. Switzerland obviously is very attractive for foreign firms as a location for performing R&D and for local knowledge and technology sourcing.

Table 6.6: Foreign ownership of domestic inventions according to the residence of the inventors
(percentage share of patent applications to the EPO owned by foreign residents in total patents invented domestically)

	1991/1992	1999/2000
Switzerland	19.0	23.2
Netherlands	18.4	20.6
Sweden	13.8	16.3
Finland	13.7	8.9
Denmark	14.7	22.7
Austria	25.4	36.6
Ireland	44.3	37.9
Germany	9.9	13.1
France	12.5	20.8
Italy	13.2	18.3
UK	28.9	37.2
EU	8.3	11.4
USA	7.8	12.0
Japan	3.6	3.8

Source: OECD, Patent Database, September 2004.

6.3.3 Restrictions on inward-FDI

The attractiveness of Switzerland as a location for inward-investments as well as innovation-related inward-investments not only depends on the knowledge base of this country but, as already mentioned, also on the barriers erected against the inflow of foreign capital. In order to get internationally comparable data, OECD recently developed an overall index of barriers to inward-FDI (Golub 2003) which takes account of limitations of foreign ownership, restrictions of employing foreign labour, specific controls and procedures for foreign business activities, etc. The results for Switzerland and eleven foreign countries are shown in Table 6.7.

It turns out that restrictions on inward-FDI were comparatively high in Switzerland in the period 1999/2000; it attained rank 9 among the twelve countries considered here. Interestingly, the index value was about the same as in some of the most innovative countries (USA, Finland, Sweden). Over time, the barriers to inward-FDI were lowered in all countries with the exception of the USA and Japan. However, since the reduction was smaller in Switzerland than in other European countries, the *relative* degree of restrictions slightly increased.

A more detailed inspection of the data shows that, in the Swiss case, about 55% of the index value reflect restrictions on employing foreign labour, the other 45% refer to limitations of foreign ownership, while specific controls and procedures are irrelevant. The free movement of labour between Switzerland and the EU applying since 2004 eliminates the restrictions on foreign labour to

Table 6.7: Restrictions on inward-FDI 1990 and 2000 (index values)

Host country	1990	2000	Percentage change 1990 till 2000
Switzerland	0.278	0.172	-38.1
Netherlands	0.243	0.083	-65.8
Sweden	0.335	0.140	-58.2
Finland	0.463	0.177	-61.8
Austria	0.432	0.268	-38.0
Ireland	0.250	0.074	-70.4
Germany	0.174	0.084	-51.7
France	0.233	0.111	-52.4
Italy	0.264	0.097	-63.3
UK	0.167	0.064	-61.7
USA	0.170	0.169	-0.6
Japan	0.237	0.230	-3.0

A high index value indicates a high level of restrictions on inward-FDI.
Source: Golub (2003).

a large extent. Consequently, an index value of about 0.13 is probably more realistic for the present situation. But even taking account of this improvement, the barriers to inward-FDI remain higher than in six of the twelve countries considered in the table, and the reduction over time still is smaller than in eight of them.

These results, however, must be set in a larger perspective. It may be the case that, if the level of restrictions is lower than a certain threshold value, foreign investments are not substantially hampered anymore. In addition, other determinants of FDI may be more relevant such as taxation or the domestic knowledge base. Therefore, we conclude that there may be some potential for attracting more foreign capital by further lowering restrictions, but it might be rather unlikely that

BOX 5: Other studies dealing with weaknesses of Switzerland as a location for innovation-related inward-FDI

There are hardly any empirical studies dealing with the economic attractiveness of Switzerland as a location for inward-FDI. To mention are, in the first place, Steiger (1999) who analysed the attractiveness of the Zurich and the Geneva area and Caluori (1993) who investigated this topic specifically for the pharmaceutical and chemical industry. Both studies primarily are based on a small number of firms assessing the relevance of a set of location factors in the early nineties. Therefore, the explanatory power of these studies is quite restricted. Nevertheless, it is interesting that both studies find that high R&D costs, various aspects of regulations (e.g. restrictions of free competition on (some) domestic markets) as well as the very moderate public support of private R&D are the most relevant obstacles for foreign firms to invest in R&D activities in Switzerland.

this potential is very large. The fact that the inward-FDI capital stock strongly increased in the nineties may be an indication that such restrictions are of rather minor importance in the Swiss case. The same argument holds for the USA where capital inflow was very high in the nineties without any relaxation of the rather high barriers to inward-FDI.

6.3.4 Contribution of foreign-owned firms to the innovation performance of the Swiss economy

It is a stylised fact observed in many foreign studies that foreign-owned firms, in most instances affiliates of foreign MNE's, are more innovative (higher R&D intensity) and more productive (higher labour productivity) than domestic firms (see Bellak 2004). These differences, usually referred to as "technology gap" and "productivity gap" respectively, may represent a high attractiveness of the host country as a location for performing R&D (attractive domestic research infrastructure, etc.). They also indicate a potential for positive technology and productivity spillovers to domestic competitors or other firms such as, for example, domestic suppliers (see Caves 1996). The size of knowledge spillovers is determined by several factors such as the size of the gap, the (voluntary or involuntary) leakage of the foreign firm's knowledge, the absorptive capacity of local firms, etc. (see Veugelers et al. 2005). It seems sensible to assume that knowledge spillovers are at highest if the technology gap is neither very small (low potential for spillovers) nor too large (insufficient absorptive capacity of domestic firms).

In 2002, 13% of the sample of the KOF Innovation Survey were foreign-owned firms. They are over-represented in manufacturing and – within this sector – in the most innovative industries (chemicals/pharmaceuticals, machinery, electronics/instruments). In the services sector, banking/insurance, computer and R&D services and, particularly, wholesaling are the most prominent industries where foreign firms are highly active. The owners of 97% of these firms are European (78%) or US companies (19%). Foreign-owned firms are significantly over-represented among medium-sized and large firms. Given this pattern, it would be no surprise if foreign-owned firms, on average, were more innovative than domestic ones.

In the following, we compare the innovativeness of foreign-owned and domestic firms by using a set of indicators representing a firm's innovation performance as well as measures reflecting the extent of a firm's use of scientific knowledge. We compare the two sets of firms, firstly, in terms of these indicators irrespective of the structural differences such as industry affiliation, firm size, etc., secondly, controlling for such differences in order to find out whether structurally similar foreign-owned firms are more (or less) innovative than domestic ones. The first comparison yields some indication of the overall contribution of foreign firms to the innovation capacity of the Swiss economy; the second one shows whether there is a knowledge gap (in a more narrow sense).

Table 6.8: Innovation activities of foreign-owned firms 2000-2002

Indicator	Foreign firms	All firms of the sample
	Percentage share of all firms	
(1) Innovation firms (new products)	59.6	48.9
(2) Innovating firms (new processes)	41.9	39.5
(3) Firms performing R&D	49.0	34.5
(4) Firms having applied for patent	12.3	6.1
(5) Firms having launched a world novelty	21.4	11.6
	Average of innovating firms	
(6) R&D expenditures as a percentage of sales	3.4	3.1
	Percentage share of innovating firms	
(7) Firms using knowledge from universities and other research institutions	24.2	14.3
(8) Firms using knowledge from patent documents	9.6	5.2
(9) Firms engaged in R&D co-operations	15.6	14.4
	Percentage share of firms co-operating in R&D	
(10) Firms engaged in R&D co-operations with universities and other research institutions		
a) Swiss partners	32.0	41.0
b) EU partners	14.7	13.7

In case of the variables “use of university knowledge” and “use of knowledge from patent documents” the percentage share refers to those firms which use the corresponding source “intensively” or “very intensively”, i.e. value 4 or 5 on a five-point Likert-scale.

Source: KOF-Innovation Survey 2002.

Table 6.8 shows the innovation performance and science-relatedness of foreign-owned firms compared to the average of the whole sample in the period 2000-2002 with respect to eleven indicators: five qualitative innovation indicators covering the input- and output-side as well as the market-orientation of innovative activity (indicators 1 till 5), R&D intensity as a quantitative input measure (6), two qualitative indicators of the intensity of use of science-related knowledge (7, 8) and three measures capturing co-operative activity in R&D (9 till 11). It turns out that foreign-owned firms are significantly more innovative than the average firm according to the qualitative indicators (1 till 5). In case of R&D intensity the margin, however, is quite small (about 10%). Foreign-owned firms are not only more innovative than the average firm but they also draw to a larger extent on science-based knowledge sources in general (7, 8) and, in particular, in the frame of formal R&D co-operations with universities and other research institutions (10a and 10b). The general propensity to co-operate in R&D (9), i.e. non-university partners of co-operation included, is about the same for the two categories of firms.

It cannot be excluded that the more favourable position of foreign-owned companies as compared to domestic ones in terms of innovation performance and proximity to science only reflects some structural differences between the two groups of firms. Foreign-owned firms, for example, are on average larger (see above) what implies that they are more inclined to perform R&D and to co-operate in R&D with universities. In order to find out whether there really is a technology gap, we have to compare the two categories of firm after having controlled for such structural differences ("comparing equals with equals").

Table 6.9 shows the results of such a comparison based on a matched-pairs analysis of seven innovation indicators, at firm level, i.e innovation input (1), innovation output (2 till 4), market-orientation of product innovations (5 and 6) and two measures of the intensity of use of science-related knowledge (7 and 8) (see Arvaniti et al. 2005, Ch. 4). The columns 1 and 2 show the mean value for the two categories of firms, the third one indicates whether the difference of the means is statistically significant. It turns out that foreign-owned firms are distinctly more innovative than structurally similar domestic companies according to four of the seven innovation measures (3, 4, 6, 7). For another two indicators the difference is statistically not significant (1, 5). Only in case of patent applications (2) domestic firms appear to have a ststistically significant advan-

Table 6.9: Innovation performance of domestic and foreign-owned firms in 2000/2002, having controlled for structural differences

Indicator	Mean		Statistical significance of the difference of the means
	Domestic firms	Foreign-owned firms	
1) R&D expenditures as a percentage of sales	0.028	0.029	n.s.
2) Number of patent applications	4.4	3.0	*
3) Importance of innovations in technical terms	3.37	3.55	***
4) Importance of innovations in economic terms	3.38	3.55	**
5) Sales share (%) of new or significantly improved products	33.0	35.7	n.s.
6) Sales share (%) of new products	15.3	18.1	*
Sales share (%) of world novelties	3.9	5.4	*
7) Relevance of knowledge from universities or other research institutions	2.38	2.54	**
8) Relevance of knowledge from patent documents	1.86	2.11	***

In case of the variables "importance of innovations in technical / economic terms respectively" and "relevance of knowledge from universities/other research institutions and from patent documents respectively", the table shows the mean value of the firms' assessments measured on a five-point Likert-scale (1: very low importance; 5: very high importance.

Source: Arvanitis et al. 2005, Ch. 4.

tage; this result, however, rather than indicating a better performance of domestic firms presumably reflects the fact that patents generated by foreign-owned firms often are filed to patent offices through the headquarter located abroad. Finally, as shown by the comparisons based on the indicators 8 and 9, innovative activities of foreign firms use to a significantly higher extent science-related knowledge than their domestic counterparts.

