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Research Report

Development and determinants of productivity in Switzerland 1990-2010: A country- , industry- and firm-level analysis. Study mandated by the country studies branch of the OECD Economics Department

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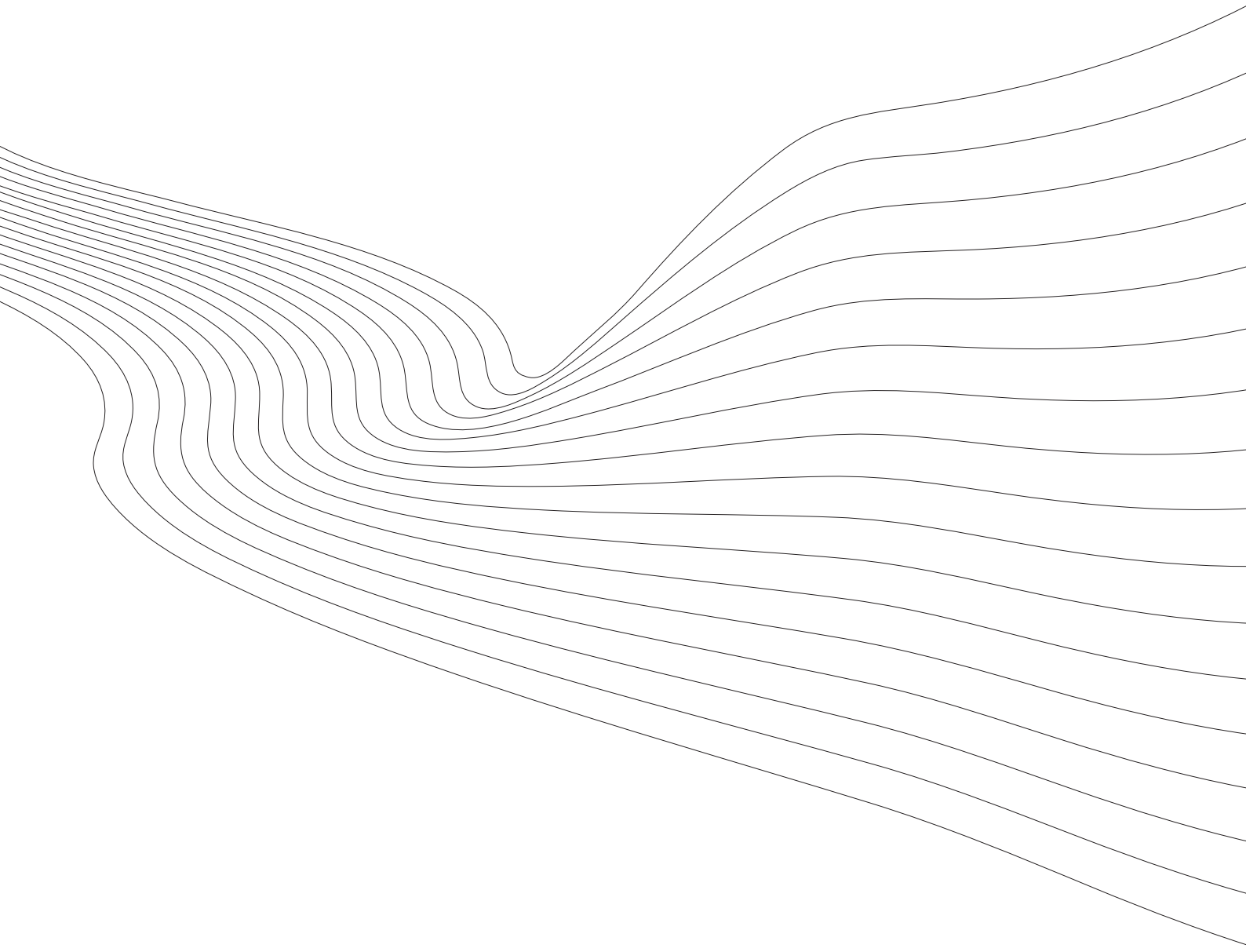
Development and Determinants of Productivity in Switzerland 1990–2010

A Country-, Industry- and Firm-level Analysis

Study Mandated by the Country Studies Branch of the OECD Economics Department

Spyros Arvanitis, Marius Ley, Florian Seliger and Tobias Stucki
ETH Zürich, KOF Swiss Economic Institute



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Authors

Spyros Arvanitis, Marius Ley, Florian Seliger and Tobias Stucki

ETH Zürich, KOF Swiss Economic Institute

Weinbergstrasse 35, 8006 Zurich, Switzerland

KOF

ETH Zurich
KOF Swiss Economic Institute
WEH D 4
Weinbergstrasse 35
8092 Zurich
Switzerland

Phone +41 44 632 42 39
Fax +41 44 632 12 18
www.kof.ethz.ch
kof@kof.ethz.ch

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1. Introduction

The aim of this study is to provide a background paper on the factors that determine productivity growth in Switzerland based (a) on publicly available data sources (primarily the OECD and the Swiss Federal Statistical Office SFSO) and (b) on micro-data from the KOF Enterprise Panel for the period 1990-2010.

In section 2 we provide a descriptive part that presents, first, comparative information on the development of multi-factor productivity and average labour productivity for Switzerland and for selected countries. Second, we describe the development of average labour productivity for Switzerland on industry level. The reason why we emphasize labour productivity is that (a) sectoral data for multi-factor productivity are not available for Switzerland and (b) the use of flow measures as proxies for physical capital on firm level do not allow the calculation of a valid multi-factor productivity variable.[1] Third, we comment on the comparative development of two important innovation indicators, namely R&D expenditures (as measure of innovation input) and patents (as measure of innovation output). Third, comparative data on ICT investment is presented.

Section 3 presents a microeconometric study of the determinants of average labour productivity on firm level based on data of six firm cross-sections between 1995 and 2010. As determinants were taken into consideration internal factors such as physical capital, several innovation indicators covering innovation input and innovation output, human capital as well as external factors such as the intensity of price and non-price competition and the number of principal competitors in a firm's main product market.

Section 4 contains a further microeconometric study of the determinants of labour productivity for a shorter period of time (2004-2010), for which additional data for ICT investment and ICT infrastructure are available.

In section 5 we summarize the available information about start-ups in Switzerland including the results of micro-studies based on data for a cohort of Swiss "greenfield" start-ups for about ten years.

In section 6 we summarize and conclude.

[1] Calculations of multi-factor productivity measures based on gross investment and the share of labour costs under the assumption of a Cobb-Douglas function did not lead to plausible results.

2. Development of productivity in Switzerland 1990-2010

2.1 Productivity growth – international comparison

Both multifactor productivity (MFP) and average labour productivity provide measures for how efficiently production factors can be turned into economic output, the latter typically being measured as GDP. Whereas average labour productivity refers only to labour as production factor, MFP takes also physical capital as production input into consideration.

Figures 2.1 and 2.2 show average growth rates for MFP and labour productivity, respectively, for Switzerland and 14 other OECD member countries between 1990 and 2010, differentiating between four five-year sub-periods within this time period. The patterns between the two measures do not vary dramatically at first glance. Labour productivity estimates are, on average, slightly higher, which can be explained by a tendency of capital intensity to increase over time. As a result of the financial crisis that started in 2008, several countries experienced negative average rates of MFP growth in the period 2005-2001, but in none of them did this translate into negative growth in average labour productivity.

The most striking feature of Switzerland is that – as the only of the countries considered here – it experienced *negative productivity growth from 1990 to 1995*, both in MFP and labour productivity. This period was marked by a severe recession in the aftermath of a real estate bubble in Switzerland that burst in the late 80s. During the remainder of the period, productivity growth remained comparatively slow in Switzerland, albeit of positive sign in all sub-periods. Among the countries considered, only Denmark, Italy and Spain showed, on average, comparatively weak (or weaker) productivity growth from 1995 onwards. Germany and France – Switzerland's two largest neighbours – performed slightly better. Conversely, Switzerland's productivity growth in the latest sub-period 2005-2010 *was not hit by the financial crisis* as badly as in other countries, especially when MFP is considered.

Reliably estimating productivity growth requires data of good quality not only related to economic output, but also with respect to the input factors of interest. In the case of Switzerland, Siegenthaler (2012) identified several quality issues for the number of hours worked series that has been used in the calculation of productivity measures by most data providers, amongst them the OECD. More precisely, he shows that growth of labour input has been systematically overestimated and, subsequently, most published estimates of productivity growth are underestimated. For the period 1990-2000, he concludes that average labour productivity growth figures as reported here need *to be corrected upwards by about one percentage point*. Although by no means negligible, this would not alter the overall finding of *comparatively weak productivity growth* in Switzerland when compared to other OECD countries.

2.2 Sectoral patterns of productivity growth in Switzerland

The contribution of different economic sectors to overall growth was subject to considerable variation, and the dynamics of productivity growth within a given sector have not followed a uniform pattern, either. This is exemplified in figure 2.3, which represents average productivity growth for eight economic sectors (manufacturing, construction and six different service activities) belonging to the private sector for the two time periods from 1991-2000 and 2000-2010, respectively.[2] The contribution of the financial sector – both banking and insurance – to labour productivity growth in the 1990s appears to have been remarkable, both of these branches exhibiting more than 6% average productivity growth. This is, however, overshadowed by very low (insurance) and even negative (banking) growth in the subsequent decade. A more moderate, yet still substantial growth over the entire time period considered can be found in manufacturing (around 2.5%) and wholesale and retail trade (around 2%). In construction and the remaining branches belonging to the service sector, growth has been lower than on average (even negative in some instances) and more erratic.

Given both the heterogeneity of activities that make up the manufacturing sector and the fact that manufacturing has attracted particular interest because of its considerable contribution to the technological advance, it may be worthwhile to have a closer look at productivity growth in manufacturing at a more disaggregated (i.e. using a two-digit industry classification) level. The corresponding data is available in Switzerland only from the year 2000 onwards and they are presented described in figure 2.4. Average growth rates lie in a range between -1.0% (basic metals) and 7.3% (motor vehicles). Besides motor vehicles, chemicals and pharmaceuticals have experienced comparatively high productivity growth (6.8% and 5.7%, respectively). Among the other industries that have traditionally played a crucial role in Switzerland (metal products, electrical equipment, machinery), productivity has grown at a moderate annual rate of about 1%.

2.3 Potential determinants of productivity growth

2.3.1 Research and Development (R&D) expenditures

Private sector

Research and Development (R&D) expenditures have been shown to be positively correlated to subsequent productivity growth by a number of empirical studies (see, e.g., Hall et al., 2009 for a survey). Expressing total R&D investments of the private sector in relation to a country's GDP is a common measure for international comparisons of R&D intensity. This indicator is reported in figure 2.5 for Switzerland and a number of countries for the years

[2] Data for sectoral productivity is available from 1991 only (as opposed to aggregate productivity which is available from 1990). Figures for 2010 are provisional. However, no fundamentally different findings emerge when restricting the period under consideration to 2009 (where final figures are available).

1996, 2000, 2004 and 2008, the years for which official Swiss R&D data are available. It reveals that Switzerland with a value of 2.1%, is well above the averages of the OECD (1.6%) and the EU-15 (1.3%). However, a number of countries (Finland, Sweden and Japan) perform considerably better with respect to this indicator. R&D intensities remain remarkably stable over time for most large countries and/or country groups over the observed time span. A slight tendency of Swiss R&D intensity to increase can be observed.

The sectoral distribution of R&D activities is highly unequal, as figure 2.6 shows for the case of Switzerland. Chemicals and pharmaceuticals, being one of the most R&D intensive branches, invested more than five billion Swiss francs in R&D in 2008 and thus accounted for 44% of total Swiss private sector R&D. Other sectors with a notable contribution to Swiss R&D activities are metals and machinery, information and communication technologies (ICT; with both production and service activities being covered by these figures) and the Research and Development (R&D) sector (which comprises firms having R&D as their primary economic activity; either as independent entities selling R&D services on the market, or as R&D conducting subsidiaries of larger enterprise groups). A tendency of R&D to decrease can be observed for metals and machinery (and for banking/insurance, whose contribution to aggregate R&D is however marginal), whereas it mostly increased in all other sectors, sometimes at impressive rates (high-tech instruments, ICT).

Public sector

Considerable R&D activities are also undertaken by the public sector in most countries. Expressed in terms of national GDP, spending by governments on R&D amounts to between 0.6% and 1% for most comparison countries as displayed in figure 2.7. The figure for the USA – with the highest government R&D in terms of GDP ratio of the countries considered here – even slightly exceeds one per cent. Switzerland's government activity in R&D amounting to 0.73% of GDP seems modest in international comparison. Similar to private sector R&D, however, there has been a considerable and continuous increase in Swiss publicly funded R&D over the course of the past decade, as shown in table 2.1. The table also reveals that the largest share – two thirds – of this has been used for direct support of R&D conducting institutions in Switzerland. Publicly funded R&D on a project basis (which can be considered a more competitive allocation channel) plays a smaller, but increasingly important role. Domestically, project level support is granted foremost by the two R&D financing agencies Swiss National Funds (SNF, for academic research) and Commission for Technology and Innovation (CTI, for knowledge and technology transfer). The bulk of international project level support consists of Swiss contributions to the European Union's framework programmes and to the European Space Agency ESA (see SFSO, 2012a).

Internationalization of R&D activities

The increasingly international nature of R&D activities is also reflected in private sector R&D. Intramuros R&D conducted by foreign affiliates of Swiss enterprise groups amounted to CHF 15.8 billion in 2008, corresponding to 132% of R&D conducted in Switzerland in the same year (see table 2.2) – an exceptionally high ratio, considering that most OECD countries report values of between 2% and 30% (see figure 2.8).[3] This can partly be explained by the importance of pharmaceutical companies in Switzerland, where R&D typically has been internationalised to a large degree (SFSO, 2011). By contrast, the amount of R&D conducted in Switzerland by affiliates of foreign enterprise groups is rather small. In relation to total domestic R&D it amounts to only 14%, as shown in figure 2.9. With the exception of Japan all comparison countries exhibit larger proportions of R&D conducted by foreign-owned firms; in Ireland and Austria, the respective shares are above 50%.

2.3.2 Patents as an indicator of invention output

As opposed to R&D spending, patents are an indicator of innovation output. One should however keep in mind that a successfully granted patent does not necessarily mean that a marketable product or a ready-to-use process has already been introduced. Another limitation of using patents as an innovativeness indicator is that innovations in the service sector are less often accompanied by a patent application than those in manufacturing. Table 2.3 sets the number of patent applications, both for triadic and for PCT patents (see table notes for definitions), in relation to country size as measured by total population, for Switzerland and several comparison countries. For both patent categories, growth rates over a 10-year period are also given. Switzerland is revealed to be a at the forefront of patent generating countries, alongside Sweden, Finland and Japan; a finding that holds to a similar degree for both indicators considered here. Germany, Denmark, the Netherlands, Austria and the USA follow with some distance, but still lie above OECD and EU-15 averages. Growth rates indicate that there seems to be some convergence among countries, as countries with a low patent intensity (Ireland, China) are among the ones having experienced the fastest growth.

For a small country like Switzerland, co-operation with foreign research partners is often indispensable for successful technological advances. Patent statistics allow insights on the magnitude of this phenomenon, as the EPO provides figures on the share of patents generated as a result of international co-operations. Table 2.4 provides these shares for the year 2008. For Belgium, Ireland and Switzerland, more than a third of patent applications are reported to stem from such co-operations, whereas a number of other small countries, such as Denmark and Austria, only have a modest share of international applications. Hardly surprising, large

[3] For a discussion of the implications of this high degree of outward R&D internationalization for domestic R&D activities see Arvanitis and Hollenstein (2007, 2011).

and long-established industrialised countries such as the USA, Japan and Germany (but also Italy) only modestly rely on international co-operations.

Internationalisation of innovation is reflected by patenting of foreign affiliates of multi-national corporations. From the point of view of each country, there is an “inward”-side (foreign owners of domestic firms generating patents here) and an “outward”-side (domestic firms having foreign affiliates generating patents abroad) to this phenomenon. Table 2.5 summarises figures for both of these aspects, again expressed in relative terms. The first column reveals that Switzerland attracts patenting activities of foreign owners to a moderate degree of 27% – above EU average, but less than several other small countries (plus the UK). The second column highlights Switzerland’s important position as a host country for ownership of patents generated elsewhere: more than half of the patents owned by Swiss entities stem from foreign activity, a proportion only paralleled by Ireland. This finding for Switzerland is in accordance with figures for international R&D flows presented in the previous subsection: Swiss firms have a strong position of conducting research abroad, but foreign firms undertake research in Switzerland only to a moderate degree.

Besides these findings on cross-country flows of research activity, both the R&D and patent statistics presented so far lead to similar conclusions with respect to international comparisons: Switzerland performs excellently, in a similar manner to Japan and most Scandinavian countries. Northern European countries tend to have above-average values in these indicators as well, however the European Union as a whole (no matter whether averages of EU-15 or EU-27 are considered) still and considerably lags behind the USA.

2.3.3 Information and Communication Technologies (ICT)

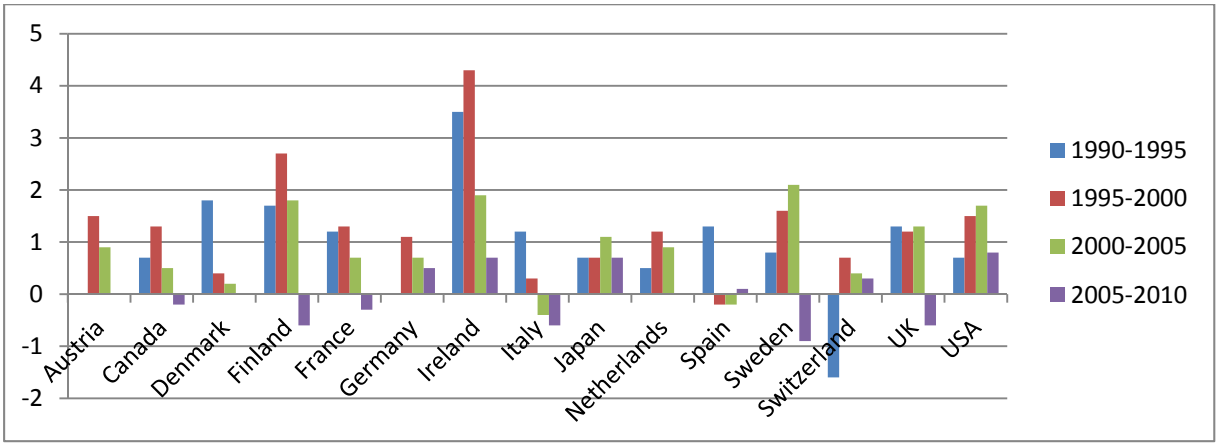
Useful indicators related to the intensity of use of modern information and communication technologies (ICT) can be calculated either on the basis of investment volumes dedicated thereon or on the share of firms (or employees within firms) that actually use specific technologies.

Figure 2.10 considers investments dedicated to the three categories IT equipment, communication equipment and software, as a share of total investments for several OECD countries. With nearly 20%, Switzerland relies on ICT more heavily than most European countries; only the Netherlands, the UK, Denmark and Sweden exhibit higher shares. The USA are the undisputed champion, with almost a third of total investments being dedicated to ICT. There are significant differences in the various countries’ composition of ICT investments: Switzerland dedicates a rather large share to communication equipment, but has only a modest share that is invested in software.

The increasing importance of ICT is exemplified in figure 2.11, showing the development of ICT related investments in Switzerland from 1990 to 2010. Obviously, part of the increase

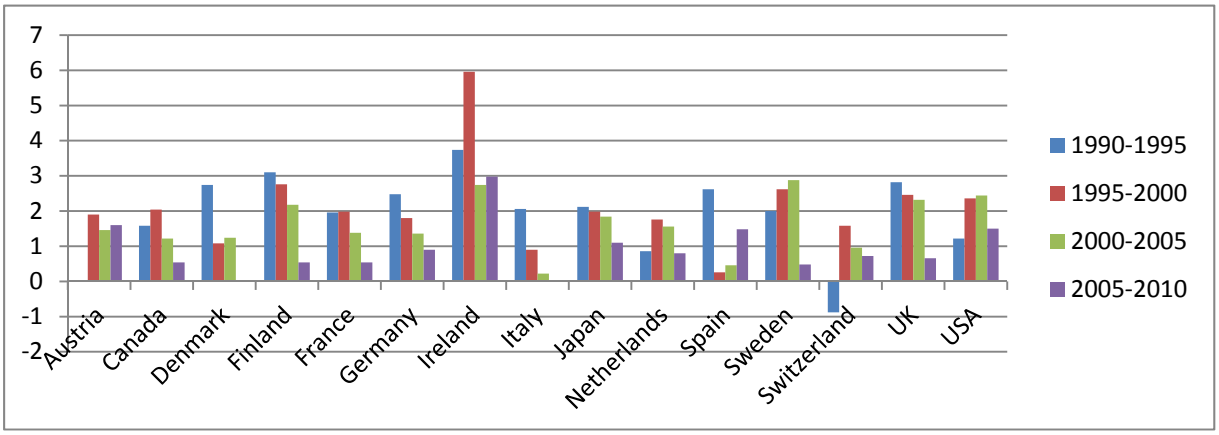
during this period can be explained by overall economic growth and by the fact that real values are computed (due to ever increasing computing power being offered at constant or even falling prices, real values rise more pronouncedly than nominal spending would suggest). Nevertheless, an impressive increase can be observed for the category "data processing and data services" (roughly by a factor of five) and for sensors and process control technologies (nearly tripling). As for communication technologies, growth has been modest in the course of the nineties, but accelerated towards the end of the period under consideration.

Figure 2.1: Average annual multifactor productivity growth rates for selected countries, 1990-2010.



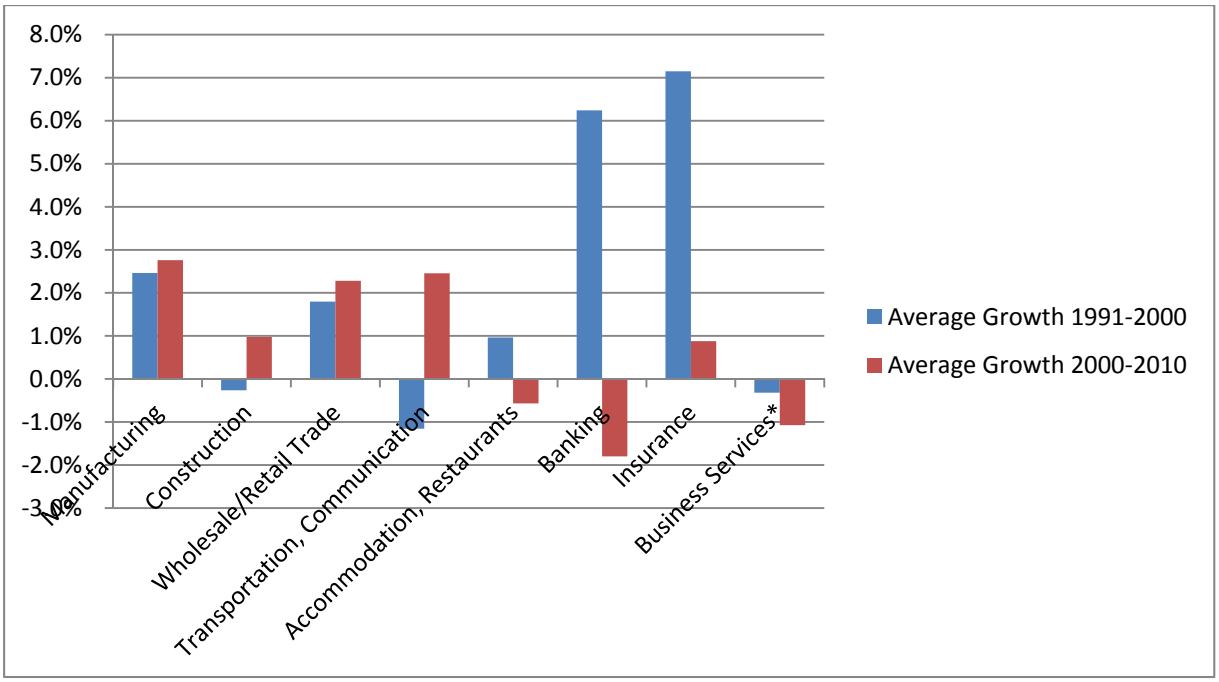
Source: OECD

Figure 2.2: Average annual labour productivity growth rates for selected countries, 1990-2010.