To sum up, foreign-owned firms, in accordance with the evidence from empirical studies for other countries, are more innovative than domestic ones, and their innovative activity is more focused on science-related knowledge sources and institutions. This result is independent of whether we do or do not control for structural differences between the two categories of firms. From these findings we conclude that inward-FDI significantly contribute to the innovation performance of the Swiss economy (even in absence of positive technology spillovers). In addition, the results imply a knowledge gap that, in principle, could help domestic firms to enhance their knowledge base. Since absorptive capacity of Swiss firms is high, it is very likely that Swiss firms significantly profit from positive knowledge spillovers.[7] Finally, foreign companies probably locate activities in Switzerland because it offers – as compared to other countries – an attractive research infrastructure.

6.4 Assessment

The extent of outward- and inward-oriented internationalisation of R&D is practically in no country as high as in Switzerland, and in the last fifteen years international R&D investment flows strongly increased in both directions.

Outward-investments often are considered as a danger for the knowledge base of the Swiss economy ("relocation"). However, the empirical analysis does not support this hypothesis. Rather there is overwhelming evidence for the alternative hypothesis according to which foreign and domestic R&D are complements. This result is independent of the approach we used, that is whether it is based on a descriptive analysis of the firms' motives to perform R&D at foreign locations, or on a cross-country investigation of domestic and foreign patenting, or on econometric work explaining foreign R&D activities of domestic firms. More specifically, it turns out that market- and resource-oriented motives as well as profiting from proximity to highly innovative firms and networks are the dominant drivers of foreign R&D, whereas efficiency-/cost-oriented motives are of minor importance. This pattern is consistent with asset-exploiting and asset-augmenting R&D strategies that, according to international cross-section analyses, dominate the pattern of foreign R&D activities of Swiss firms. In accordance with these results, the econometric analysis did not yield any evidence for disadvantages of Switzerland as a location of performing R&D, while there is overwhelming support for asset-exploiting and asset-augmenting strategies.

7 We dare to draw this conclusion although there is no econometric work dealing with this problem for Switzerland.

As far as inward-FDI is concerned, we found that these significantly contribute to the innovation performance of the Swiss economy, that is *directly* due to the presence of highly innovative foreign-owned firms and *indirectly* because of positive knowledge spillovers resulting from a technology gap between foreign and domestic firms (higher innovation performance of foreign-owned companies). Finally, foreign firms, in the first place, perform R&D in Switzerland because of its attractive research infrastructure and industry structure (strong presence of high-tech and knowledge-intensive industries). Foreign-owned firms are present in Switzerland for reasons that are, with the exception of market-oriented motives, similar to those inducing Swiss companies to performing R&D in technologically advanced countries.

7 Knowledge and Technology Transfer Activities (KTT) between Private Enterprises and Science Institutions: Some More Detailed Information

7.1 Introduction

The interaction of business sector and science institutions through the exchange of knowledge and technology has become a central concern not only for applied economics but also for economic policy in the last years. In a knowledge economy, science is exerting an increasingly large influence on innovation, especially in fast-growing knowledge-intensive industries. Thus, the extent and intensity of industry-science relationships is considered to be a major factor contributing to high innovation performance, either at the firm-level, industry-level or country-level (see e.g. OECD 2002).

Experiences for the USA suggest that research excellence of publicly financed science institutions and commercialization of research results by private enterprises are compatible goals which reinforce each other, if both sides adopt a long-term perspective (as e.g. in aerospace, computers and telecommunication). However, there is accumulating evidence that many OECD countries are lagging behind in this aspect. The interface between business firms and science institutions, especially universities has to be improved and, as a consequence, knowledge and technology transfer activities have to be intensified. Also in Switzerland it is asserted by many observers that the industry-science interface is far from being satisfactory (see e.g. Zinkl and Huber 2003). However, so far there does not exist a comprehensive study on extent, intensity, channels, content, goals, and impediments of KTT activities in Switzerland.

An important part of KTT activities is dedicated to research, particularly contract research performed in the universities on behalf of private enterprises. Official R&D statistics contain some information on the share of total contract R&D performed by universities and universities of applied sciences in the period 1989-2004 (see table 7.1). The business sector spent for contract-R&D performed in Switzerland by universities and private enterprises 243 Mio. Sfr. in 1992. These expenditures increased continually during the nineties (1992: 243 Mio. Sfr; 2000: 535 Mio. Sfr.). A significant acceleration of the growth of these expenditures took place between 2000 and 2004; in this year they amounted to 1312 Mio. Sfr.[8] University research claimed 45 Mio. Sfr. in 1992 and 259 Mio. Sfr. in 2004 respectively out of the total, thus showing about the same growth by about 5.5 times as private enterprises in Switzerland. The share of contract research performed by universities was on average about 23%. Unfortunately there is no published information available on the share of foreign universities of contract research abroad. In 2000, i.e. the last year for which more detailed information is available, 20% of university contract R&D was performed on behalf of the pharmaceutical industry, 12% on behalf of machinery, 24% of private research laboratories and

8 During 1992 and 2004 the *total* extramuros expenditures of Swiss firms increased by 6.3 times from 638 Mio. Sfr. to 4046 Mio. Sfr.. Thus, parallel to the process of increasing internationalization of R&D activities described in Ch. 6 also an accelerated internationalization of contract R&D took place.

44% of firms of all other industries. According to literature (see e.g. Rammer et al. 2004), there was internationally during the nineties a tendency of private enterprises of outsourcing R&D activities, particularly those activities that were oriented to basic research, but also a tendency of shifting overall R&D to more applied research. Thus, it is not possible to make an assessment of the performance of the Swiss university sector with respect to private contract R&D only based on the figures presented in table 7.1.

Table 7.1: Extramuros R&D expenditures of the Swiss business sector in Switzerland

	Domestic universities	Percentage change	Domestic private enterprises	Percentage change	Percentage share of universities[1]	Total	Percentage change
1992	45		198		18.5	638	
1996	150	233.3	370	86.9	28.8	1000	56.7
2000	125	-16.7	410	10.8	23.4	1760	76.0
2004	259	107.2	1053	156.8	19.7	4046	129.9

Note: (1): Percentage share of the sum of the amounts of domestic universities and domestic private enterprises.

Source: FSO, several years.

In this chapter we report on selected results of a large KOF-project on behalf of the ETH-Board aiming at the investigation of a) extent and b) economic relevance of *knowledge and technology transfer* (KTT) between science institutions (universities, universities of applied science and other public research institutions) and private corporations in Switzerland.

Under knowledge and technology transfer we understand very broadly any activity targeted at transferring knowledge and technology that may help a company or a research institution – depending on the direction of the transfer – to further promote its activities.

The data for this study were collected by means of a large postal survey of Swiss enterprises based on a questionnaire on the exchange of knowledge and technology with Swiss universities and other research institutions. The survey was addressed to about 6000 firms from all sectors of the economy (with exception of hotels/catering, retail trade, transportation and personal services) and from different size classes. We received answers from 2582 firms, i.e. 45.4% of the firms in the underlying sample.

7.2 KTT activities in the Swiss business sector

7.2.1 Incidence of KTT activities

According to the results presented in table 7.2, 27.6% of all firms were involved in KTT activities with science institutions (see column 2). This figure is somewhat lower for small firms (25.1%) and increases to 47.1% for large firms. The share of firms with KTT activities is almost the same in manufacturing and in the service sector (31.0% and 32.4% respectively). Only 14.1% of firms in the construction sector are involved in KTT activities. Firms in high-tech manufacturing and in the knowledge-based services show the highest incidence of KTT activities. Especially firms in the chemical industry, in electronics/instruments and in business services are most often engaged in KTT. 8.6% of all firms are involved in KTT activities with foreign universities and/or other research institutions (column 3 in table 7.2); this share is significantly larger for high-tech firms (18.9%).

7.2.2 Forms of KTT activities

The KTT-active firms were asked to evaluate the importance of 19 different single forms of KTT activities on a five-point Likert scale ranging from 1 ("not important") to 5 ("very important"). These 19 single forms were classified in five categories: informal informational activities, educational activities, activities related to technical infrastructure, research activities and consulting (see table 7.3). "Tacit" forms of KTT were more important than "codified" ones. More than 50% of KTT-active firms in Switzerland found (a) informal, personal contacts which aim at gaining some general information on technological opportunities and/or (b) a wide spectrum of education activities as the most important forms of KTT activities (see row 1 and 8 in table 7.3). Between 12% and 18% had a focus on research, infrastructure and consulting activities (see row 5, 18 and 22 in table 7.3).

At a more detailed level, firms reported "reading of and referring to publications" (33.1% of KTT-active firms), "attending conferences and workshops" (30.4%) and "informal contacts" (30.4%) as the most important single KTT activities (see table 7.3). Other important activities were "attending university training courses by firm employees" (22.1%), and "employing graduates in R&D" (18.4%). Among educational activities writing diploma theses on a subject of special interest for a firm was also of a certain importance (15.7%). Finally, co-operation in R&D was very important for 16.3% of KTT-active firms.

In fact, KTT-active firms combined different forms of KTT. High-tech firms as well as firms in the knowledge-based services and in construction most frequently combined two main groups of forms, namely informal informational and educational activities.

Table 7.2: Incidence of overall KTT activities by industry, sector and firm size class

Industries	Number of firms	Percentage of firms with KTT activities	Percentage of firms with KTT activities abroad
Food/beverage	127	33.0	10.2
Textile	30	30.1	22.1
Clothing/leather	11	0.0	0.0
Wood processing	56	26.5	7.0
Paper	31	31.2	3.8
Printing	91	26.7	0.9
Chemicals	93	41.9	26.6
Plastics/rubber	58	29.7	19.4
Glass/stone/clay	47	31.8	4.1
Metal	39	26.7	5.9
Metalworking	173	28.4	14.3
Machinery	269	35.8	17.0
Electrical machinery	87	33.9	18.4
Electronic/instruments	152	40.1	17.7
Watches	54	26.2	4.1
Vehicles	29	32.4	20.3
Other manufacturing	54	25.4	16.7
Energy/water	49	30.5	10.6
Wholesale	215	31.6	9.5
Transport	154	28.4	1.2
Banking/insurance	179	26.5	5.4
Computer services	79	26.4	4.8
Business services	216	37.9	11.6
Telecommunication	18	32.9	2.3
Sectors			
Manufacturing	1450	31.0	13.2
Construction	271	14.2	4.1
Services	861	32.4	8.3
Subsectors			
High-tech	688	36.7	18.9
Low-tech	762	28.0	10.1
Knowledge-based services	492	33.9	9.2
Traditional services	369	30.8	7.4
Firm size classes			
Small (5-49 employees)	1287	25.1	7.7
Medium (50-249 employees)	924	37.7	11.9
Large (250 and more employees)	371	47.1	18.3
Total	*2582*	*27.6*	*8.6*

Note: KTT activities in the period 2002-2004 and/or before 2002. Source: KOF-Survey 2005 on KTT activities.

Table 7.3: Forms of KTT activities

KTT main forms / single forms	Percentage of KTT-active firms reporting 4 or 5 on a five-point Likert scale (1: 'not important'; 5: 'very important')
INFORMAL (variable INFO)(1)	*56.6*
Informal contacts	30.4
Attending conferences	30.4
Reading of, referring to publications	33.1
TECHNICAL INFRASTRUCTURE (variable INFR)(1)	*11.9*
Common laboratory	3.9
Use of university technical infrastructure	10.7
EDUCATION (variable EDUC)(1)	*52.3*
Employing graduates in R&D	18.4
Contacts with university of graduates employed in R&D	10.1
Students' participation in firm R&D	10.9
Joint diploma theses	15.7
Joint PhDs	7.0
University researchers' participation in firm R&D	10.1
Common courses	3.8
Teaching of firm researchers at the university	7.7
Attending university training courses	22.1
RESEARCH (variable REAS)(1)	*17.8*
Joint R&D projects	16.3
Long-term research contracts	5.0
Research consortium	4.1
CONSULTING (variable CONS)(1)	*15.3*
Expertise	11.1
Consulting	13.8
N	669

Note: (1): percentage of firms reporting a value 4 or 5 on a five-point Likert scale (1: not important'; 5: 'very important') at least in one of the single forms belonging to the corresponding main category of forms of KTT activities. Source: KOF-Survey 2005 on KTT activities.