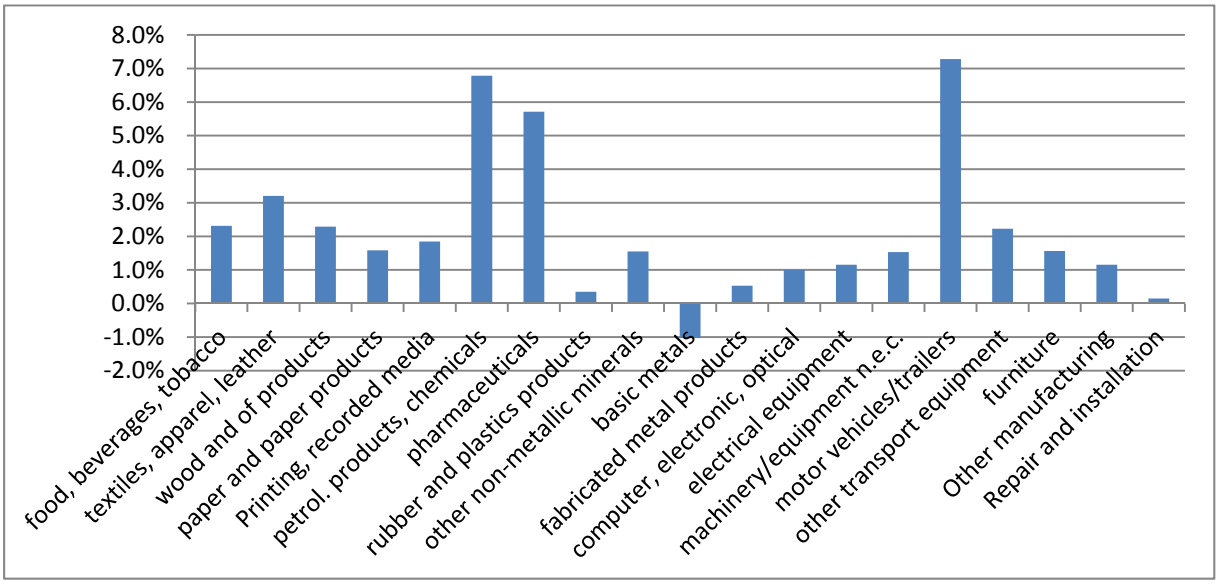
Source: OECD

Figure 2.3: Average annual labour productivity growth rates for different economic sectors in Switzerland, 1991-2010.



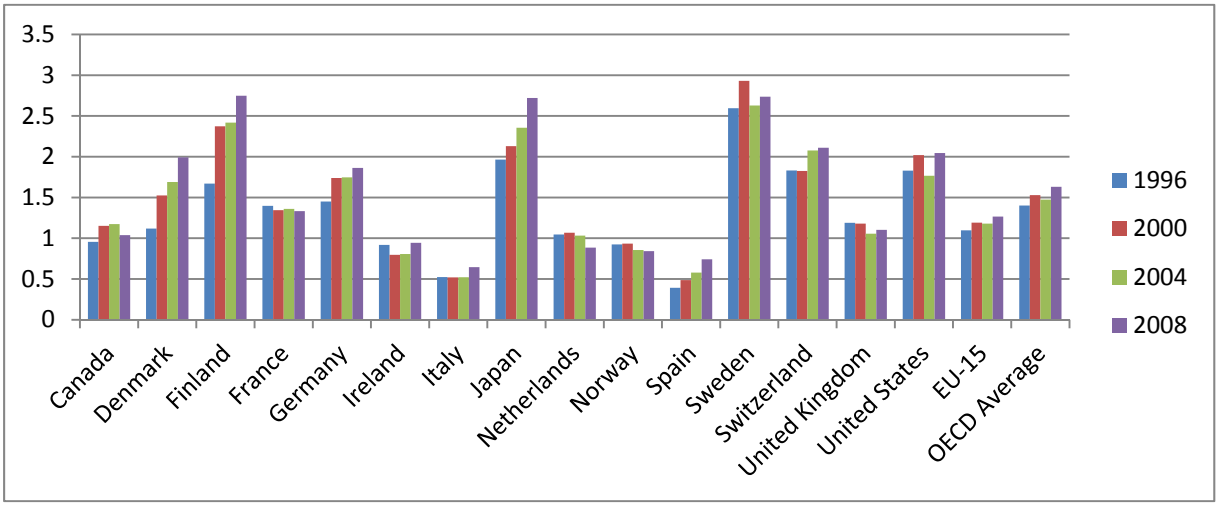
(*): Business Services are defined as ISIC Rev. 4 codes 68-82 (real estate services; scientific, technical and other business oriented services.). Source: SFSO

Figure 2.4: Average annual labour productivity growth rates for two-digit manufacturing industries in Switzerland, 2000-2010.



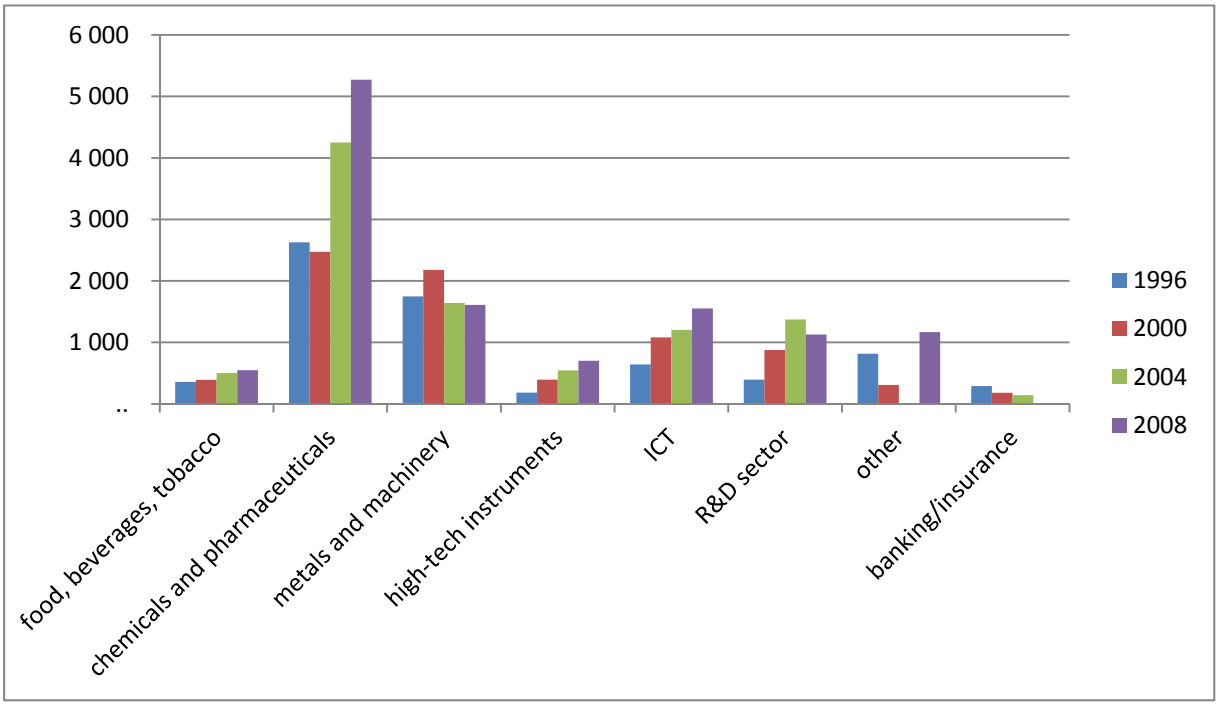
Source: SFSO

Figure 2.5: Development of R&D intensity (R&D investments by the private sector divided by GDP) for selected countries, 1996-2008.



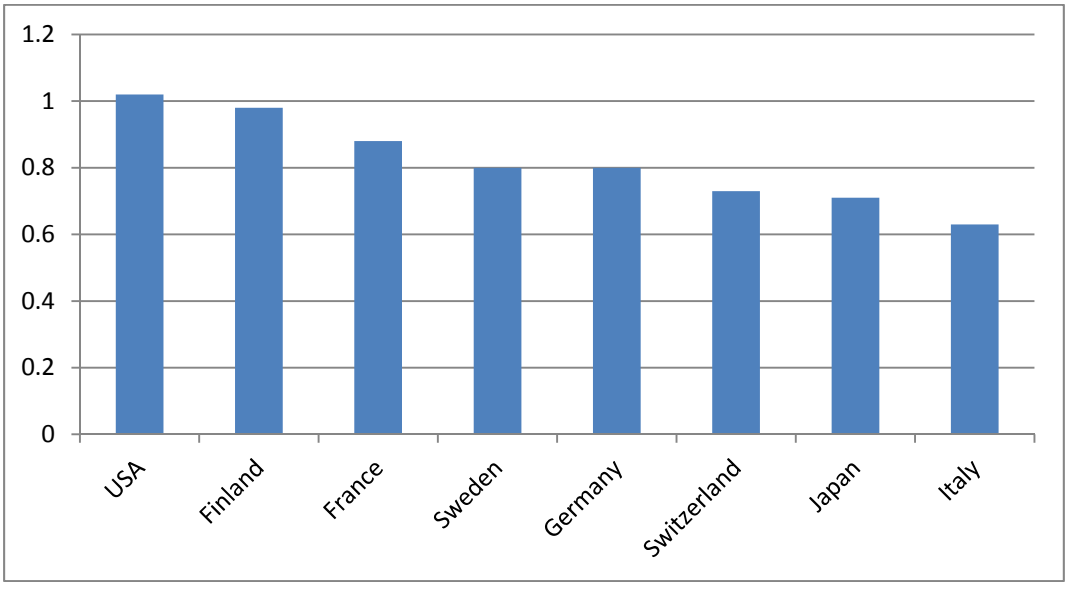
Source: OECD Main Science and Technology Indicators

Figure 2.6: Development of annual R&D investments for different economic sectors in Switzerland, in millions of CHF, 1996-2008.



Source: SFSO

Figure 2.7: Comparison of GBAORD(*) across several countries, expressed as a percentage of GDP; 2008.



(*): GBAORD: Government Budget Appropriation or Outlays for R&D; Source: OECD

Source: SFSO, OECD

Table 2.1: GBAORD(*) in Switzerland, institution vs. project and domestic vs. foreign support, in millions of CHF (current prices); 2000-2010.

Destination:	2000	2002	2004	2006	2008	2010	Share 2010
Domestic institutions	2024	2250	2297	2410	2837	3059	66%
Domestic projects	518	504	635	649	854	1017	22%
Foreign institutions	107	130	119	82	67	97	2%
Foreign projects	121	131	331	365	407	466	10%
Total	2770	3015	3382	3506	4166	4639	100%

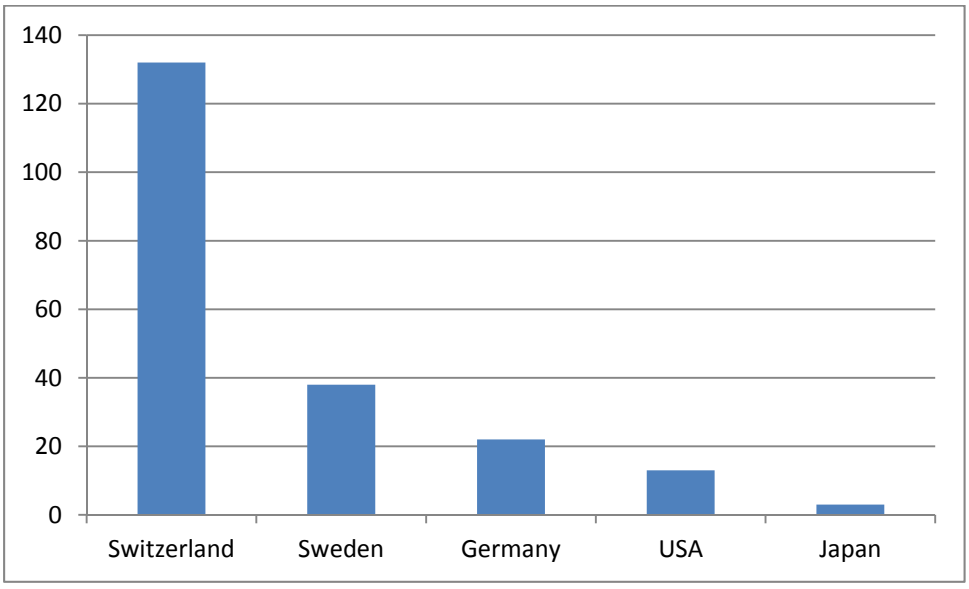
(*): GBAORD: Government Budget Appropriation or Outlays for R&D. Source: SFOE

Table 2.2: Intramuros R&D spending abroad (by foreign affiliates of Swiss enterprise groups) and domestic private sector R&D, in millions of CHF (current prices); 1989-2008.

	1989	1992	1996	2000	2004	2008
(1) Swiss private sector	6 210	6 370	7 060	7 890	9 659	11 979
(2) Swiss affiliates abroad	5 270	7 090	8 060	9 788	9 603	15 769
(2) in relation to (1)	85%	111%	114%	124%	99%	132%

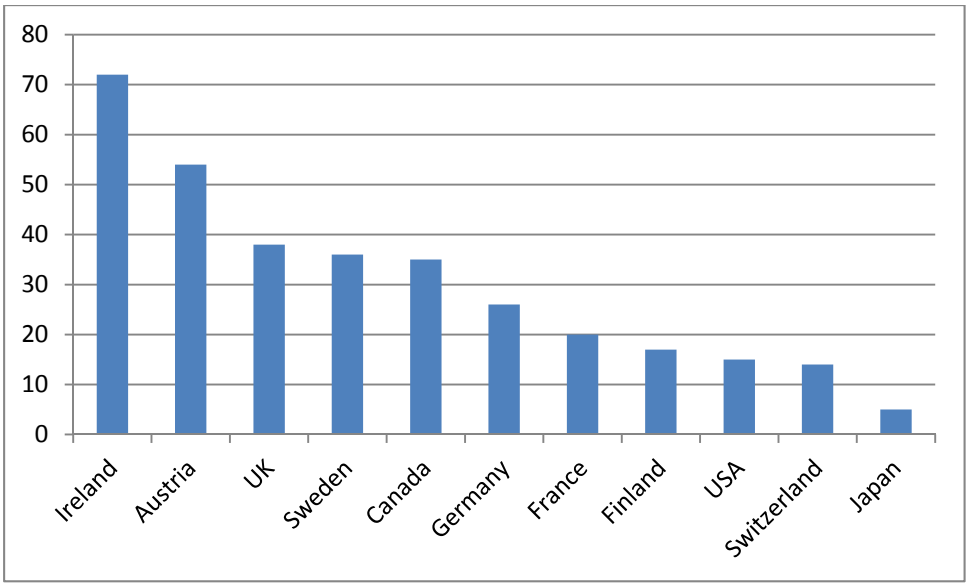
Source: SFOS (2011)

Figure 2.8: Intramuros R&D spending abroad by affiliates of national enterprise groups in relation to domestic private sector R&D; 2008.



Source: SFSO (2011)

Figure 2.9: Share of domestic intramuros R&D conducted by foreign owned affiliates; 2007 or nearest available (*).



(*): 2006 for Finland; 2008 for Switzerland. Source: SFSO (2011).

Table 2.3: Patent applications

	Triadic patents (1)		PCT patents (2)	
	Per capita (pat/mio pop), 2010	Growth rate (%), 2000-2010	Per capita (pat/mio pop), 2010	Growth rate (%), 2000-2010
Switzerland	108.8	-3.4	278.6	33.5
Belgium	38.0	19.0	102.9	30.9
Germany	69.5	-1.5	198.7	22.7
Denmark	54.7	30.8	182.8	6.2
Finland	65.9	-2.6	285.7	5.9
France	37.8	7.1	105.8	36.9
UK	25.7	-6.8	79.8	-19.1
Ireland	17.1	106.9	67.8	19.1
Italy	11.7	4.4	48.4	51.1
Netherlands	49.8	-22.4	144.9	-23.4
Austria	48.5	41.4	151.7	56.8
Sweden	108.8	-3.4	286.7	-11.2
Japan	117.7	1.2	267.2	211.4
USA	44.6	-8.6	122.4	-15.3
China	0.7	1065.7	10.0	704.8
EU-15	35.1	0.4	108.6	12.8
OECD	38.5	-2.0	108.3	24.6

(1) Triadic Patent Families (OECD definition): sub-set of patents all filed together at the EPO, at the Japan Patent Office (JPO) and granted by the USPTO, protecting the same set of inventions; (2) The Patent Co-operation Treaty (PCT) is a patent law treaty providing a unified procedure for filing patent applications to protect inventions at an international level. Source: OECD (2011); KOF (2013).

Table 2.4: Patents filed at EPO that are generated in co-operation with foreign inventors (% of total applications from the respective home country filed at EPO)

	2008
Switzerland	35.8
Belgium	36.9
Germany	13.8
Denmark	19.5
Finland	23.0
France	17.7
UK	24.1
Ireland	35.8
Italy	9.5
Netherlands	18.7
Austria	24.7
Sweden	19.7
Japan	2.6
USA	13.6
China	20.4
EU-27	8.2
OECD	8.3

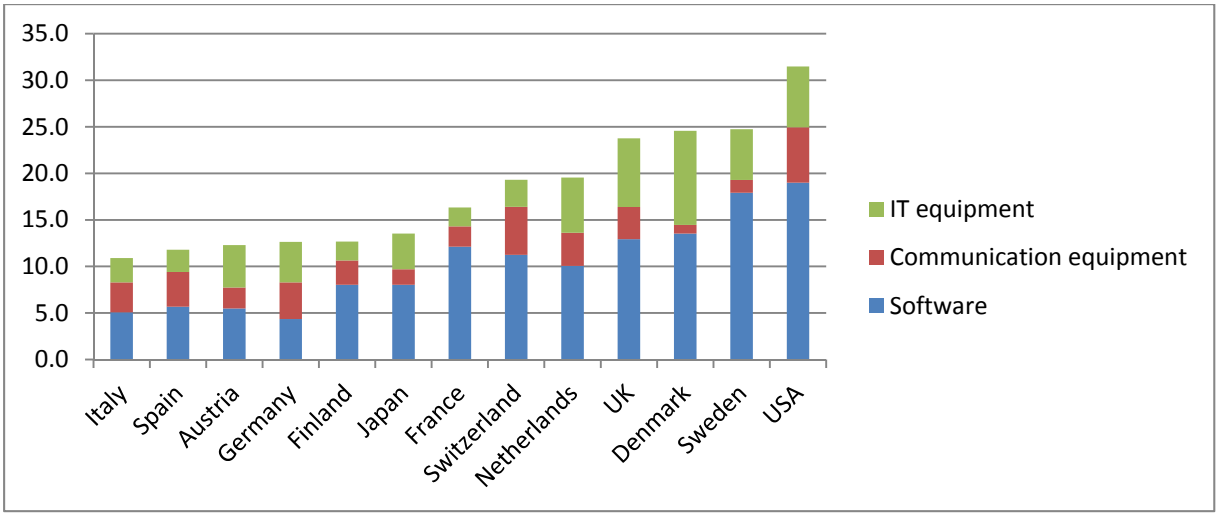
Source: OECD (2011); KOF (2013)

Table 2.5: Inventions generated domestically and held in foreign ownership filed at EPO; inventions generated abroad and held in domestic ownership filed at EPO. (as a percentage of all patents generated domestically and of all domestically owned patents, respectively; 2008)

	Patents generated domestically in foreign ownership: Total	Patents generated abroad in domestic ownership:			
		Total	Share of USA	Share of most important EU country	
Switzerland	26.9	56.9	14.6	18.1	Germany
Belgium	45.9	40.2	7.9	9.1	France
Germany	17.0	15.8	3.1	1.9	Netherlands
Denmark	23.1	21.8	5.3	3.9	Sweden
Finland	18.6	39.3	5.0	15.2	Sweden
France	22.3	21.3	6.3	5.6	Germany
UK	40.7	18.8	5.3	2.0	Germany
Ireland	38.2	55.5	18.8	13.7	UK
Italy	20.6	4.0	1.5	1.4	Germany
Netherlands	27.6	36.4	14.1	7.9	UK
Austria	31.8	22.8	0.8	10.8	Germany
Sweden	20.6	35.3	8.5	6.4	Germany
Japan	3.4	4.8	1.7	1.1	Germany
USA	15.0	18.1	NA	3.2	Germany
China	36.5	10.9	4.0	1.0	Germany
EU-27	11.5	9.4	4.9	NA	
OECD	17.2	17.9	3.7	3.3	Germany

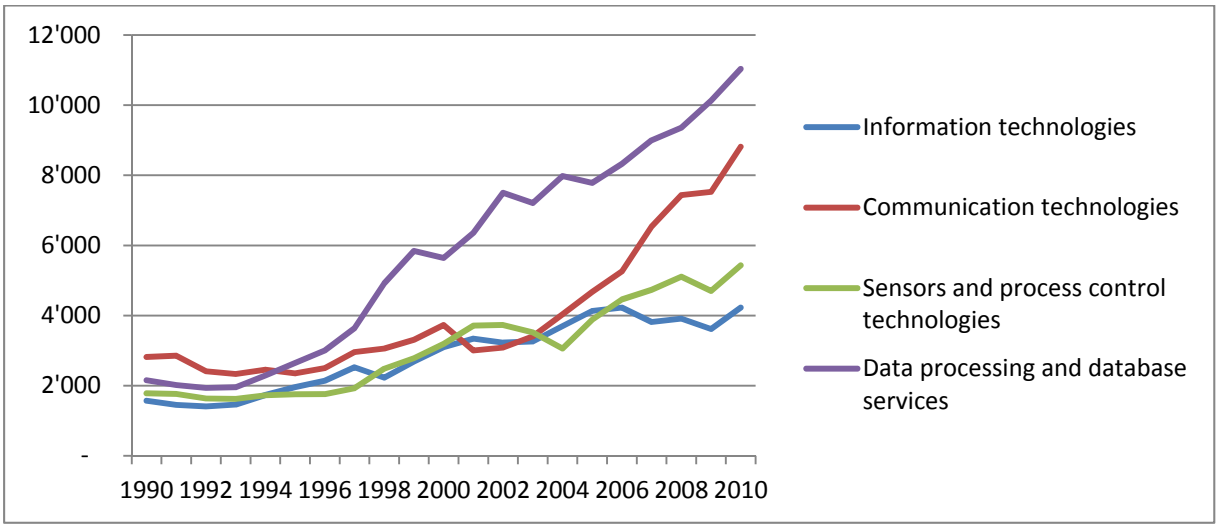
Source: OECD (2011); KOF (2013)

Figure 2.10: Percentage share of ICT related investments in total investments for selected OECD countries, according to three ICT subcategories; 2009 or latest available(*).



(*): 2008 for Japan; 2007 for Austria, Netherlands, UK and Denmark. Source: SFSO, OECD STI Scoreboard 2011

Figure 2.11: Evolution of ICT related investments in Switzerland, according to four sub-categories, in millions of Swiss Francs (real values); 1990-2010.



Source: SFSO

3. Determinants of productivity at firm level 1995-2010: the role of innovation

3.1 Specification of the empirical model

Conceptual background of the study is the well-known framework of a production function. Our main hypothesis is that innovation input (PRDL) and/or innovation output (LINNS) contributes, as additional production factor, to an improvement of labour productivity.