7.3 Transfer institutions and transfer channels

7.3.1 Transfer (mediating) institutions

Firms with KTT activities were asked how important are the following mediating institutions in order to establish formal contacts with universities: Technology Transfer Offices of the Universities, the Commission for Technology and Innovation (KTI), the Swiss Science Foundation (SNF), the Framework Programmes of the European Union and other Research Programmes of the European Union (e.g. EUREKA). 82.7% of KTT-active firms stated that none of the mentioned institutions is "very important" for gaining formal contacts with universities (i.e. they reported 1 or 2 or 3 on a five-point Likert-scale (1: "not important"; 5: "very important"; see Table 7.4). This result is valid for all firm size classes. Manufacturing firms appreciated the service of mediating institutions more frequently than other sectors. In contrast, 98.6% of the firms in the construction sector found that mediating institutions are not very important for their KTT activities. At the subsector level, high-tech firms perceived the service of mediating institutions more often as more relevant than firms in any other sub-sector.

The services of the KTI are highly appreciated by around 11% of KTT-active firms, while 9.5% ranked the services of the Transfer Offices as “very important” for gaining formal contacts with university. The EU Framework Programmes, other EU research programmes and the SNF are “very important” for a much lower number of firms.

Firms of all sizes appreciate at most the services of the KTI, followed by those of Transfer Offices. The services from the EU Framework Programmes, the SNF and other EU research programmes are appreciated to a much lower extent than those of the first two categories of mediating institutions. Firms in the manufacturing sector (high-tech and low-tech to the same extent) and the service sector (mainly modern services) most frequently found the services of the KTI as very useful. Firms in the construction sector and in the subsector of traditional service industries appreciated more the services of Transfer Offices. The activities of the SNF in the field of KTT is more often appreciated by firms in the service sector and here especially in the subsector of modern service industries than in other ones. In contrast, firms in the high-tech subsector and in the sector of traditional services (for the “Framework Programmes” only) find the services of international programmes and institutions (EU) relatively often very helpful.

Table 7.4: Importance of single mediating institutions (share of firms in % reporting 4 or 5 at a five-point Likert scale)

	Transfer-offices	Innovation Promotion Agency (KTI)	Swiss National Science Foundation (SNF)	Framework Programmes EU	Other Research Programmes EU
Sectors					
Manufacturing	13.7	17.7	1.5	3.0	2.7
Construction	1.4	0.2	0.2	0.3	0.2
Services	9.1	9.9	5.6	3.9	1.2
Subsectors					
High-tech	12.6	17.7	3.1	6.5	5.7
Low-tech	14.4	17.8	0.4	0.6	0.6
Modern services	6.7	9.5	6.0	2.8	2.3
Traditional services	11.9	10.5	5.3	5.3	0.0
Firm size classes					
Small (5-49 employees)	10.5	11.1	3.7	2.9	1.2
Medium (50-249 employees)	6.3	10.9	3.4	3.7	2.1
Large (250 and more employees)	6.6	10.4	2.6	5.0	4.0
Total	9.5	11.0	3.6	3.2	1.5

Source: KOF-Survey 2005 on KTT activities.

In sum, Technology Transfer Offices are more oriented towards firms in the modern service sector and the construction sector. The KTI services are focusing on firms in the manufacturing sector (high-tech and low-tech), independent of firm size. The SNF is more relevant for large firms in the service sector (modern as well as traditional services). The EU programmes are predominantly interesting for large firms in the high-tech and to some extent in the traditional service subsector (EU Framework Programme).

7.3.2 Transfer channels

In the policy discussion about the economic impact of universities indicators such as the number of patents, licenses and/or spin-offs/start-ups are often used as performance measures. These three indicators are considered as important vehicles of commercialisation of university inventions. We asked firms to assess the relevance of these channels for their own KTT activities and included scientific publications as an additional channel of information exchange.

More than half of the KTT active firms stated that at least one of these channels is "very important" for transferring knowledge. This figure is clearly higher for firms in the high-tech industry and lower for firms in the traditional service subsector and the construction sector (see Table 7.5).

Table 7.5: Importance of channels of KTT activities (share of firms in % reporting 4 or 5 at a five-point Likert scale)

	Scientific Publications	Patents	Licenses	Spin-offs/Start-ups
Sectors				
Manufacturing	34.1	20.0	8.2	7.5
Construction	19.3	1.3	0.2	0.0
Services	36.8	3.9	5.2	5.2
Subsectors				
High-tech	30.4	20.7	13.8	6.8
Low-tech	36.6	19.6	4.3	8.0
Modern services	48.5	6.6	9.5	4.7
Traditional services	22.8	0.7	0.0	5.8
Firm size classes				
Small (5-49 employees)	32.9	8.2	5.4	6.1
Medium (50-249 employees)	36.0	8.1	5.8	2.7
Large (250 and more employees)	34.4	14.8	4.2	3.6
Total	33.6	8.5	5.4	5.3

Source: KOF-Survey 2005 on KTT activities.

Scientific publications are the most important channel for KTT from a firms' perspective, independent of firm size, sector or subsector. 33.6% of the KTT-active firms stated that scientific publications are "very important" for transferring knowledge. In contrast, patents are very important for only 8.5% of the firms, licenses for 5.4% and spin-off/start-ups for 5.3%. This ranking is valid for medium-sized and large firms and for firms of the manufacturing and the construction sector. Firms of the service sector emphasises licenses and spin-offs/start-ups more than patents. At the subsector level, high-tech and low-tech firms appreciate patents clearly above average. So do firms of the traditional service industries, high-tech and low-tech manufacturing in the case of spin-offs/start-ups. Licenses seem to be of particular importance for high-tech firms and firms of modern services.

7.4 Transfer partners

Firms reported also the institutions(s) (Federal Institutions, Canton Universities and Universities of Applied Sciences) with which they interacted. Many firms reported more than one institution. The information on the frequency of contacts of firms with Swiss science institutions is presented in Table 7.6. About 31.5% of KTT-active firms reported that they have KTT activities with the Federal Institute of Technology in Zurich (ETHZ), 25.4% of the firms are in contact with the Federal Laboratories for Materials Testing and Research (EMPA) and 19.1% stated that they have KTT contact(s) with the Federal Institute of Technology Lausanne (EPFL). Outside the ETH-Domain, the University of St. Gallen was mentioned by 17.1% of the KTT-active firms and 12.1% of the firms have KTT contacts with the University of Zurich and the University of Berne. As to the Universities of Applied Sciences (UAS), 9.1% stated to have KTT contacts with the University of Applied Sciences Zurich (Winterthur) and 8.7% mentioned the School of Aargau which is part of the University of Applied Sciences of North-western Switzerland.

Table 7.6: Percentage of firms with KTT activities with a certain science institution as KTT partner

Science institutions	*Total*
Federal Institute of Technology Zurich	31.5
Federal Institute of Technology Lausanne	19.1
Paul Scherrer Institute (PSI)	7.9
Swiss Federal Institute of Aquatic Science and Technology (EAWAG)	3.2
Swiss Federal Laboratories for Testing and Research of Materials (EMPA)	25.4
Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	7.5
University of	
Berne	12.1
Basle	3.3
Fribourg	3.7
Geneva	3.1
Lausanne	2.4
Neuchatel	3.4
St.Gallen	17.1
Italian Switzerland	0.0
Zurich	12.1
University of Applied Sciences of North-western Switzerland:	
School of Aargau	8.7
School of Basle	7.4
School of Solothurn	2.4
University of Applied Sciences of Italian Switzerland	2.0
University of Applied Sciences of Berne:	
School of Engineering St. Imier	0.8
School of Engineering & Architecture Berne	4.0
School of Engineering & Architecture Biel	6.0
School of Engineering & Architecture Burgdorf	5.7
School of Business & Administration	0.9
School of Business (private)	0.6
School of Business Berne (private)	0.1
School of Wood Technology	3.8
School of Agriculture	0.5
University of Applied Sciences of Eastern Switzerland:	
School of Buchs	5.8
School of St.Gallen	3.7
School of Rapperswil	0.2
University of Applied Sciences of Central Switzerland:	
School of Social Work Luzern	0.3
School of Engineering & Architecture Luzern	7.0
School of Business Luzern	3.2
University of Applied Sciences of Western Switzerland:	
School of Engineering Changins	0.7
School of Engineering Canton Neuchâtel	2.3
School of Engineering Canton Vaud	2.1
School of Engineering & Architecture Fribourg	2.3
School of Administration Fribourg	0.2
School of Valais	3.0
School of Geneva	0.3
University of Applied Sciences of Zurich:	
School of Engineering, Business & Administration Zurich	3.7
School of Wädenswil	2.8
School of Zurich Winterthur	9.1
N	*669*

7.5 Motives for and obstacles to KTT activities

7.5.1 Goals of / motives for KTT Activities

The KTT-active firms were asked to evaluate the importance of 20 different single motives of and objectives for KTT activities on a five-point Likert scale ranging from 1 ("not important") to 5 ("very important"). The 20 different motives were pooled into 4 main groups of motives, i.e. "access to human capital ("tacit" knowledge)" (containing the information for 3 single motives; see table 3), "access to research results ("codified" knowledge)" (7 single motives), "financial motives" (5 single motives) and "institutional/organizational motives" (5 single motives). We used the share of firms reporting 4 or 5 on the Likert scale for any of the single motives in a certain group of motives to characterize the overall importance of this group of motives (see Table 7.7).

Table 7.7: Motives for KTT activities

Motives	Percentage of KTT-active firms reporting 4 or 5 on a five-point Likert scale (1: 'not important'; 5: 'very important')
ACCESS TO "TACIT KNOWLEDGE":	*65.9*
Access to specific skills in addition to internal know-how	46.3
Further education, training possibilities	29.5
Recruitment of graduates	15.5
ACCESS TO "CODIFIED KNOWLEDGE":	*29.3*
New research ideas	18.0
Access to basic research	14.5
Access to university patents, licenses	5.7
Access to research results for subsequent internal use	11.7
Access to research results for developing new products	16.7
Access to research results for developing new processes	15.5
Access to R&D infrastructure	10.3
FINANCIAL MOTIVES:	*41.1*
Cost-saving in R&D	10.3
Reduction of technical R&D risks	7.5
Time-saving in R&D	13.4
Insufficient firm R&D resources	21.7
Project characteristics require co-operation with science institutions	25.6
INSTITUTIONAL, ORGANIZATIONAL MOTIVES:	*25.0*
Building up a new research domain	3.7
R&D outsourcing as strategic measure	6.1
R&D co-operation as condition for public funding	7.8
Improvement of firm image through co-operation with science institutions	13.3
Indirect access to knowledge of competitors	5.9
N	669

Source: KOF-Survey 2005 on KTT activities.