We specified at firm level productivity equations (dependent variable: value added per employee, i.e. average labour productivity LQL) that contained measures for physical capital (variable LCL), for human capital (share employees with tertiary-level education; LHC), for lack of qualified personnel (SKILL_IMPED) as an impediment of innovation activities, for innovation performance (alternatively: R&D intensity LRDL; sales share of innovative products LINNS; introduction of process innovations INNOPC; patent applications PATENT), and for market conditions: number of competitors NCOMP; intensity of price competition (IPC) and intensity of non-price competition (INPC) (see table 3.1 for the variable description). In addition, we included controls for foreign-owned firms (FOREIGN), firm size (LEMPL), industry affiliation (2-digit industries) and time. A formal expression of the equation for firm i and year t is as follows:

$$LQL_{it} = \alpha_0 + \alpha_1 LCL_{it} + \alpha_2 INNOV_{it} + \alpha_3 LHC_{it} + \alpha_4 SKILL\_IMPED_{it} + \alpha_5 NCOMP_{it} + \alpha_6 IPC_{it} + \alpha_7 INPC_{it} + \alpha_8 FOREIGN_{it} + \alpha_9 LEMPL_{it} + industry\ and\ year\ dummies + e_{it} \quad (1)$$

Where INNOV: alternatively, LRDL; LINNS; INNOPC; and PATENT.

In a further step we inserted in equation (1) interaction terms of the variables measuring market conditions (NPCOMP; IPC; INPC) with the variables for physical capital, human capital and R&D intensity in order to test whether the market conditions affect the effectiveness of these resource endowment factors (indirect effects on productivity).

We expect positive and statistically significant elasticities for physical capital, human capital and the innovation variables, particularly the metric measures LINNDL and LINNS. Further, we expect a negative sign for the variable SKILL_IMPED given the chronic problem of insufficient domestic supply of qualified personnel of the Swiss economy. It is not a priori clear whether the market conditions, firm size and the foreign ownership exert an influence on labour productivity.

3.2 Data

The data used in this study were collected in the course of six surveys among Swiss enterprises in the years 1996, 1999, 2002, 2005, 2008 and 2011 using a questionnaire which included besides questions on some basic firm characteristics (sales, exports, employment, investment and employees' vocational education) also several innovation indicators quite

similar to those in the Innovation Surveys of the European Community (CIS). The survey was based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all relevant industries of the manufacturing sector, the construction sector and selected service industries as well as firm size classes (on the whole 28 industries and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms). Answers were received from 32.5% (1996), 33.8% (1999), 39.6% (2002), 38.7% (2005), 36.1% (2008) and 35.9% (2011) respectively of the firms in the underlying sample. The response rates do not vary much across industries and size classes with a few exceptions (for example, over-representation of machinery, under-representation of clothing/leather, wood processing and personal services). The final data set includes 13'803 observations from all fields of activity and size classes and may be considered as representative of Swiss business sector (see table A.3.1 in appendix for the structure of the used data set by industry, firm size class and year respectively).[4]

Table 3.2 shows the average (nominal) value added per employee by industry over the entire period 1995-2010. The industries with the highest values of labour productivity are – besides the energy sector and wholesale trade with their specific characteristics as high value added industries – banks/insurance, chemicals/ pharmaceuticals and computer services. The tables 3.3a and 3.3b show discernible differences between manufacturing and services with respect to the shares of product and process innovators as well as the shares of firms performing R&D and applying for patents.

3.3 Method

We did not assume a concrete functional form for the production function (underlying the productivity equation that we estimated) because our data would not allow an identification of this functional form. We used as in most studies a linear logarithmic specification.

Several preliminary tests showed that there is considerable heterogeneity in the data referring to innovation performance due to differences between sectors (see also tables 3.3a and 3.3b). This is the reason, why we estimated the productivity equations separately for manufacturing and services. In addition, we conducted also quantile regressions to capture differences of high- and low-productivity segments with respect to the impact of innovation, particularly of R&D intensity and sales share of innovation, on productivity.

We used GLS random effects regression as estimation method (software: STATA 12) throughout this study. Tests with first difference equations and fix effects as alternative panel estimation method led to unstable results presumably due to fact that our firm panel is highly unbalanced and the variance of our variable across time is rather low as "R2 within" figures

[4] See table A.3.2a and A.3.2b for descriptive statistics and tables A.3.3a and A.3.3b for the correlations between the model variables.

for the productivity equation (see tables 3.4 and 3.5) as well as for the equations for LRDL and LINNS (see table A.3.4, column 1 and table A.3.5, column 1 in the appendix). With respect to the adequateness of a random effect estimator as compared to a fixed effect estimator we follow here the argumentation in Hsiao (2003): „When inferences will be made about a population of effects from which those in the data are considered to be a random sample, then the effects should be considered random....In this respect, if N becomes large, one would not be interested in the specific effect of each individual but rather in the characteristics of the population. A random-effects framework would be more appropriate“ (Hsiao 2003, S. 41ff., S. 320).

In order to avoid problems of endogeneity of the right-hand variables because they are contemporaneous to the dependent variable we tested for exogeneity (procedure of Rivers and Vuong 1988) for those variables that interest at most in this study. To this end, we estimated a first stage equation for the right-hand variables LRDL and LINNS, respectively, using the variables OBSTACLE-COPY, OBSTACLE_ACCEPTANCE and D as instruments.[5] The residuals of the first stage equations (effective values of LRDL and LINNS respectively minus the predicted values for LRDL and LINNS respectively from the first stage equations) were inserted in the LQL equations and the models were once more estimated. The standard errors were bootstrapped. The residuals were throughout statistically insignificant, so that we presume that there is no endogeneity bias in our estimates with respect to these two variables (see tables A.3.4 and A.3.5 in the appendix).

We also estimated productivity equations with lagged right-hand variables (lag of a period of 3 years in our dataset). By using the lagged value, for example, for LRDL the data set manufacturing was reduced from 6063 observations to 2714 observations, i.e. to about 45% of the available observations. In this case any inference from the smaller sample could imply serious selection bias. However, the results were qualitatively similar to those without lagged variables, which can be considered as a hint that our results are robust.

3.4 Results

Basic results[6]

Table 3.4 and table 3.5 contain the estimates of the productivity equation (1) separately for manufacturing and services. In the estimates for both sectors the variables for physical capital and human capital show the expected positive sign; both elasticities are statistically

[5] The instruments fulfill the following conditions: correlate significantly (10% test level) with the right-hand variables to be tested, do not correlate with LQL and with residuals of the LQL equation (Wooldridge 2002).

[6] In principle similar results were obtained also in earlier studies based on different cross-sections. Differences as to single innovation variables can be traced back mainly to differences with respect to the composition of the used data sets (see Arvanitis and von Arx 2004; Arvanitis 2008a, b; Arvanitis and Sturm 2008).

significant and of the same magnitude in both sectors.[7] The negative sign of the variable for the lack of qualified personnel indicates that personnel shortage might have been a hindrance for the improvement of labour productivity, primarily in manufacturing. The respective coefficient is only for this sector statistically significant. This difference between manufacturing and services can be explained by the different qualification profiles, much more technicians and natural scientists are needed in manufacturing than in the service sector. It is exactly this kind of qualification that is insufficiently supplied by the Swiss educational system.

Effect of innovation

In manufacturing, positive and statistically significant elasticities are found for R&D intensity and patent applications but not for the share of innovative products and process innovation. In the estimates for the service sector only the sales share of innovative products is positive and statistically significant. Separate estimates not presented here for the sales shares of *new* products and *significantly modified* products for both sectors did not bring out additional insights. It is not surprising that R&D is much less important for most service firms (with the exception of firms in computer services, engineering, etc.). It is more difficult to understand why innovation output does not show any effect on productivity in manufacturing. However, firms with patent applications, an intermediate form of innovation output, seem to be more productive than firms without patent applications. Additional quantile regression estimates yield some evidence that R&D intensity in manufacturing shows a significantly positive effect from Q30 upwards (table 3.6, column 1). The estimates indicate also an increase of the R&D intensity effect between Q50 and Q60, further between Q80 and Q90. The effect of LINNS in the service sector seems to be concentrated to the high productivity quantiles (Q80).

Effects of market conditions

There are differences between the two sectors with respect to the effects of market conditions productivity. For manufacturing we find a negative effect for the number of competitors (NCOMP), that is a positive effect of market concentration (if we interpret the variable NCOMP as reverse to market concentration). High-productive firms are found in more concentrated markets. In the estimates for the service sector the respective variable shows also a negative sign but the respective coefficient is not statistically significant. Obviously, the concentration effect is less relevant for the service sector. Throughout the estimates for both sectors we find a positive effect of non-price competition and no significant effect for price competition. Thus, high-productive enterprise operate in concentrated markets with high non-price competition, in case of many Swiss SMEs these are “niches” for highly specialized high-tech products.

[7] The elasticity of LCL is considerably larger than that estimated in Ch. 4. The reason is not only the differing size of the data sets used but primarily the fact that for the first three cross-section in the estimates in the chapter at hand physical capital was approximated not by gross investment but by capital income (see table 3.1).

Finally, we find a positive non-linear effect for firm size and a positive effect for foreign-owned firms.

Interaction terms

The market conditions might impact productivity at firm level directly but also indirectly through the enhancing of the productivity effectiveness of the endowment resource factors physical capital, human capital and knowledge capital (approximated by innovation input and/or innovation output measures). To this end, we inserted interaction terms of the three variables reflecting market conditions with the three resource endowment factors. We estimated a productivity equation for each interaction term separately in order to diminish multicollinearity problems (see tables 3.7 to 3.9).

For both sectors we find a positive interaction term for LCL and NCOMP (table 3.8). This means that the productivity effect of physical capital is enhanced by a larger number of competitors. This is opposite to the negative effect for the interaction term for LHC and NCOMP, which is in accordance to the negative direct effect of NCOMP. No interaction effect could be found for R&D intensity.

For manufacturing we find further positive interaction terms for the interaction of the intensity of non-price competition with physical capital and human capital but not for the R&D intensity (table 3.7). The indirect effect for INPC is in accordance with the positive direct effect for the same variable. No interaction effects for INPC are found for the service sector.

The results with respect to price competition seem to be ambiguous. We find a positive interaction for physical capital in manufacturing but a negative one in the service sector. Finally, an enhancement effect is found for human capital in the service sector.

Table 3.1: Definition of model variables

Variables	Definition
LQL	Value added (sales minus intermediate inputs) per employee; natural logarithm
LCL	Gross investment / capital income (value added minus labour costs) per employee
LHC	Share of employees with tertiary-level education; natural logarithm
LRDL	R&D expenditures per employee; natural logarithm
LINNS	Sales share of innovative products (new products plus significantly modified products); natural logarithm
PATENT	At least 1 patent application; dummy variable
INNOPC	Introduction of process innovations; dummy variable
SKILL_IMPED	Lack of qualified personnel as an impediment of innovation; dummy variable: value 1 for the levels 4 and 5 of the original 5-point ordinal variable (1: 'not important'; 5: 'very important'); else value 0
LEMPL	Number of employees in full-time equivalents; natural logarithm
IPC	Intensity of price competition; dummy variable: : value 1 for the levels 4 and 5 of the original 5-point ordinal variable (1: 'very low'; 5: 'very high'); else value 0
INPC	Intensity of non-price competition (quality; technical advance, etc.); dummy variable: : value 1 for the levels 4 and 5 of the original 5-point ordinal variable (1: 'very low'; 5: 'very high'); else value 0
NCOMP	Number of principal competitors in the main product market (worldwide);
FOREIGN	Foreign-owned firm; dummy variable
Industry controls	Manufacturing: dummy variables for 17 2-digit industries (reference industry: food, beverage, tobacco); services: dummy variables for 8 2-digut industries (reference: wholesale trade)
Year controls	Reference year: 1996
Obstacle: copy	Easiness of copying a firm's products as an impediment of innovation; 5-point ordinal variable (1: 'not important'; 5: 'very important')
Obstacle: acceptance	Lack of technology acceptance as an impediment of innovation; 5-point ordinal variable (1: 'not important'; 5: 'very important')
D	Demand development; 5-point ordinal variable (1: 'very low'; 5: 'very high');

Table 3.2: Average nominal value added per employee by industry 1995-2010

	Industry average in SFR
Manufacturing	
Food, beverage, tobacco	173‘561
Textiles	129‘835
Clothing, leather	125‘999
Wood processing	134‘861
Paper	155‘702
Printing	142‘474
Chemicals, pharmaceuticals	208‘572
Plastics, rubber	142‘977
Glass, stone, clay	171‘105
Metal	135‘371
Metalworking	132‘302
Machinery	152‘743
Electrical machinery	144‘133
Electronics, instruments	154‘193
Matches	131‘388
Vehicles	136‘098
Other manufacturing	130‘275
Energy	266‘404
Construction	126‘615
Services	
Wholesale trade	194‘986
Retail trade	138‘344
Hotels, catering	114‘541
Transport, telecommunication	154‘858
Banks, insurance	293‘274
Real estate, leasing	181‘601
Computer services	178‘457
Business services	164‘110
Personal services	130’191