"Access to human capital ("tacit" knowledge")" through the access to specific skills, the utilization of the possibilities for further education and training offered by the scientific institutions as well as the recruitment of university graduates was by far the most important main group of motivation for KTT activities: 65.9% of KTT-active firms reported a high importance of this motive. This ranking in importance is valid independent of firm size and affiliation to a specific sector or sub-sector. Financial motives (41.1%) and access to research results (29.3%) were next in importance, followed by institutional/organisational motives (25.0%). Access to “codified” knowledge is especially relevant for manufacturing for the development of new products (rather “development-oriented”) and for firms of the knowledge-based service industries for gaining new research ideas and the access to basic research (rather “research-oriented”). Financial motives, particularly the financial and technological necessity to co-operate with science institutions, time-saving in R&D as well as insufficient firm R&D resources are particularly important for manufacturing firms. Finally, institutional and/or organizational factors (e.g. R&D co-operation with science institutions as precondition for public funding) do not seem to be an important motive behind KTT activities.

Focusing on the four most frequently reported single motives (for more than 20% of all KTT-active firms), we can see that the motive “access to abilities in addition to internal know-how” was the most important individual motive for KTT (46.3% of all KTT-active firms). The single motives “further education and training possibilities” (29.5%), “project characteristics require co-operation with science institutions” (25.6%) and “insufficient firm R&D resources” (21.7%) are next in importance. All other single motives are relevant for less than 20% of all KTT-active firms.

In sum, firms pursue several motives at the same time. However, access to tacit knowledge seemed to be their most preferred motive.

7.5.2 Obstacles to KTT Activities

All firms were asked to evaluate the importance of 26 different possible single obstacles to KTT activities on a five-point Likert scale ranging from 1 (“not important”) to 5 (“very important”). The 26 different obstacles were pooled into 5 main groups of obstacles, i.e. “lack of information” (containing the information for 3 single obstacles; see table 4), “firm deficiencies” (4 single obstacles), “deficiencies of the science institutions” (4 single obstacles), “costs, risks, uncertainty” (7 single obstacles) and “institutional/organizational obstacles” (8 single obstacles). We use the share of firms reporting 4 or 5 on the Likert scale for any of the single motives in a certain group of motives to characterize the overall importance of this group of motives (see Table 7.8).

“Firm deficiencies” are most frequently perceived as a category of severe impediments of KTT activities with science institutions (49.2% of all firms; 53% of firms that were not involved in KTT activities, but only 36.1% of the KTT-active ones; see table 7.8). “Firm’s questions being not interesting for science institutions” (25.0% of all firms) and “lack of interest for scientific projects” (35.9%) are the most frequently reported single obstacles to importance in this category. The obstacle categories “cost, risks, uncertainty” (42.4% of all firms) and “deficiencies of the science

Table 7.8: Obstacles to KTT activities

Obstacles	Percentage of KTT-active firms reporting 4 or 5 on a five-point Likert scale (1: 'not important'; 5: 'very important')
LACK OF INFORMATION	*24.1*
Difficulties to get information about R&D activities in science institutions	13.9
Difficulties to find contact persons	17.9
Lack of resources for "interface" activities in the science institutions (e.g. transfer office)	9.7
FIRM DEFICIENCIES	*49.2*
Lack of qualified staff	12.8
Lack of technical equipment	9.6
Lack of interest in scientific projects	25.0
Firms' R&D questions are not interesting for science institutions	35.9
DEFICIENCIES OF THE SCIENCE INSTITUTIONS	*42.0*
Lack of scientific staff for transfer activities	11.7
Lack of entrepreneurial spirit	11.5
R&D orientation of science institutions not interesting for firms	25.6
Possible R&D outcomes cannot be commercialized	25.3
COSTS, RISKS, UNCERTAINTY	*42.4*
Secrecy with respect to firms' know-how not guaranteed	10.3
Need of comprehensive additional follow-up work in order to implement public R&D results	12.3
Lack of in-house financial resources for transfer activities	27.4
Lack of financial resources of science institutions for co-operation on an equal basis with firms	12.3
Insufficient efficiency of university staff compared to firms' staff	10.9
Technological dependency from external institutions	6.3
Uncertainty about outcomes of co-operations	10.8
INSTITUTIONAL, ORGANIZATIONAL OBSTACLES	*24.5*
Costly administrative and approval procedures	15.0
Lack of administrative support of joint R&D project from science institutions	6.7
Lack of administrative support of commercialization of R&D result from science institutions	8.7
Problems with Property Rights	6.4
Problems with project management in science institutions (e.g. communication problems)	5.6
Different understanding of priorities	10.1
Lack of trust (firm)	4.1
Risk of loosing reputation (firm)	1.6
N	2582

Source: KOF-Survey 2005 on KTT activities.

institutions" (42.0%) are somewhat less important than "firm deficiencies". The differences between KTT-active and non-active firms is not significant in this case. The largest single obstacle in the category "cost, risks, uncertainty" is "lack of in-house financial resources for transfer activities" (27.4% of all firms). "R&D orientation of science institutions not interesting for firms" (25.6%) and "possible R&D outcome cannot be commercialized" (25.3%) are the two most frequently reported single obstacles to relevance in the category "deficiencies of the science institutions". Least important for the firms are the categories "lack of information" (24.1% of all firms) and "institutional/organizational obstacles (24.5%). Both categories are assessed considerably more often as severe by KTT-active firms than non-active ones. No single obstacle in these two categories is perceived as a severe impediment by more than 20% of all firms.

The ranking of importance of the five main categories of obstacles resulting for all firms is valid also for all sectors and firm sizes with the exemption of high-tech manufacturing in which "costs, risks, uncertainty" is the most important obstacle category.

In sum, the most important obstacles to KTT activities could be localized at the interface between firms and science institutions. Many firms, especially those without KTT activities, thought that their R&D questions would not find any interest among academicians, while on the other hand many firms, however less than in the former case, had the impression that the research interests of science institutions do not correspond to their presumably more application-oriented interests.

7.6 Assessment

Access to "tacit" knowledge through the access to specific skills, the engagement in further education and training offered by the scientific institutions and the recruitment of university graduates seems to be the most important motive for KTT activities independent of sector and firm size. Access to "codified" knowledge is especially relevant for manufacturing firms for the development of new products (rather "development-oriented") and for firms of the knowledge-based service industries for gaining new research ideas and having access to basic research (rather "research-oriented"). Financial motives, particularly the financial and technological necessity to co-operate with science institutions, time-saving in R&D and insufficient in-house R&D resources are particularly important for manufacturing firms. Finally, institutional and/or organizational factors (e.g. R&D co-operation with science institutions as condition for public funding) do not seem to be an important motive behind KTT activities. As econometric results show (see BOX 6), on the whole, firms are not driven by a specific motive when getting involved in KTT activities but they rather pursue a series of parallel goals covering quite diverging areas of activities.

The most important obstacles to KTT activities can be localized at the interface between firms and science institutions. Many firms, especially those without KTT activities, think that their R&D questions would not find any interest among academicians. On the other hand many firms, however less than in the former case, have the impression that the research interests of science institutions do not correspond to their presumably more application-oriented interests. This mismatch of business and science expectations is also confirmed by econometric results. Is this mismatch a hint for an *overall* "dys-functionality" of industry-science interface, as some observers think? There are two arguments against such a "pessimistic" interpretation of our results. First, most enterprises seem to have a "knowledge portfolio", therefore they prefer to pursue several goals at the same time when collaborating with science institutions. In this process some goals may be not or only only partly accomplished, so we can expect that the efficiency of the one or other specific form of KTT activities has to be improved. The analysis of different forms of KTT activities shows that the mismatch of expectations can be traced back mainly to problems related to informational and educational activities. Firms with a focus on research activities do not seem to be seriously hampered by this category of impediments. Second, the econometric evidence (see BOX 6) also shows that other important firm characteristics do exist, e.g. the endowment with human capital and in-house R&D activities, that enable a firm to utilize new scientific information. In sum, the assertion of a largely insufficient knowledge and technology transfer between corporations and science institutions in Switzerland is not supported by empirical evidence.

BOX 6: KTT activities in Switzerland: A literature survey

In a recent study Vock et al. (2004) presented and discussed the results of a survey on codified forms of KTT (number of R&D projects in co-operation with firms, patents, licences); this survey was addressed to technology transfer offices at universities. Thierstein et al. (2002) investigated the spin-offs/start-ups of graduates of the universities of Eastern Switzerland, Berwert et al. (2002) the spin-offs/start-ups of Swiss technical universities. The study of Lenz (1998) dealt mainly with horizontal innovation co-operation between firms.

We further report on the results of a series of studies which were based on the data collected in the two surveys (private enterprises, institutes) already mentioned in the main text:

Determinants of KTT activities (Arvanitis et al. 2005a):

This study explores econometrically the factors determining the propensity of Swiss firms to interact with public science institutions in Switzerland (universities and other research institutions). The propensity to KTT activities is significantly positive correlated with human capital intensity (measured by the share of employees with tertiary-level education), the existence of R&D activities (but not with R&D-intensity, also not with capital intensity – measured by gross investment per employee), in high-tech manufacturing also with firm age. In sum, the ability to absorb new knowledge, measured by human capital intensity and the existence of R&D activities, is an important precondition for KTT activities. As the econometric results further show, on the whole, firms are not driven by a specific motive when getting involved in KTT activities but they seem to pursue a series of parallel goals covering quite diverging areas of activities. Finally, firm deficiencies with respect to the utilization of the potential of KTT activities seem to be the most important category of obstacles.

Impact of KTT activities on the performance of private enterprises (Arvanitis et al. 2005b):

This study investigates the impacts of a palette of (KTT) activities (a) on several innovation indicators (a_1) in the framework of an innovation equation with variables of endogenized KTT activities (overall activities, specific *forms* of activities) as additional determinants of innovation, and (a_2) based on a matched-pairs analysis for several *forms* of KTT activities; (b) on labour productivity in the framework of a production function with endogenized KTT activities as an additional production factor. The authors found that KTT activities improve the innovation performance of firms both in terms of R&D intensity and sales of innovative products. The positive effect of overall KTT activities can be traced back mainly to *research* and *educational* activities. This could be shown by several methods: the innovation equation approach with endogenized KTT variable as well as three matching methods. Further, KTT activities seem to exercise a positive influence on labour productivity both through a direct effect as well as through an indirect effect by raising the elasticity of R&D intensity with respect to labour productivity.

Determinants of KTT activities: The university view (Arvanitis et al. 2005b):

The most important findings of the study refer to the overall propensity to KTT activities with private enterprises. Institutes with a stronger orientation to applied research and/or lower teaching obligations are also stronger inclined to get involved in KTT activities. The same is valid for institutes which have already experience with industry co-operations as reflected by a high share of external funds in an institute's budget. There is also a weak positive effect of institute size. This is also confirmed by the results with regard to the alternative specification based on a linear and a quadratic term for the number of employees: only the coefficient of the linear term is positive and statistically significant at the usual test level. Rather unexpectedly, institutes belonging to the federal institutes of technology (ETH) are more inclined to KTT activities than institutes of the other three groups of institutions (universities, universities of applied sciences and federal research organisations). In accordance to expectations, institutes of economics and business administration, natural sciences, engineering and medicine, ranking as just presented, are stronger involved in KTT activities than institutes of mathematics and physics. Institutes not involved in KTT activities were seriously impeded from undertaking such activities by a series of single obstacles which primarily reflect the (legitimate) fears of academics of neglecting their main task or reduce the quality of their work in case they get involved in KTT activities.

The results with respect to patenting, licensing and the formation of new knowledge-based firms showed considerable differences with respect to the importance of the determinants set used in this study. The most important finding was that all three types of activities were hampered by the same category of reported obstacles reflecting the perception of academics of an industry research profile which does not correspond well to their own needs and interests.