Table 3.3a: Percentage of firms with R&D, product and process innovations and patent applications by year; manufacturing

Variables	R&D	Product innovation	Process innovation	Patent applications
1996	65.4	70.1	68.0	28.9
1999	61.1	63.9	54.9	26.3
2002	59.0	65.3	51.3	19.8
2005	54.9	62.9	50.6	23.9
2008	53.9	66.1	50.5	26.5
2011	53.4	63.4	46.5	23.2
All periods	*57.8*	*65.2*	*53.3*	*24.5*

Table 3.3b: Percentage of firms with R&D, product and process innovations by year; services

Variables	R&D	Product innovation	Process innovation	Patent applications
1996	40.2	51.1	50.5	5.2
1999	23.6	40.5	39.4	3.2
2002	24.2	39.3	33.7	3.1
2005	23.5	39.4	36.7	3.3
2008	18.4	36.9	32.6	3.3
2011	18.4	37.3	31.8	3.8
All periods	*24.1*	*40.4*	*36.9*	*3.6*

Table 3.4: Random-effects GLS estimates of average labour productivity LQL; manufacturing

Variables	LQL	LQL	LQL	LQL
LCL	0.124***	0.120***	0.122***	0.123***
	(0.004)	(0.004)	(0.004)	(0.004)
LRDL	0.004***			
	(0.001)			
LINNS		0.002		
		(0.003)		
PATENT			0.034***	
			(0.12)	
INNOPC				-0.010
				(0.009)
LHC	0.025***	0.028***	0.027***	0.028***
	(0.005)	(0.005)	(0.005)	(0.005)
SKILL_IMPED	-0.026**	-0.026**	-0.022**	-0.022**
	(0.011)	(0.011)	(0.011)	(0.011)
LEMPL	0.016***	0.018***	0.015***	0.019***
	(0.004)	(0.004)	(0.004)	(0.004)
IPC	0.001	0.004	0.002	0.002
	(0.010)	(0.010)	(0.010)	(0.010)
INPC	0.025***	0.029***	0.026***	0.027***
	(0.009)	(0.009)	(0.009)	(0.009)
NCOMP	-0.011***	-0.013***	-0.012***	-0.013***
	(0.003)	(0.004)	(0.003)	(0.003)
FOREIGN	0.131***	0.131***	0.132***	0.130***
	(0.014)	(0.015)	(0.014)	(0.014)
Industry controls	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes
Const.	10.284***	10.321***	10.313***	10.292***
	(0.056)	(0.056)	(0.055)	(0.055)
N	6063	5989	6212	6212
R2 overall	0.331	0.317	0.324	0.323
R2 within	0.129	0.108	0.120	0.120
R2 between	0.367	0.357	0.365	0.365
Wald chi2	2071.9***	1897.2***	2045.9***	2036.5***
Sigma_u	0.234	0.233	0.232	0.232
Sigma_e	0.262	0.267	0.265	0.265
Rho	0.445	0.433	0.434	0.434

Note: ***. **, * denote statistical significance at the 1%, 5% and 10% test level resp.; reference industry: food industry; reference year: 1996.

Table 3.5: Random-effects GLS estimates of average labour productivity LQL; services

Variables	LQL	LQL	LQL
LCL	0.129***	0.126***	0.127***
	(0.005)	(0.005r)	(0.005)
LRDL	0.003		
	(0.002)		
LINNS		0.010**	
		(0.004)	
INNOPC			0.017
			(0.014)
LHC	0.024***	0.025***	0.025***
	(0.006)	(0.006)	(0.006)
SKILL_IMPED	-0.015	-0.013	-0.014
	(0.019)	(0.019)	(0.018)
LEMPL	-0.002	-0.000	-0.002
	(0.005)	(0.005)	(0.005)
IPC	-0.004	-0.006	0.002
	(0.014)	(0.014)	(0.014)
INPC	0.026**	0.030**	0.026**
	(0.013)	(0.013)	(0.013)
NCOMP	-0.001	-0.001	-0.001
	(0.005)	(0.005)	(0.004)
FOREIGN	0.172***	0.175***	0.167***
	(0.022)	(0.022)	(0.022)
Industry controls	Yes	Yes	Yes
Year controls	Yes	Yes	Yes
Const.	10.519***	10.540***	10.542***
	(0.069)	(0.068)	(0.067)
N	4318	4325	4493
R2 overall	0.364	0.368	0.366
R2 within	0.113	0.116	0.111
R2 between	0.377	0.378	0.366
Wald chi2	1696.6***	1730.7***	1770.4***
Sigma_u	0.301	0.299	0.297
Sigma_e	0.330	0.329	0.332
Rho	0.454	0.451	0.445

Note: ***. **, * denote statistical significance at the 1%, 5% and 10% test level resp.; reference industry: food industry; reference year: 1996.

Table 3.6: Average labour productivity LQL and innovation; quantile regression estimates

	Manufacturing		Services	
	LRDL	LINNS	LRDL	LINNS
Q10	0.002	-0.002	-0.001	0.002
	(0.002)	(0.004)	(0.003)	(0.006)
Q20	0.002	-0.003	-0.002	-0.001
	(0.002)	(0.003)	(0.002)	(0.005)
Q30	0.003**	-0.000	-0.001	0.004
	(0.001)	(0.003)	(0.002)	(0.005)
Q40	0.003**	-0.001	0.001	0.005
	(0.001)	(0.003)	(0.002)	(0.005)
Q50	0.003**	-0.002	0.002	0.006
	(0.001)	(0.003)	(0.002)	(0.004)
Q60	*0.004***	-0.000	0.002)	0.006
	(0.001)	(0.003)	(0.002)	(0.005)
Q70	0.004**	-0.001	0.002	0.006
	(0.002)	(0.004)	(0.003)	(0.005)
Q80	0.004**	-0.003	0.004	0.013*
	(0.002)	(0.004)	(0.004)	(0.007)
Q90	0.005**	-0.001	0.008	0.014
	(0.002)	(0.005)	(0.005)	(0.012)

Note: Simultaneous quantile regression (bootstrap standard errors); only the coefficients of the variables LRDL and LINNS respectively are presented. The specification of all other variables is as in the tables 3.4 and 3.5; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp.

Table 3.7: Random-effects GLS estimates of average labour productivity LQL; interaction terms with NCOMP

Variables	Manufacturing	Services
LCL	0.165***	0.162***
	(0.009)	(0.010)
*LCL*NCOMP*	*0.011***	*0.010***
	(0.002)	*(0.002)*
NCOMP	-0.121***	-0.097***
	(0.022)	(0.025)
LRDL	0.005*	0.009**
	(0.003)	(0.005)
*LRDL*NCOMP*	*0.000*	*0.002*
	(0.001)	*(0.001)*
NCOMP	-0.012***	-0.004
	(0.005)	(0.005)
LHC	-0.005	0.002
	(0.011)	(0.001)
*LHC*NCOMP*	*-0.009***	*-0.007***
	(0.003)	*(0.003)*
NCOMP	-0.012	0.018*
	(0.008)	(0.009)

Note: Only the coefficients and the standard errors for the interaction terms and the underlying variables are shown. ***. **, * denote statistical significance at the 1%, 5% and 10% test level resp.

Table 3.8: Random-effects GLS estimates of average labour productivity LQL; interaction terms with INPC

Variables	Manufacturing	Services
LCL	0.118***	0.133**
	(0.005)	(0.006)
*LCL*INPC*	*0.019****	*-0.010*
	(0.006)	*(0.008)*
INPC	-0.166***	0.129*
	(0.062)	(0.076)
LRDL	0.004***	0.005*
	(0.001)	(0.003)
*LRDL*INPC*	*-0.000*	*-0.003*
	(0.002)	*(0.004)*
INPC	0.027**	0.032**
	(0.014)	(0.015)
LHC	0.019***	0.024***
	(0.006)	(0.007)
*LHC*INPC*	*0.018***	*-0.001*
	(0.009)	*(0.010)*
INPC	-0.021	0.028
	(0.024)	(0.029)

Note: Only the coefficients and the standard errors for the interaction terms and the underlying variables are shown. ***. **, * denote statistical significance at the 1%, 5% and 10% test level resp.

Table 3.9: Random-effects GLS estimates of average labour productivity LQL; interaction terms with IPC

Variables	Manufacturing	Services
LCL	0.114***	0.144***
	(0.006)	(0.008)
*LCL*IPC*	*0.016****	*-0.021****
	(0.006)	*(0.008)*
IPC	-0.158***	0.202***
	(0.063)	(0.082)
LRDL	0.002	0.004
	(0.002)	(0.003)
*LRDL*IPC*	*0.002*	*-0.001*
	(0.002)	*(0.004)*
IPC	-0.011	-0.001
	(0.014)	(0.016)
LHC	0.021***	0.013
	(0.008)	(0.009)
*LHC*IPC*	*0.006*	*0.016**
	(0.009)	*(0010)*
IPC	-0.015	-0.046
	(0.024)	(0.029)

Note: Only the coefficients and the standard errors for the interaction terms and the underlying variables are shown. ***. **, * denote statistical significance at the 1%, 5% and 10% test level resp.

APPENDIX TO CHAPTER 3:

Table A.3.1: Composition of the dataset by industry, firm size class and year

	N	%
Manufacturing	6947	100
Food, beverage, tobacco	540	7.8
Textiles	185	2.7
Clothing, leather	84	1.2
Wood processing	281	4.0
Paper	155	2.2
Printing	401	5.8
Chemicals	485	7.0
Plastics, rubber	317	4.6
Glass, stone, clay	276	4.0
Metal	165	2.4
Metalworking	975	14.0
Machinery	1139	16.4
Electrical machinery	332	4.8
Electronics, instruments	731	10.5
Matches	253	3.6
Vehicles	137	2.0
Other manufacturing	259	3.7
Energy	232	3.3
Construction	1346	
Services	5510	100
Wholesale trade	1135	20.6
Retail trade	894	16.2
Hotels, catering	560	10.2
Transport, telecommunication	748	13.7
Banks, insurance	680	12.3
Real estate, leasing	99	1.8
Computer services	294	5.3
Business services	957	17.4
Personal services, other	138	2.5
Firm size (incl. construction)	*13803*	*100*
5-49 employees	6919	50.1
50-249 employees	4797	34.8
250 employees and more	2087	15.1
Year (incl. construction)	*13803*	*100*
2011	1989	14.4
2008	2172	15.7
2005	2586	18.7
2002	2552	18.5
1999	2141	15.5
1996	2363	17.1

Table A.3.2a: Descriptive statistics; manufacturing

Variables	N	Average	Standard deviation
LQL	6855	11.850	0.421
LCL	6404	9.901	1.395
LRDL	6781	4.727	4.204
LINNS	6707	2.237	1.733
PATENT	6843	0.245	0.430
LHC	6947	2.527	1.048
SKILL_IMPED	6947	0.175	0.380
LEMPL	6946	4.114	1.420
IPC	6947	0.719	0.449
INPC	6947	0.378	0.485
CONC	6843	3.485	1.397
FOREIGN	6866	0.157	0.364

Table A.3.2b: Descriptive statistics; services

Variables	N	Average	Standard deviation
LQL	5261	11.926	0.532
LCL	4778	9.768	1.644
LRDL	5306	1.775	3.342
LINNS	5304	1.307	1.609
PATENT	-	-	-
LHC	5510	2.546	1.328
SKILL_IMPED	5510	0.124	0.330
LEMPL	5509	3.833	1.612
IPC	5510	0.667	0.471
INPC	5510	0.381	0.486
CONC	5338	3.114	1.579
FOREIGN	5453	0.136	0.343