8 Does Switzerland Suffer from an Innovation Gap?

8.1 Basic arguments

In the political discussion as well as in the minds of a large section of population it is a general belief that the Swiss economy, though technologically advanced, is losing grounds in terms of innovative activities as compared to other rich countries. As set out in Section 5 and, more specifically, in the following subsections, the Swiss position indeed deteriorated during the nineties.

In order to assess whether this tendency points to an innovation gap it is necessary to know whether the unsatisfactory trend reflects structural weaknesses of the Swiss economy, or whether it is the outcome of unfavourable cyclical developments. In our interpretation, an innovation gap only exists if the reason of the deterioration is structural in nature.

Supporters of the "gap hypothesis" argue that Switzerland, firstly, suffers from an unfavourable regulatory framework (high impediments to innovation), secondly, that the pattern of specialisation of the Swiss economy is too "traditional" (weak position in the production of some leading-edge technologies such as ICT or biotechnology), thirdly, that Swiss firms do perform not as well as those from other countries in turning novelties into cash (insufficient market-orientation of innovative activities).

In the following, we describe, firstly, the main trends in innovative activities of the Swiss economy since 1990. Secondly, we present some information on obstacles to innovation with special emphasis on the regulatory framework. Thirdly, we assess whether the Swiss economy really suffers from a (structural) innovation gap.

8.2 Innovative activities of the Swiss economy

8.2.1 Innovation performance in the period 2000-2002

The innovation performance is measured in this report by five indicators (see Table 8.1) that reflect the input-side of the innovation process (share of R&D performing firms, R&D expenditures, innovation expenditures), the output-side (share of innovating firms) as well as the market-orientation of innovation activities (sales share of innovative products). In addition, we use a summary measure calculated as the arithmetic mean of the ranks a country attains at the level of the five indicators (see the last column of the table); the lower the average rank of a country, the higher is its innovation performance.

Based on this overall measure we find that Switzerland is the most innovative economy in Europe, followed by Sweden, Finland and Germany. According to all indicators Switzerland belongs to the top performers. It takes a somewhat lower rank in case of the sales share of innovative products than with respect to innovation input and output. However, there are only two countries that significantly outperform Switzerland in case of this market-oriented indicator (Finland, Germany).

Table 8.1: Innovation performance in Switzerland and the EU countries

	Share of firms with innovations (%)	Sales share of innovation expenditures (%)	Share of firms performing R&D (%)	Sales share of R&D expenditures (%)	Sales share of innovative products (%)	Ranking (mean rank across the five indicators)
	Reference					
Country	All firms	All firms	Innovative firms	Innovative firms	All firms	
Switzerland 2000-02	*67.6*	*4.2*	*65.4*	*2.4*	*23.5*	*3.4*
Switzerland 1997-99	*70.5*	*4.3*	*62.8*	*2.0*	*-*	*-*
Germany	62.1	2.9	51.6	1.4	29.7	4.6
France	40.8	2.5	77.0	2.1	18.3	6.8
Italy	36.3	2.0	35.3	0.8	25.6	11.0
Sweden	46.8	12.1	59.9	3.6	25.9	3.8
Denmark	44.3	0.5	70.2	0.4	20.1	10.6
Finland	44.8	2.5	70.9	2.2	32.0	4.4
Norway	36.4	1.2	55.1	1.0	8.9	12.4
Netherlands	45.3	1.5	54.3	1.1	12.1	10.4
Belgium	50.1	2.7	60.2	1.3	19.0	6.0
Austria	48.8	1.7	50.3	1.1	17.8	9.4
Luxembourg	48.3	1.3	38.6	0.7	9.5	11.8
Iceland	55.1	1.7	70.6	1.3	4.0	7.6
Spain	32.6	1.2	37.9	0.6	25.3	12.6
Greece	28.1	2.1	56.4	-	11.7	11.3
Portugal	46.4	2.6	39.2	0.4	25.9	9.0

The EU data refer to the period 1998-2000.

Switzerland takes the first position in manufacturing as well as in services. The lead is particularly large in case of the services sector (see below, Table 8.3). This is a favourable result in view of the ongoing structural change of the economy towards the services sector (see Chapter 1).

In case of small and medium-sized firms, the leading position of Switzerland is even more pronounced than in the economy as a whole (see Arvanitis et al. 2004, section 6.4). Since SME's are more important in terms of their employment share than in most other countries, this result is of particular relevance. It implies that the generation of innovations is broadly based (diversification of risks) and that a large section of the economy can make use of firm-external knowledge (high absorptive capacity). Therefore, the Swiss economy is in a favourable position in terms of the diffusion of knowledge and technology. The particularly high innovation performance of Swiss SME's is a strength of the Swiss economy that cannot be overvalued.

8.2.2 Change of the innovation performance over the nineties

Table 8.2 shows the development of the innovation performance of the Swiss manufacturing and services sector over the nineties. The table is based on simple innovation indicators measuring the share of firms having performed four specific types innovative activities. Since more complex indicators capturing the intensity of innovative activities (e.g. sales share of R&D expenditures or sales share of innovative products) yield about the same trends, Table 8.2 is representative for the overall development (see Arvanitis et al. 2004, section 4.3).

Table 8.2: Innovation performance in Switzerland in the period 1988/90 till 2000/02

	Share of firms having introduced innovations (%)	Share of firms having performed R&D (%)	Share of firms having filed at least one patent (%)	Share of firms having generated world novelties (%)
Manufacturing				
1988-1990	81.0	70.0	-	17.5
1991-1993	84.1	81.6	31.6	23.5
1994-1996	78.0	68.5	34.0	30.3
1997-1999	70.6	49.3	13.0	16.6
2000-2002	65.9	49.2	11.3	16.9
Services				
1994-1996	63.7	-	-	-
1997-1999	54.3	17.7	3.4	21.2
2000-2002	52.4	24.0	2.4	12.4

Source: KOF Innovation Survey.

In the manufacturing sector, the share of innovative companies, which introduced product innovations at the marketplace and/or process innovations within the firm, decreased continuously since 1991/93. The share of R&D performing firms declined even stronger, but stabilised in the last period. The same tendency is observed in case of the share of patenting firms and those launching world novelties; in these two cases the decline started later, reflecting the fact that such far-reaching innovations are based on previous R&D activities.

Innovative activities in the services sector are generally less widespread than in manufacturing, since (technological) opportunities are lower in some service industries (e.g. retailing, restaurants/tourism, certain business services such as lawyers offices and the like) and technology-related innovation indicators like R&D and patents do not fully capture innovative activities of this sector (e.g. restricted scope for patenting). Since the available data only cover a relatively short period, at least as far as the indicators shown in the last three columns are concerned, it is rather difficult to identify a clear tendency. However, there is no doubt that innovative activities in the services sector decreased as well, but it seems that the negative trend is somewhat less pronounced than in manufacturing.

The decline of innovative activities in the Swiss economy may have weakened the relative position compared to other countries. Whether, and to what extent, this is the case is shown in Table 8.3. The data presented in the table differ somewhat from those shown in the two previous tables since we had to adjust our calculations according to the procedures of Eurostat (e.g. firms with less than ten employees had to be excluded in Switzerland). In addition, some adjustments of the EU figures were necessary as well, since the indicators are not fully harmonised among the EU countries. The comparison is based on a small number of indicators; nevertheless, these cover, at least in manufacturing, all stages of the innovation process (input, output, market-orientation).

The table clearly shows that the relative innovation performance of the Swiss economy weakened during the nineties, in particular in manufacturing. In this sector, Switzerland lost much of the lead it had over its followers in the early nineties. However, in 2000/02 it still comes first in terms of the share of innovative firms (column 3). The Swiss position also deteriorated with respect to the other two indicators. Taking account of the higher proportion of innovating firms (which are the denominator of the second and third measure), Switzerland again takes the first rank regarding the share of R&D performing firms (column 6), whereas it is placed second with respect to the market-oriented innovation indicator (column 9). In the services sector, Switzerland is the leading country in both periods for which data are available, in case of the second indicator this only holds true when the very high proportion of innovating firm, serving as denominator, is taken into account. However, some countries reduced their lag in this sector as well.

To sum up, we find that Switzerland still is the most innovative economy in Europe. However, its performance, compared to the EU countries, deteriorated over the nineties. Similar tendencies can be observed for indicators not considered in this section such as R&D expenditures (see Chapter 5) or patent applications (see Arvanitis et al. 2005 and OECD 2006).

Table 8.3: International comparison of the innovation performance 1993 till 2000

MANUFACTURING	Share of firms with innovations (%)			Share of firms performing R&D (%)			Sales share of innovative products (%)			SERVICES	Share of firms with innovations (%)		Share of firms performing R&D (%)	
Reference:	All firms			Innovative firms			Innovative firms			Reference:	All firms		Innovative firms	
	1993	1996	2000	1993	1996	2000	1993	1996	2000		1996	2000	1996	2000
Switzerland	*84*	*78*	*68*	*82*	*69*	*76*	*42*	*45*	*34*	*Switzerland*	*64*	*67*	-	*47*
Germany	67	69	66	66	77	60	51	50	50	Germany	46	58	44	42
France	39	43	46	72	75	81	27	29	26	France	31	34	71	67
Italy	34	48	40	57	54	37	29	43	45	Italy	-	25	-	28
Sweden	-	54	47	-	80	69	-	37	-	Sweden	32	46	56	51
Denmark	56	71	52	73	73	79	45	29	36	Denmark	30	37	68	58
Finland	-	36	49	-	92	79	-	32	33	Finland	24	40	80	58
Norway	53	48	39	64	63	61	32	31	13	Norway	22	34	66	50
Netherlands	57	62	55	65	74	61	37	33	30	Netherlands	36	38	59	47
Belgium	61	34	59	78	75	74	39	28	22	Belgium	13	42	59	42
Austria	-	67	53	-	76	61	-	40	44	Austria	55	45	48	37

The EU data refer to the years 1991/93, 1994/96 and 1998/2000 respectively; in the Swiss case, the last period covers the period 2000/02.

Source: NewCronos (Eurostat), KOF Innovation Survey.

8.3 Obstacles to innovation

8.3.1 Obstacles to innovation in the Swiss economy

In this section we consider a large set of factors that may hamper a firm's innovative activities. We distinguish five categories of obstacles (see Table 8.4): cost- and risk-related factors, financing restrictions, lack of qualified personnel, information and organisational problems, and, finally, regulatory and other policy-related restrictions. In a policy perspective, manpower deficiencies and regulation are of prime interest; financing restrictions may also a subject of policy concern.

Table 8.4: Obstacles to innovation 1990 till 2002
(percentage share of firms assessing a specific factor as a (very) important obstacle to innovation: value 4 or 5 on a 5-point Likert-scale)

	Manufacturing					Services / construction		
	1990	1993	1996	1999	2002	1996	1999	2002
High innovation costs	-	-	50.0	38.8	40.7	42.5	31.0	35.5
Long amortisation period	-	-	42.4	29.9	32.3	28.7	21.3	28.1
Easy imitation	-	-	34.7	25.7	27.9	31.3	16.6	21.3
High technical risks	-	-	23.7	18.8	18.5	-	16.0	11.5
High market risks	-	-	35.4	27.3	26.4	-	14.8	19.2
Lack of internal finance	19.5	26.7	29.9	29.3	30.9	26.8	25.9	24.7
Lack of external finance	3.4	16.7	20.9	24.0	25.6	20.1	20.0	23.2
High taxes	17.7	17.6	16.0	16.1	17.5	19.3	19.0	19.4
Lack of R&D personnel	34.2	29.2	27.5	19.0	20.0	-	12.6	10.8
Lack of qualified manpower	47.4	26.0	25.2	20.6	20.7	28.3	16.5	16.4
Insufficient technological information	13.5	7.9	5.8	7.3	5.2	6.8	6.6	4.0
Insufficient market information	-	14.6	21.4	14.8	16.5	16.6	10.4	8.4
Insufficient acceptance of the new technology	10.9	8.8	15.8	10.1	9.7	12.7	6.8	11.2
Organisational problems	-	-	-	12.2	10.8	-	10.0	13.9
Restricted access to EU markets	-	-	31.5	19.1	14.3	18.3	8.9	8.2
Tight product market regulation	-	12.2	15.5	12.9	12.3	17.9	10.8	11.9
Restrictive immigration policy	28.4	18.3	18.1	11.8	10.2	21.9	10.7	13.9
Insufficient promotion of research	6.1	14.4	13.4	9.8	9.3	-	4.3	4.7
Insufficient support of technology diffusion	-	10.1	10.0	8.1	6.5	-	2.0	3.1
Rigorous environmental legislation	19.4	26.8	21.2	19.6	14.0	20.5	10.4	17.7
Restrictive regulation of land use and construction	23.5	33.4	26.4	19.6	16.4	33.6	18.7	22.9

Source: KOF Innovation Survey.

Table 8.4 shows the percentage share of firms assessing a specific factor as an important or very important obstacle to innovation. According to our experience a share of about 20% (or higher) points to an effective restriction. Applying this criterion to the data for 2002, we find that cost- and risk-related factors (20% to 40% of firms), financial restrictions (20% to 30%) and the lack of qualified personnel (20%; manufacturing only) were the most important categories of innovation impediments. Among the eight items of regulatory and other policy-related obstacles only one exceeds the threshold of 20% (restrictive regulation of land use and construction; services sector only). To some extent, rigorous environmental protection (services only) and taxation are perceived as important obstacles as well.

In the course of the nineties, most of the impediments lost much of their relevance. This was particularly the case between 1996 and 1999. Cost- and risk-related obstacles, although decreasing in importance as well, were still considered as a serious problem in 2002. This holds true, in particular, as far as high costs of innovation projects and, in manufacturing, high market risks are concerned. These barriers, however, have to be overcome by the firms themselves since the handling of these matters is a genuine entrepreneurial task.

The importance of shortages of R&D and other highly qualified personnel as an obstacle to innovation decreased in the early nineties and once more between 1996 and 1999. Subsequently, the relevance of this type of impediment, which strongly depends on general economic conditions, remained alsmost unchanged at a medium level. Parallel to this, (restrictive) labour market policies for foreigners became almost negligible as an obstacle to innovation. In contrast to the eighties, immigration policy, as time went by, gave highly skilled persons more and more a preferential treatment.

Lack of finance is the only category of innovation impediments that did not lose importance during the nineties. Lack of internal funds was reported by a constantly high proportion of firms as hindering innovation activities. External finance was perceived as a highly relevant obstacle by a continuously increasing number of companies. It was only in the period 1999-2002 that this tendency came to a halt in the course of the overall economic upturn. The problem of financing innovation, although it depends to a large extent on general economic conditions, may have a structural component as well, since many small and/or young firms have difficulties of getting access to the capital market (see Arvanitis and Marmet 2002; specifically for the case of new and young firms see Chapter 2).

Over the nineties, most aspects of market regulation became negligible obstacles to innovation (restricted access to the EU market, rigorous environmental protection, restrictive regulation of land use and construction), others remained irrelevant (tight regulation of domestic markets). However, since a few strongly regulated industries are not covered by the innovation survey (e.g. agriculture, health sector, education, and, at least to some extent, public transport and postal services,), the role of market regulation as an impediment of innovation may be somewhat underestimated. Finally, insufficient government promotion of research and innovation, which never has been perceived as a serious obstacle to innovation, became even more irrelevant in the course of the last decade.

8.3.2 International comparison of innovation impediments

It is difficult to compare Switzerland and the EU countries with regard to the importance of potential obstacles to innovation for several reasons: firstly, some of the impediments are measured in a very global way in the Community Innovation Survey (CIS); this particularly holds true for the policy-related obstacles, which probably are the most interesting factors. Secondly, Eurostat changed the measurement scale in its last survey (from a five-point to a four-point scale), rendering impossible reliable comparisons over time (inconsistent time series); consequently, we only are able to make a cross-country comparison for the most recent year (Switzerland: 2002; EU countries: 2000). Thirdly, since macroeconomic conditions in Switzerland and the European countries significantly differed in this point in time, the cyclical component had to be filtered out in order to obtain more or less comparable figures; in such a "structural" view, the lack of qualified personnel in Switzerland becomes relatively more important, whereas the opposite holds true in case of financial restrictions and economic risks.

Table 8.5 shows the relevance of a series of obstacles to innovation for Switzerland and twelve EU countries (percentage share of firms assessing a specific factor as an important obstacle to innovation). By concentrating on a comparison with the most innovative countries (Sweden, Finland, Germany) and those obstacles which are relevant from a policy perspective (financing problems, lack of qualified personnel, government regulations), we draw the following (tentative) conclusions. Firstly, the climate for generating innovations is most favourable in any respect in Finland, most pronounced with regard to the regulatory framework. Secondly, financing problems (having been (approximately) filtered out the cyclical component) may be restrictive in Switzerland to a similar extent as in Sweden, whereas Germany is confronted with higher barriers in this respect. Thirdly, again looking at the structural component, the lack of qualified personnel is hindering innovation in Switzerland at about the same (or somewhat higher) degree as in Germany, whereas Sweden is in a much more comfortable situation. Fourthly, the firms are hampered by government regulations to a similar extent in Germany, Sweden and Switzerland (in the Swiss case, the overall degree of regulatory obstacles is higher than the figures for the individual items would suggest due to the multiplicity of firm answers).

To sum up, the Swiss economy is confronted with obstacles to innovation to a similar extent as the Swedish one, whereas German firms have to operate in less favourable conditions. The Finnish economy benefits from an innovation climate that is much more favourable than in the other countries which belong to the leading group in terms of the innovation performance.

Table 8.5: Obstacles to innovation: international comparison 2000/02
(percentage share of firms assessing a specific factor as a (very) important obstacle to innovation)

	High market risks	High innovation costs	Lack of finance	Organisational problems	Lack of qualified personnel	Insufficient technical information	Insufficient market information	Government regulations
Switzerland	23.2	37.3	26.0 Internal funds 22.5 External funds	9.6	17.7 R&D personnel 17.2 Other qualified workers	4.9	12.2	11.3 12.3 13.8 14.3
Germany	24.7	31.4	23.3	8.2	23.8	3.9	5.2	18.1
France	14.3	22.4	19.4	6.6	8.4	2.1	3.8	11.9
Italy	11.8	17.0	13.5	5.0	10.1	5.5	4.7	7.2
Sweden	12.6	13.3	18.9	22.9	16.0	27.1	27.6	22.0
Finland	10.2	12.1	8.1	3.2	6.7	4.0	5.0	2.8
Norway	12.8	13.1	9.8	4.2	4.2	1.6	2.3	3.3
Netherlands	16.6	16.7	18.1	10.7	24.0	7.0	11.9	9.7
Belgium	7.0	14.3	15.5	4.4	15.6	2.9	2.3	10.3
Austria	20.3	30.4	19.1	8.8	15.4	5.6	7.0	13.7
Spain	21.3	32.2	17.9	6.8	13.8	8.6	8.2	10.1
Greece	27.0	29.0	28.2	6.9	11.7	6.5	5.2	12.0
Portugal	23.1	37.4	31.0	11.5	23.7	12.1	10.7	11.8

The EU and the Swiss data refer to the year 2000 and 2002 respectively.

Government regulations: In the Swiss case, four obstacles to innovation are taken into account; from above to below: restrictive regulation of domestic markets, restrictive immigration policy, rigorous environmental legislation, and, finally, strict regulation of land use and construction.

Source: NewCronos (Eurostat), KOF-Innovation Survey.

8.3.3 Market regulation and innovation

In subsection 8.3.1, we pointed out that the role of market regulation as an impediment of innovation may be somewhat underestimated, since some highly regulated domestic sectors are not considered. Therefore, we look at the regulatory framework in a broader perspective.

In recent years, OECD collected detailed information on product market regulations, which then were aggregated into an overall index and some sub-indices (see Nicoletti et al. 2000 and Conway et al. 2005). The underlying system of indicators covers a whole series of regulatory domains such as state ownership of firms, state intervention in the market process, administrative opacity, administrative burden for new firms, barriers to competition, trade and investment barriers, etc.

Table 8.6 shows the overall index of product market regulation and sub-indices related to three domains for Switzerland and twelve other countries. We notice that only in Italy the product markets are regulated to a higher extent than in Switzerland in 2003. Although restrictions have diminished in Switzerland in recent years, it could not improve its ranking. Additional data not reported here show that in the period 1990 till 1998 the Swiss position even worsened in relative terms; it slipped from rank 8 to rank 11. We conclude that deregulation of product markets started later in Switzerland, and then (i.e. from 1998 onwards) progressed at a lower pace than other countries. However, the current high level of market regulation has to be further qualified: firstly, the distance from the leading countries has shrunken quite substantially (see column 8); therefore, it is not clear whether the effective level of regulation is still a big problem. Secondly, since we are looking at the innovation performance of incumbents, regulations related with the domain "entrepreneurship" play a minor role (this aspect is treated in Chapter 2); if we consider only the other two categories of restrictions, the distance from the leading countries is somewhat smaller than that shown by the overall index.

Nevertheless, a negative impact of restrictive market regulations on the innovation performance of the Swiss economy cannot be ruled out. There is some new empirical evidence for a significant negative correlation between the R&D intensity and the OECD indicator for "inward-oriented economic regulation" (see Bassanini and Ernst 2002). This negative relationship, however, refers to the levels of these variables. In this respect, Switzerland is a puzzling case, since we observe at the same time a high level of R&D intensity and a restrictive regulatory framework. Therefore, the crucial issue is whether there exists a close negative relationship between the *change* of the density of regulations and the *change* of innovation activities; in other words, deregulation in the nineties should have been accompanied by an increase of the innovation performance. To date, however, there is no empirical evidence for such a relationship. In the Swiss case, we observe for the nineties the opposite; a diminishing density of market regulation was accompanied by a decrease of innovation activity. This result indicates that either the proposed relationship does not hold true or that other determinants of innovative activities had a stronger impact than regulation.

To sum up, there is no evidence that deregulation, as generally believed (see OECD 2006), fosters innovative activities. There may be some exceptions, e.g the liberalisation of industries where technological change is very fast such as in telecommunication. This finding, however, does not mean that there are no good reasons for liberalising product markets, since deregulation leads to a more efficient allocation of resources away from less towards more productive activities (static effect). In addition, more competition forces firms to permanently increase their productivity (dynamic effect).