Table A.3.3a: Correlation matrix; manufacturing

	LCL	LRDL	LINNS	PATENT	INNOPC	LHC	SKILL_IMPED	IPC	INPC	NCOMP	FOREIGN
LRDL	0.084	1.000									
LINNS	0.088	0.685	1.000								
PATENT	0.040	0.475	0.381	1.000							
INNOPC	0.121	0.474	0.554	0.252	1.000						
LHC	-0.042	0.326	0.225	0.229	0.120	1.000					
SKILL_IMPED	-0.006	-0.009	0.005	-0.012	0.037	-0.005	1.000				
IPC	0.002	0.055	0.066	0.062	0.060	0.009	0.044	1.000			
INPC	0.074	0.152	0.153	0.103	0.104	0.064	0.027	-0.027	1.000		
NCOMP	-0.038	0.187	0.109	0.151	0.043	0.152	-0.044	-0.098	-0.021	1.000	
FOREIGN	-0.044	0.120	0.074	0.096	0.028	0.148	-0.009	0.028	0.037	0.131	1.000
LEMPL	0.086	0.315	0.247	0.368	0.262	0.221	-0.041	0.117	0.084	0.155	0.164

Table A.3.3b: Correlation matrix; services

	LCL	LRDL	LINNS	PATENT	INNOPC	LHC	SKILL_IMPED	IPC	INPC	NCOMP	FOREIGN
LRDL	0.067	1.000									
LINNS	0.098	0.541	1.000								
PATENT	0.014	0.289	0.191	1.000							
INNOPC	0.092	0.453	0.612	0.150	1.000						
LHC	-0.091	0.235	0.173	0.115	0.137	1.000					
SKILL_IMPED	0.046	0.066	0.077	0.026	0.071	0.013	1.000				
IPC	-0.030	0.023	0.052	-0.002	0.058	0.045	0.062	1.000			
INPC	0.042	0.092	0.154	0.039	0.104	0.061	0.060	0.083	1.000		
NCOMP	-0.052	0.056	0.038	0.065	0.014	-0.014	-0.064	-0.068	-0.069	1.000	
FOREIGN	-0.019	0.016	0.046	0.056	-0.011	0.120	-0.029	0.059	0.076	0.062	1.000
LEMPL	0.004	0.130	0.129	0.100	0.185	0.089	-0.054	0.111	0.078	0.170	0.136

Table A.3.4: Endogeneity test for LRDL and LINNS (Rivers und Vuong 1988); manufacturing

	LRDL Instrument equation	LQL Bootstrapped (100 replications)	LINNS Instrument equation	LQL Bootstrapped (100 replications)
OBSTACLE_ COPY	0.143***			
	(0.036)			
D			0.193***	
			(0.025)	
LCL	0.030***	0.117***	0.083***	0.116***
	(0.004)	(0.012)	(0.019)	(0.008)
LRDL		0.028		
		(0.033)		
RES_LRDL		*-0.024*		
		(0.033)		
LINNS				0.031
				(0.031)
RES_LINNS				*-0.029*
				(0.031)
LHC	0.581***	0.011	0.185***	0.024**
	(0.005)	(0.020)	(0.023)	(0.008)
SKILL_IMPED	-0.166	-0.024**	-0.004	-0.026**
	(0.112)	(0.013)	(0.051)	(0.012)
LEMPL	0.717***	-0.001	0.224**	0.011
	(0.042)	(0.023)	(0.018)	(0.009)
IPC	0.161*	-0.003	0.100**	0.003
	(0.098)	(0.012)	(0.044)	(0.010)
INPC	0.393***	0.016	0.184***	0.025**
	(0.089)	(0.015)	(0.040)	(0.013)
NCOMP	-0.287***	-0.004	-0.069***	-0.012***
	(0.035)	(0.010)	(0.016)	(0.004)
FOREIGN	-0.277***	0.138***	-0.143**	0.136***
	(0.143)	(0.017)	(0.063)	(0.017)
Industry controls	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes
Const.	-4.928***	10.392***	-0.907***	10.348***
	(0.563)	(0.165)	(0.251)	(0.091)
N	6100	6062	5977	5938
R2 overall	0.316	0.331	0.216	0.316
R2 within	0.017	0.129	0.025	0.107
R2 between	0.354	0.367	0.242	0.356
Wald chi2	1690.0***	2452.1***	1047.1***	2453.6***
Sigma_u	2.173	0.234	0.919	0.233
Sigma_e	2.735	0.262	1.244	0.267
Rho	0.387	0.445	0.353	0.431

Note: ***. **, * denote statistical significance at the 1%, 5% and 10% test level resp.; reference industry: food industry; reference year: 1996.

Table A.3.5: Endogeneity test for LRDL and LINNS (Rivers und Vuong 1988); services

	LRDL Instrument equation	LQL Bootstrapped (100 replications)	LINNS Instrument equation	LQL Bootstrapped (100 replications)
OBSTACLE_ COPY	0.258***			
	(0.047)			
OBSTACLE_ACCEPTANCE			0.043*	
			(0.023)	
LCL	0.117***	0.128***	0.080***	0.120***
	(0.037)	(0.009)	(0.018)	(0.016)
LRDL		0.013		
		(0.033)		
RES_LRDL		*-0.010*		
		(0.032)		
LINNS				0.093
				(0.172)
RES_LINNS				*-0.084*
				(0.172)
LHC	0.226***	0.021**	0.118***	0.015
	(0.045)	(0.010)	(0.022)	(0.022)
SKILL_IMPED	0.195	-0.019	0.163**	-0.028
	(0.136)	(0.026)	(0.069)	(0.040)
LEMPL	0.238***	-0.004	0.114**	-0.010
	(0.035)	(0.009)	(0.018)	(0.020)
IPC	-0.052	-0.003	0.070	-0.012
	(0.100)	(0.014)	(0.050)	(0.020)
INPC	0.384***	0.022	0.312***	0.004
	(0.094)	(0.020)	(0.047)	(0.056)
NCOMP	-0.083***	0.000	-0.035**	0.002
	(0.032)	(0.005)	(0.016)	(0.008)
FOREIGN	-0.294*	0.176***	0.026	0.173***
	(0.153)	(0.026)	(0.076)	(0.026)
Industry controls	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes
Const.	-1.564***	10.530***	-0.488***	10.574***
	(0.488)	(0.104)	(0.243)	(0.114)
N	4431	4318	4442	4325
R2 overall	0.185	0.364	0.116	0.368
R2 within	0.009	0.113	0.022	0.116
R2 between	0.219	0.377	0.130	0.378
Wald chi2	712.7***	3307.4***	430.5***	2710.5***
Sigma_u	1.743	0.301	0.867	0.299
Sigma_e	2.537	0.331	1.261	0.329
Rho	0.321	0.454	0.321	0.451

Note: ***. **, * denote statistical significance at the 1%, 5% and 10% test level resp.; reference industry: food industry; reference year: 1996.

4. Determinants of productivity at firm level 1995-2010: the role of ICT

4.1. Specification of the empirical model

In this section, our main hypothesis is that ICT investments (LICT) positively affect labour productivity. In this way, they are expected to complement non-ICT investments (LNICT) that should also have a positive effect on labour productivity. In addition, we examine the effect of internet user rates, IT infrastructure and IT methods and devices to enhance interconnectedness within the firm and with the outside world.

Our firm level productivity equations (dependent variable: logarithm of value added per employee; LQL) contain measures for human capital (share employees with tertiary-level education; LHC), for R&D expenditures per employee (natural logarithm, LRDL), for intensity of price competition (IPC), intensity of non-price competition (INPC) (see table 4.1 for the variable description). In addition, we included controls for foreign-owned firms (FOREIGN), firm size (natural logarithm of the number of employees, LEMPL), industry affiliation (2-digit industries), time and structural changes (STRUCT) due to takeovers or mergers.

In a first step we focused on the role of *ICT investments* compared to the role of *non-ICT investments* and specified a productivity equation containing these ICT variables. A formal expression of the equation is as follows:

$$LQL_{it} = \alpha_0 + \alpha_1 LNICT_{it} + \alpha_2 LICT_{it} + \alpha_3 LRDL_{it} + \alpha_4 LHC_{it} + \alpha_5 LEMPL_{it} + \alpha_6 IPC_{it} + \alpha_7 INPC_{it} + \alpha_8 FOREIGN_{it} + \alpha_9 STRUCT_{it} + industry\ and\ time\ dummies + e_{it}$$

(for firm i and year t) *(1)*

In a second step we focused on the effects of *internet use* taking into account variables for the share of employees using the internet at their work (INTER2-INTER6). The dummy variables reflect different categories of an ordinal variable measuring the share of employees using internet for their work (1: 0%; 2: 1-20%; 3: 21-40%; 4: 41-60%; 5: 61-80%; 6: 81-100%; category 1 is used as reference category). A formal expression of this second specification is as follows:

$$LQL_{it} = \alpha_0 + \alpha_1 LNICT_{it} + \alpha_2 LICT_{it} + \alpha_3 LRDL_{it} + \alpha_4 LHC_{it} + \alpha_5 LEMPL_{it} + \alpha_6 IPC_{it} + \alpha_7 INPC_{it} + \alpha_8 FOREIGN_{it} + \alpha_9 STRUCT_{it} + \beta_{10} INTER2_{it} + \beta_{11} INTER3_{it} + \beta_{12} INTER4_{it} + \beta_{13} INTER5_{it} + \beta_{14} INTER6_{it} + industry\ and\ time\ dummies + e_{it} \quad (2)$$

In a third and fourth step, we investigated the effects of *IT systems for business processes* (dummy variables for enterprise resource planning, ERP, customer relationship management, CRM, and supply chain management, SCM) and *the use of open source operating systems* (OPEN), *social media* (SOCIAL), *instant messaging* (INSTANT), *online collaboration* (COLL), *cloud based technologies* (CLOUD), and *voice over IP* (VOIP). These specifications can be formulated as follows:

$$LQL_{it} = \alpha_0 + \alpha_1 LNICT_{it} + \alpha_2 LICT_{it} + \alpha_3 LRDL_{it} + \alpha_4 LHC_{it} + \alpha_5 LEMPL_{it} + \alpha_6 IPC_{it} + \alpha_7 INPC_{it} + \alpha_8 FOREIGN_{it} + \alpha_9 STRUCT_{it} + \beta_{10} ERP_{it} + \beta_{11} CRM_{it} + \beta_{12} SCM_{it} + \textit{industry and time dummies} + e_{it} \quad (3)$$

$$LQL_{it} = \alpha_0 + \alpha_1 LNICT_{it} + \alpha_2 LICT_{it} + \alpha_3 LRDL_{it} + \alpha_4 LHC_{it} + \alpha_5 LEMPL_{it} + \alpha_6 IPC_{it} + \alpha_7 INPC_{it} + \alpha_8 FOREIGN_{it} + \alpha_9 STRUCT_{it} + \beta_{10} OPEN_{it} + \beta_{11} SOCIAL_{it} + \beta_{12} INSTANT_{it} + \beta_{13} COLL_{it} + \beta_{14} CLOUD_{it} + \beta_{15} VOIP_{it} + \textit{industry and time dummies} + e_{it} \quad (4)$$

We expect positive and significant elasticities for ICT investment, non-ICT investment, R&D expenditures, human capital, and internet use, and software for business processes. Concerning modern communication technologies (open source, social media etc.), firm size, foreign ownership, competition, and structural change, the effect on labour productivity is not clear a priori.

Finally, we estimated an alternative specification, namely

$$LQL_{it} = \alpha_0 + \alpha_1 LCL_{it} + \alpha_2 LICT\_SHARE_{it} + \alpha_3 LRDL_{it} + \alpha_4 LHC_{it} + \alpha_5 LEMPL_{it} + \alpha_6 IPC_{it} + \alpha_7 INPC_{it} + \alpha_8 FOREIGN_{it} + \alpha_9 STRUCT_{it} \quad (5)$$

where LCL is gross investment per employee comprising both ICT and non-ICT investments and LICT_SHARE is the share of ICT investments on total investments.

4.2 Data

The data used in this study draws on the same survey as the data used in section 3. However, we can only use three cross-sections, namely from 2005, 2008, and 2011 as the share of ICT investments is only available from 2005 onwards.[8] For the examination of modern communication methods (open source, social media etc.), we can only use one cross-section from 2011. The three cross-sections include 7'056 observations from all fields of activity and size classes.

4.3 Method

We do not assume a concrete functional form for the production function underlying the productivity equation we estimate because our data would not allow an identification of this functional form. Instead, we use a linear logarithmic specification as in section 3.