Table 8.6: Summary indicators of product market regulation

	Degree of restriction (Scale ranging from 0 up to 6, with high values corresponding to highly restrictive regulations)								Ranking	
	State control		Entre-preneurship		Trade and Investment		Total		Total	
	1998	2003	1998	2003	1998	2003	1998	2003	1998	2003
Switzerland	*2.8*	*2.2*	*2.3*	*1.9*	*1.7*	*1.0*	*2.2*	*1.7*	*11*	*11*
Netherlands	2.7	1.9	1.9	1.6	0.9	0.7	1.8	1.4	8	8
Sweden	2.2	1.9	1.9	1.1	1.4	0.8	1.8	1.2	5	5
Finland	3.3	2.3	2.1	1.1	1.1	0.6	2.1	1.3	6	6
Denmark	2.2	1.3	1.4	1.2	0.9	0.8	1.5	1.1	3	3
Austria	2.5	1.9	1.7	1.6	1.3	0.7	1.8	1.4	8	8
Ireland	2.6	2.0	1.2	0.9	0.8	0.5	1.5	1.1	3	3
Germany	2.9	2.2	2.0	1.6	0.9	0.6	1.9	1.4	8	8
France	3.3	2.7	2.8	1.6	1.5	1.0	2.5	1.7	11	11
Italy	4.4	3.2	2.7	1.4	1.5	1.1	2.8	1.9	13	13
UK	1.8	1.7	1.1	0.8	0.6	0.4	1.1	0.9	1	1
USA	1.4	1.2	1.5	1.2	1.1	0.7	1.3	1.0	2	2
Japan	1.9	1.5	2.4	1.4	1.3	0.9	1.9	1.3	6	6

Source: Conway et al. (2005).

8.4 Does Switzerland suffer from an innovation gap?

Over the nineties, the Swiss economy lost much of its lead in innovation performance, particularly in the manufacturing sector, but it still takes the first rank in a comparison with the EU countries. The negative trend does not "automatically" mean that there is an innovation gap, since, in our interpretation, this only holds true if the causes of the decreasing performance is "structural" in nature; or the other way round: if the negative outcome primarily reflects unfavourable macroeconomic developments, we would expect that the negative innovation trend is transitory, thus not a structural problem.

As mentioned in subsection 8.1, there are three central arguments put forward in favour of a "structural interpretation", that is the existence, as compared to other countries, of, firstly, a restrictive regulatory framework, secondly, a traditional pattern of technological and economic specialisation, and, thirdly, a weak capability of turning innovations into market success (weak market-orientation of innovative activities). What is the empirical evidence?

First of all, the facts do not allow to rejecting the hypothesis of a (primarily) cyclical causation of the unsatisfactory development of the innovation performance in Switzerland during the nineties (what does not mean that structural factors may not have played a role as well). In the last decade, the Swiss economy passed through two recession periods, the first one, as in other European countries in the early nineties, the second one, this time a purely Swiss phenomenon, in 1996/97. The subsequent upswing till 2000/01 occurred again parallel with to rest of Europe. The long period of stagnation (1991 till 1997) drained the internal financial funds of firms that are the main source of financing (risky) innovation projects. In addition, the companies were confronted with higher costs of external finance reflecting higher risks for lenders. The upswing between mid-1997 and 2000/01 was too short to correct the lack of finance (see Table 8.4) and allowed not more than a stabilisation of innovative activities at relatively low level (see Table 8.2). Recent data show that R&D expenditures of the business sector were significantly higher in 2004 than in 2000 (BFS 2005). This increase is in line with a (primarily) cyclical explanation of the change of innovation activities. The results of the Swiss Innovation Survey 2005, which will become available in spring 2006, will show whether the recent positive trend in R&D expenditures is a phenomenon based on a broader base. In sum, we conclude that macroeconomic developments and the change of innovative activities are positively correlated. Consequently, the hypothesis stressing a (primarily) cyclical causation of the unfavourable development of the innovation performance over the nineties cannot be rejected. This conclusion is confirmed by the evolution of EPO patent applications, which shows a strong cyclical pattern in the period 1985 till 2002 (see OECD 2005, p.73).

What about the “structural” interpretation of the declining innovation performance over the nineties, which, if confirmed, would point to an innovation gap of the Swiss economy?

Firstly, a “structural explanation” of the unsatisfactory development of the innovation performance would require a tightening of the regulatory restrictions over the nineties. In contrast, we found that practically all regulation-related obstacles to innovation lost importance in the period 1990 till 2002 (see Table 8.4). Moreover, the detailed measurement of product market regulation (see Table 8.6) also indicates to a certain degree of liberalisation. These results tend to contradict a structural causation of the downturn in innovative activities. However, we are not able to assess sufficiently well whether the regulatory framework in Switzerland also improved in relative terms, i.e. compared to other countries. As already mentioned, the OECD data on product market regulations (see Table 8.6) show that the relative position of Switzerland remained stable in terms of the ranking, but the lead of the other countries significantly shrunk in the nineties. No time series data are available with respect to the obstacles to innovation in case of the EU Innovation Survey. In sum, the evidence with respect to this first argument put forward to supporting the “structural view” of the declining innovation performance is not convincing.

The specific Swiss pattern of technological and economic specialisation may be a second structural factor having induced the unsatisfactory development of the (relative) innovation performance of the Swiss economy in the past decade. It is argued that Switzerland is rather weak in new and promising technologies such as ICT and biotechnology (indicator: patent applications) as well as in terms of "high-technology" exports. It is true that the share of ICT and biotechnology patents as a percentage of total patents is relatively low (see Chapter 4); however, the fact that (a) Switzerland has a high *absolute* number of patents being the leading country in terms of patenting per capita and (b) that the country benefits from the ownership of inventions made abroad ("asset augmenting" foreign R&D strategies of Swiss MNE's; see Chapter 6) clearly weakens the argument. Moreover, the negative asessment with respect to the trade specialisation is not confirmed by the data (see Arvanitis et al. 2005a and 2005b). Switzerland strongly improved its relative position during the nineties in terms of the share of "high-technology" products in total exports of goods, although it could not benefit from the strong growth of demand for ICT products. In addition, it upgraded the mix of this category of exports (extraordinary increase of pharmaceutical exports; see Chapter 4). Moreover, in assessing the export specialisation we have also to take account of the role of knowledge-intensive services (telecommunication, banking, insurance, business services). In this respect, Switzerland is the leading country, and it even increased the distance to the other countries during the nineties (see Arvanitis et al. 2005b). In sum, although there are some structural weaknesses in terms of the technological and economic specialisation, reflecting the difficulty to rapidly changing traditional industrial structures ("path-dependency"), these do not suffice to explain the absolute and relative decline of innovative activities in the nineties.

Finally, there is (more than purely anecdotal) evidence for the hypothesis stating that Swiss firms, though performing well in the early stages of the innovation process (R&D, patenting), are less successful than their foreign competitors in turning this performance into market success? There are several arguments used to support this proposition. A first one refers to the fact that "time to market" has become shorter and customer-orientation is much more important nowadays than in the past. However, there is no evidence, that Swiss firms perform worse in this respect than their foreign competitors. The fact that Switzerland is one of the leading countries in the diffusion of ICT (without being a significant ICT producer) is a strong counter-argument (early and broadly-based adoption of a technology with a high potential for customising products and accelerating internal business processes; see Hollenstein et al. 2003). A second argument is related to the result that the Swiss economy, as compared to other countries, is ranked higher in terms of input- and output-oriented measures of innovation than with respect to market-oriented indicators (see Table 8.1). However, there are only two countries that significantly outperform Switzerland in this respect. Moreover, this market-oriented indicator depends on the length of the product cycle (an increase of the duration of the product cycle reduces the sales share of innovative products). Since the product cycle in Switzerland is presumably longer on average than in other countries because of the high importance of pharmaceuticals, the Swiss position with respect to this market-oriented indicator might be underestimated. At least it is impossible to draw "strong" conclusions. Thirdly, it is argued that the “science-industry” interface works in Switzerland not as well as in other countries, with the effect that scientific knowledge is used insufficiently to producing leading-edge products. However, this assessment is not backed by evidence (see the Chapters 5 and 7 and OECD 2006, p. 118). Against this background, we conclude that the argument of Switzerland being weaker than other countries in turning innovations into market success is not supported by empirical evidence.

To sum up, the empirical evidence is in line with the proposition stressing a (primarily) cyclical causation of the declining innovation performance during the nineties (and some indication of a reversal in most recent years). In contrast, the facts do not support the alternative explanation that refers to structural deficiencies of the Swiss innovation system. Therefore, we conclude that Switzerland does not suffer from a structural innovation gap. However, since negative cyclical effects on innovation performance may become permanent if a downturn lasts too long, it is crucial that the current upswing continues and, hopefully, gains in strength.

BOX 7: The erosion of the Swiss R&D lead: is it cyclical or structural

OECD (2006, pp. 51-52) is the only publication addressing the question whether the declining innovation performance of Switzerland during the nineties was due to cyclical or structural factors. The authors admit that, to a significant extent, the erosion of the Swiss position has been caused by unfavourable macroeconomic conditions. However, they argue that some structural factors have been important as well. Firstly, they point to the slowdown of potential growth (caused by a reduced employment growth) in the nineties as compared to the previous decade. Secondly, they stress that mandatory increases of social security spending led to a crowding out of public funding of innovative activities. Thirdly, they mention the danger that a cyclical weakening of the innovation performance may have negative long-term effects on potential growth and thus on the resources available to finance future innovations.

In our view, it is questionable whether these arguments suffice to conclude that a significant part of the decline of the innovation performance in the nineties was due to structural factors. Firstly, the reduction of employment growth (and the concomitant reduction of potential growth) in the nineties might be to a significant extent the effect of the two cyclical downturns of the Swiss economy had to pass through; therefore, this argument does not contradict a “cyclical interpretation” of the declining innovation performance. Secondly, it is true that the strong upward trend in social security spending may be an obstacle to the expansion of public R&D funding. However, direct public funding of business R&D is very low in Switzerland. Therefore, a reduction of R&D subsidies cannot have a significant negative impact on innovative activities; much more dangerous is an under-investment in university research, which, however, would be a long-term problem. The third argument (which we mentioned as well) is sound in principle, but it is primarily relevant for the development of innovative activities in the current decade rather than for the trends in the nineties.

8.5 Assessment

The innovation performance of the Swiss economy declined in absolute terms from the early nineties till 1997/99, and then remained more or less unchanged until 2000/02. Consequently, the Swiss position weakened as compared to other European countries. Although Switzerland still ranks first, it lost most of its lead in manufacturing. In the services sector it could preserve the distance to the other countries quite well, but there was some catch-up of other countries in this case as well. A specific strength of the Swiss innovation system is the outstanding innovation performance of SME's.

In the course of the nineties, most obstacles to innovation lost much of their relevance. This holds true particularly in case of impediments related to market regulation. Lack of finance remains an important problem (although it may become less relevant when macroeconomic conditions improve). Lack of qualified (R&D) personnel still was a quite significant impediment in 2000/02, but we expect that this problem will diminish because of the liberalisation of immigration from EU countries. Although the relaxation of regulatory impediments is highly appreciated, there are still countries offering a more favourable environment for innovative activities.

An analysis of the causes of the deterioration of the Swiss innovation performance in the nineties showed that it rather reflects unfavourable macroeconomic conditions in the period 1991 till 1997 than structural factors such as an unfavourable regulatory framework, an overly traditional pattern of technological and economic specialisation or weaknesses in turning innovations into market success. We conclude that the Swiss economy does not suffer from a structural innovation gap. Therefore, we expect that the current economic upturn will lead to a rebound of the Swiss innovation position. Some first signs are already visible.

9 The Most Important Results – an Overview

It is the objective of the present study to analyse structure and development of innovative activities of the Swiss economy with special emphasis on the business sector. To this end, we investigated selected topics which for an assessment of the functioning and the quality of the Swiss Innovation System are particularly important.

In this perspective, we firstly describe the change of the industrial structure in order to assess to what extent the Swiss economy already proceeded towards a knowledge-based economy. The third chapter is devoted to an analysis of the process of the formation of new knowledge-based enterprises that contribute to the renewal of the industry structure. In chapter 4, we present information on the specialisation of the Swiss economy in the high-tech sector and knowledge-intensive services and analyse the Swiss performance in some leading-edge technological fields. In the next two chapters we investigate structure and evolution of the R&D activities of the business sector. Special emphasis is given to the analysis of R&D co-operation, the role of foreign R&D activities of Swiss firms as well the contribution of foreign-owned domestic firms to the innovation performance of the Swiss economy. Chapter 7 presents the results of an empirical analysis of the functioning of the science/industry interface in Switzerland based on recently collected unpublished data. Finally, we trace the evolution of the innovation performance and the obstacles to innovation over the nineties in absolute terms as well as in comparison to the EU countries. The negative trend of innovative activities we observe gives rise to the question whether it is caused by unfavourable macroeconomic conditions or whether it rather reflects structural deficiencies (innovation gap). In the following we present the main results in the same order as the study is structered.

a) Structural Change: Towards a Knowledge-based Economy

The Swiss business sector has well proceeded on the way to a knowledge-based economy in the last fifteen years. This is demonstrated by the high shares in value added and employment of the „knowledge-intensive“ sector as well as the large increase of these shares compared to the 12 reference countries in the period 1990-2002. The sector of modern services represents the bulk of the „knowledge-intensive“ sector. The financial sector clearly dominates the sector of modern services what is a structural strength of the Swiss business sector. Viewed the other way around, the small share of other business services, particularly computer services, seems to be a structural weakness of the Swiss economy. The high-tech sector builds primarily on pharmaceutical products and scientific instruments, both product groups with a large growth potential. The share of the Swiss high-tech sector did not grow between 1990 and 2002 as e.g. in Finland because the leading manufacturing industries of the nineties (computers, electronics, aircraft and aerospace) remained poorly developed in Switzerland, what is a further structural weakness of Swiss manufacturing.

b) Formation of Knowledge-based Firms

Modern services are the most dynamic sector of the Swiss economy also with respect to the formation of new firms. In manufacturing what has been much less dynamic than modern services in terms of value added and employment growth in the last fifteen years, we observe in the high-tech sector a considerably higher growth potential also for new firms than in the low-tech sector. An international comparison shows that in Switzerland the rate of new firm formation, defined as a net, effective rate corresponds to the OECD average. Moreover, the contribution of start-ups in the most dynamic sectors of the economy to new firm formation as a whole is about of the same magnitude as in other European countries.

New high-tech firms seem to be exposed to considerable financial pressure due either to insufficient internal finance and too high income taxes (at the stage of firm formation), or unfavourable conditions of external financing and too high revenue and capital taxes (at the stage of early growth) which are presumably the main reason why firms cease to exist four years after their foundation. A further important obstacle of firm activities at both stages of development is the availability of qualified personnel. At the early growth stage the survival of new high-tech firms is also endangered by insufficient imitation protection. Finally, more public promotion of technology would enhance innovation activities of newly founded firms. Start-ups of the modern services seem to be considerably more robust than new firms of high-tech manufacturing. They do not differ in any significant way from all firms on average.

c) Technological Specialisation and Leading-edge Technologies

Is there enough growth potential in the existing technological specialisation of the Swiss economy? With respect to three leading technologies, information and communication technologies (ICT), biotechnology and nanotechnology, we obtain the following picture for Switzerland:

- The Swiss presence in the R&D and production of hardware ICT is weak. Swiss manufacturing could not participate as a supplier of the fast-growing markets for computer and electronics in the nineties. Nevertheless, the Swiss economy is a very intensive user of ICT.
- The Swiss specialisation in software ICT is weak compared to the OECD average. Contrary to the hardware sector, the development of the software industry was quite promising in the nineties; this knowledge-intensive industry, starting at a rather low level, has noticeably grown in the last ten years.
- Switzerland has a rather strong presence in nanotechnology, particularly in research. Being highly specialised in the development and production of precision machinery and scientific instruments Swiss manufacturing is endowed with capabilities that could be of great use in the development of applications of nanotechnology. This is a field in which the relative advantage in research today could be transformed to a relative strength at the market place in the future.

- The Swiss position in the biotech sector is quite strong. Swiss research is highly specialised in Life Science. Besides the enormous potential of the large firms around Basle both at home and abroad, there is meanwhile also a sector of smaller biotech firms, many of them highly specialised suppliers of intermediate biotech products and sophisticated equipment.
- In the service sector a relative strength is high specialisation in the financial and insurance services.

Is there a technological "lock-in" problem for the Swiss economy? Only partly. The high specialisation in "old", mature industries without a large potential in the future such as non-electrical machinery and chemicals could be considered as a potential disadvantage. An expansion of activities in the direction of computer and electronics industry has not taken place. But the existing capabilities were successfully used to focus activities in market "niches" for high-technology products such as scientific instruments and medical technology products. Moreover, a transformation from traditional chemicals to high-technology pharmaceuticals has taken place in the nineties. Both transformation processes were performed without subsidies and caused only moderate social costs. Both the industry for pharmaceutical products and that for products of medical technology showed an extraordinarily high employment growth in the period 1995-2001 of about 40%.

d) R&D Activities and Networking

Switzerland belongs to the leading countries in terms of R&D intensity and R&D networking. The structure of R&D is advantageous as compared to other countries in several respects. Firstly, the share of private R&D is high, implying that R&D investments are allocated according to market demand. Secondly, SMEs are heavily involved in R&D activities, which is supportive to the economy's absorptive capacity for external knowledge. Thirdly, the structure of public R&D is favourable since it is to a very large extent allocated to basic research performed at universities.

Worrying, however, is the sluggish evolution of R&D expenditures in the nineties: R&D outlays more or less stagnated, with public R&D even decreasing. As a result, Switzerland lost some of its previously excellent position. This unfavourable trend may negatively impact on the long term growth potential of the economy (long lags in the R&D process). However, there are signs of a rebound of private R&D expenditures since the year 2000. A reversal of the trend also is necessary in case of public spending for R&D (and education), which must be prioritised among public expenditures.

Networking of R&D activities is indispensable in a world characterised by intensive and increasing international competition based on product and process innovations. It turned out that every second firm follows an R&D strategy involving some form of external R&D, i.e. out-contracting of R&D and/or R&D co-operation. We found that contract-R&D more often complements internal R&D than it substitutes for it. Similarly, R&D co-operation serves, in the first instance, to enhance a firm's knowledge base. Moreover, R&D co-operation is highly "productive" in terms of publications, patents, prototypes as well as product and process innovations. Co-operation with research institutes seems to be particular productive, even with regard to outcomes readily applicable on the market (new products) and within the own firm (new processes). In sum, R&D networking is a means to concentrate internal R&D on core competencies and to use external R&D to strengthen the firm's overall knowledge base. A strong international orientation is another feature of R&D networking in the business sector; this holds for contract-R&D, but even more for R&D co-operation, with special emphasis on partnerships with suppliers and universities. In addition, (international) co-operation in basic research also is very intensive in the Swiss case.

e) Internationalisation of R&D

The extent of outward- and inward-oriented internationalisation of R&D is practically in no other country as high as in Switzerland, and in the last fifteen years international R&D investment flows strongly increased in both directions.

Outward-investments often are considered as a danger for the knowledge base of the Swiss economy ("relocation"). However, the empirical analysis does not support this hypothesis. Rather there is overwhelming evidence for the alternative hypothesis according to which foreign and domestic R&D are complements. This result is independent of the approach we used, that is whether it is based on a descriptive analysis of the firms' motives to perform R&D at foreign locations, or on a cross-country investigation of domestic and foreign patenting, or on econometric work explaining foreign R&D activities of domestic firms. More specifically, it turns out that market- and resource-oriented motives as well as benefiting from geographical proximity to highly innovative firms and networks are the dominant drivers of foreign R&D, whereas efficiency-/cost-oriented motives are of minor importance. This pattern is consistent with asset-exploiting and asset-augmenting R&D strategies that according to international cross-section analyses dominate the pattern of foreign R&D activities of Swiss firms. In accordance with these results, the econometric analysis did not yield any evidence for disadvantages of Switzerland as a location for performing R&D, while there is overwhelming support for asset-exploiting and asset-augmenting strategies.

As far as inward-FDI is concerned, we found that it significantly contributes to the innovation performance of the Swiss economy, directly due to the presence of highly innovative foreign-owned firms and indirectly because of positive knowledge spillovers resulting from a technology gap between foreign and domestic firms (higher innovation performance of foreign-owned companies). Finally, foreign firms, in the first place, perform R&D in Switzerland because of its attractive research infrastructure and industry structure (dominance of high-tech and knowledge-intensive industries). Foreign-owned firms are present in Switzerland for reasons that are, with the exception of market-oriented motives, similar to those inducing Swiss companies to performing R&D in technologically advanced countries.

f) Knowledge and Technology Transfer Activities (KTT) between Private Enterprises and Science Institutions

Access to "tacit" knowledge through the access to specific skills, the engagement in further education and training offered by the scientific institutions and the recruitment of university graduates seems to be the most important motive for KTT activities independent of sector and firm size. Access to "codified" knowledge is especially relevant for manufacturing firms for the development of new products (rather "development-oriented") and for firms of knowledge-based service industries for gaining new research ideas and having access to basic research (rather "research-oriented"). Financial motives, particularly the financial and technological necessity to co-operate with science institutions, time-saving in R&D and insufficient in-house R&D resources are particularly important for manufacturing firms. Finally, institutional and/or organizational factors (e.g. R&D co-operation with science institutions as condition for public funding) do not seem to be an important motive behind KTT activities. As econometric results show, firms are not driven by a specific motive when getting involved in KTT activities but they rather pursue a series of parallel goals covering quite diverging areas of activities.

The most important obstacles to KTT activities can be localized at the interface between firms and science institutions. Many firms, especially those without KTT activities, think that their R&D questions would not find any interest among academicians. On the other hand many firms, however less than in the former case, have the impression that the research interests of science institutions do not correspond to their presumably more application-oriented interests. This mismatch of business and science expectations is also confirmed by econometric results. Is this mismatch a hint for an overall "dys-functionality" of industry-science interface, as some observers think? There are two arguments against such a "pessimistic" interpretation of our results. First, most enterprises seem to have a "knowledge portfolio", therefore they prefer to pursue several goals at the same time when collaborating with science institutions. In this process some goals may be not or only partly accomplished, so we can expect that the efficiency of the one or other specific form of KTT activities has to be improved. The analysis of different forms of KTT activities shows that the mismatch of expectations can be traced back mainly to problems related to informational and educational activities. Firms with a focus on research activities do not seem to be seriously hampered by this category of impediments. Second, the econometric evidence also shows that other important firm characteristics do exist, e.g. the endowment with human capital and in-house R&D activities, that enable a firm to utilize new scientific information. In sum, the assertion of a largely insufficient knowledge and technology transfer between corporations and science institutions in Switzerland is not supported by empirical evidence.

g) Does Switzerland Suffer from an Innovation Gap?

The innovation performance of the Swiss economy declined in absolute terms from the early nineties till 1997/99, and then remained more or less unchanged until 2000/02. Consequently, the Swiss position weakened as compared to other European countries. Although Switzerland still ranks first, it lost most of its lead in manufacturing. In the services sector it could preserve its lead quite well, but there was some catch-up of other countries in this case as well. A specific strength of the Swiss innovation system is the outstanding innovation performance of SMEs.

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