We also estimate the equations separately for manufacturing and services. We again focus on results from GLS random effects regressions. For the examination of modern communication methods (open source, social media etc.), we can only use one cross-section and, therefore, have to use OLS.

[8] See section 3.2 for a description of the survey.

In order to avoid problems of endogeneity of ICT investments in case they are contemporaneous to the dependent variable we test for exogeneity of them. The first stage for LICT includes the two dummies EBUY and ESELL as instruments indicating whether a firm purchases or sell products and services online and one dummy OBSTACLE_FUNDS as instrument indicating whether a firm perceives a lack of internal and external funds as impediment to innovation. These instruments fulfil the conditions formulated by Wooldridge at least for the manufacturing sector.[9] However, the residuals from the first stage regression were statistically insignificant after including them in the LQL equations (see table A.4.3). Hence, we cannot reject the hypothesis that ICT investments are exogenous.

Estimating the productivity equations with lagged right-hand variables for ICT investments, non-ICT investments and R&D expenditures, the dataset for manufacturing is reduced from 2037 to 938 observations, but the results stay qualitatively similar to those without lagged variables.

4.4 Results

The effect of ICT investment

The results from estimating the productivity equation for manufacturing and services can be seen from Table 4.2 and 4.3. As ICT and non-ICT investments are multicollinear (correlation of 0.69), we firstly examine the effects of ICT investments and non-ICT investments separately (first and second column of table 4.2 and 4.3). For manufacturing, we find the expected positively significant elasticities for both ICT and non-ICT investments.

Putting both variables into the equation at the same time, the effect of ICT investments becomes insignificant. This supports the notion that multicollinearity imposes problems as the effects cannot be attributed to the variables in a distinguishable way.

For the services sector, there is a significantly positive elasticity only for ICT investments in either specification. This difference between manufacturing and services might indicate that ICT investments are more important in the services sector compared to the manufacturing sector where investments in machines and equipment might be more important.

In the last column of table 4.2 and 4.3, we estimate our alternative model with gross investments and the share of ICT investments. In fact, LICT_SHARE has only a positively significant effect for services, whereas the elasticity of gross investments is positively significant for both sectors. This result supports the notion above that investments in machines and equipment might be a more important driver of labour productivity in manufacturing compared to ICT investments.

[9] See footnote 5 in section 3.

As expected, there is a significantly positive elasticity for the share of employees with tertiary degree in both manufacturing and services. For manufacturing, a significantly positive elasticity can also be found for R&D intensity. Non-price competition exerts a significantly positive impact in both sectors. Firm size only has a weakly significant elasticity for the baseline specification for manufacturing. For other controlling factors as structural changes and price competition we do not find any evidence of an impact on labour productivity (except for IPC in the last column for services) .

The effect of internet use intensity

The use of internet has a significantly positive effect on labour productivity only for higher user rates (for user rates > 40%) and for firms in the manufacturing sector. The effect of a user rate between 41 and 60% (INTER4) and between 61 and 80% (INTER5) is significant on the 5% significance level. The effect of internet users with a rate of larger than 80% (INTER6) is even significant on the 1% significance level and the magnitude of the coefficient is much larger than for user rates below 80%. An additional test of equality of coefficients of user shares higher than 40% (i.e. INTER4, INTER5, and INTER6) shows that the hypothesis that coefficients are equal can be rejected on the 0.1% significance level. Interestingly, such effects cannot be found in the services sector.

The effect of IT infrastructure

We were also interested in the effect of IT infrastructure within a firm. In particular, we studied the effect of IT systems for different business processes, i.e. of customer relationship management systems (CRM), enterprise resource planning systems (ERP), and supply chain management systems (SCM). The use of CRM has a significantly positive effect for both manufacturing and services firms. ERP only has a significantly positive effect for manufacturing. We do not find empirical evidence of an effect of SCM on labour productivity. A positive effect of ERP in the manufacturing sector clearly indicates the need to have a IT system for steering of the whole production process in manufacturing. It points to the importance of coordination of different automated tasks in a production line that is not needed in services.

The effect of tools of communication and data exchange

Adding dummies for different modern computer-based methods and tools for communication and data exchange (OPEN, SOCIAL, INSTANT, COLL, CLOUD, VOIP), we only find weak evidence of an effect of cloud computing on labour productivity in the manufacturing and of instant messaging in the services sector. We therefore do not find any evidence of an impact of external interconnectedness via social media and open source software on labour productivity. The impact of cloud computing might point to positive effects of more efficient data storage and data exchange. The impact of instant messaging might refer to a positive effect of more efficient forms of communication within a firm.

Table 4.1: Definition of model variables

Variables	Definition
LQL	Value added (sales minus intermediate inputs) per employee; natural logarithm
LNICT	Non-ICT investment per employee; natural logarithm
LICT	ICT investment per employee; natural logarithm
LCL	Gross investment per employee
LICT_SHARE	Share of ICT investments in gross investment; natural logarithm
LHC	Share of employees with tertiary-level education; natural logarithm
LRDL	R&D expenditures per employee; natural logarithm
LEMPL	Number of employees in full-time equivalents; natural logarithm
IPC	Intensity of price competition; dummy variable: value 1 for the levels 4 and 5 of the original 5-point ordinal variable (1: 'very low'; 5: 'very high'); else value 0
INPC	Intensity of non-price competition (quality; technical advance, etc.); dummy variable: value 1 for the levels 4 and 5 of the original 5-point ordinal variable (1: 'very low'; 5: 'very high'); else value 0
FOREIGN	Foreign-owned firm; dummy variable
STRUCT	Structural change dummy (1: Takeover of other companies or merger with another company; 0: no takeover or merger)
INTER	Share of employees using internet for their work; five dummies for five categories (1: 0%; 2: 1-20%; 3: 21-40%; 4: 41-60%; 5: 61-80%; 6: 81-100%) (reference category: 0%)
ERP	1: Firm uses an enterprise resource planning system; 0: else
CRM	1: Firm uses a customer relationship management system; 0: else
SCM	1: Firm uses a supply chain management system; 0: else
OPEN	1: Firm uses open source operating systems; 0: else
SOCIAL	1: Firm uses social media; 0: else
INSTANT	1: Firm uses instant messaging; 0: else
COLL	1: Firm uses online collaboration tools; 0: else
CLOUD	1: Firm uses cloud based tools; 0: else
VOIP	1: Firm uses Voice over IP or Video over IP; 0: else

Industry controls	Manufacturing: dummy variables for 17 2-digit industries (reference industry: energy); services: dummy variables for 8 2-digit industries (reference: entertainment, culture, sports)
Year controls	Reference year: 2005
OBSTACLE_FUNDS	Lack of equity and debt as impediment of innovation; dummy variable: value 1 for the levels 4 and 5 of the original 5-point ordinal variable (1: 'not important'; 5: 'very important); else value 0
EBUY	1: Firm purchases products and services online; 0: else
ESELL	1: Firm sells products and services online; 0: else

Table 4.2: Random effects GLS / OLS estimates of average labour productivity LQL; manufacturing

Variables	LQL	LQL	LQL	LQL	LQL	LQL	LQL
LNICT	0.030***		0.032***	0.035***	0.032***	0.028**	
	(0.01)		(0.01)	(0.01)	(0.01)	(0.01)	
LICT		0.016***	-0.002	-0.005	-0.002	-0.008	
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
LCL							0.046***
							(0.01)
LICT_SHARE							-0.008
							(0.01)
LRDL	0.007***	0.007***	0.007***	0.006**	0.007***	0.008*	0.007***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
LHC	0.058***	0.055***	0.058***	0.041***	0.054***	0.081***	0.059***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
LEMPL	0.019*	0.023**	0.019*	0.016	0.011	0.015	0.016
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
IPC	-0.015	-0.012	-0.015	-0.005	-0.016	-0.004	-0.013
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)
INPC	0.036**	0.038**	0.036**	0.036**	0.033**	0.038	0.032**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
FOREIGN	0.158***	0.153***	0.158***	0.142***	0.155***	0.169***	0.158***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)
STRUCT	0.028	0.027	0.029	0.026	0.024	0.028	0.027
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)
INTER2				0.021			
				(0.05)			
INTER3				0.078			
				(0.05)			
INTER4				0.106**			
				(0.05)			
INTER5				0.176***			
				(0.05)			
INTER6				0.259***			
				(0.06)			
ERP					0.041**		
					(0.02)		
CRM					0.054***		
					(0.02)		
SCM					-0.005		
					(0.02)		
OPEN						-0.022	
						(0.02)	
SOCIAL						0.009	
						(0.02)	
INSTANT						-0.016	

						(0.02)	
COLL						0.016	
						(0.02)	
CLOUD						0.031*	
						(0.02)	
VOIP						0.004	
						(0.01)	
Industry controls	YES	YES	YES	YES	YES	YES	YES
Year controls	YES	YES	YES	YES	YES	YES	YES
Const.	11.879***	12.072***	11.880***	11.794***	11.874***	11.923***	11.714***
	(0.11)	(0.09)	(0.11)	(0.12)	(0.11)	(0.17)	(0.14)
N	2307	2311	2307	2305	2304	680	2259
R2						0.285	
R2 overall	0.245	0.235	0.245	0.271	0.251		0.243
R2 within	0.021	0.015	0.022	0.031	0.026		0.023
R2 between	0.277	0.268	0.277	0.303	0.284		0.274
F						7.090	
Wald chi2	492.717	483.258	492.972	559.471	518.055		472.069
Sigma_u	0.291	0.293	0.291	0.283	0.289		0.29
Sigma_e	0.259	0.26	0.259	0.259	0.259		0.258
Rho	0.557	0.56	0.558	0.545	0.554		0.56

* p<0.1, ** p<0.05, *** p<0.01

Table 4.2: Random effects GLS / OLS estimates of average labour productivity LQL; services

Variables	LQL	LQL	LQL	LQL	LQL	LQL	LQL
LNICT	0.006		-0.008	-0.004	-0.006	-0.003	
	(0.01)		(0.01)	(0.01)	(0.01)	(0.01)	
LICT		0.021***	0.025***	0.022***	0.022***	0.032***	
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
LCL							0.050***
							(0.01)
LICT_SHARE							0.033***
							(0.01)
LRDL	0.003	0.003	0.003	0.002	0.000	0.000	0.003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
LHC	0.065***	0.061***	0.062***	0.055***	0.063***	0.125***	0.058***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.03)	(0.02)
LEMPL	0.005	0.005	0.004	0.008	-0.005	0.030*	0.004
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
IPC	-0.034	-0.030	-0.033	-0.037	-0.028	-0.116**	-0.036
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.03)
INPC	0.046**	0.050**	0.047**	0.047**	0.045**	0.110***	0.047**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)
FOREIGN	0.130***	0.134***	0.127***	0.119***	0.120***	0.081	0.142***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.05)	(0.04)
STRUCT	0.022	0.018	0.019	0.018	0.018	-0.064	0.011
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)
INTER2				-0.135			
				(0.10)			
INTER3				-0.125			
				(0.11)			
INTER4				-0.112			
				(0.11)			
INTER5				-0.035			
				(0.11)			
INTER6				-0.027			
				(0.11)			
ERP					0.011		
					(0.03)		
CRM					0.090***		
					(0.03)		
SCM					0.032		
					(0.04)		
OPEN						-0.002	
						(0.03)	
SOCIAL						0.004	
						(0.01)	
INSTANT						0.039*	

						(0.02)	
COLL						-0.002	
						(0.02)	
CLOUD						-0.001	
						(0.02)	
VOIP						0.027	
						(0.02)	
Industry controls	YES	YES	YES	YES	YES	YES	YES
Year controls	YES	YES	YES	YES	YES	YES	YES
Const.	11.066***	10.977***	11.022***	11.091***	10.984***	10.527***	10.616***
	(0.16)	(0.17)	(0.16)	(0.18)	(0.15)	(0.26)	(0.22)
N	1594	1598	1594	1592	1591	502	1547
R2						0.438	
R2 overall	0.359	0.367	0.366	0.374	0.380		0.384
R2 within	0.015	0.015	0.017	0.023	0.017		0.02
R2 between	0.384	0.391	0.392	0.399	0.409		0.409
F						17.004	
Wald chi2	806.569	840.035	845.863	861.095	906.154		831.477
Sigma_u	0.333	0.332	0.33	0.328	0.323		0.322
Sigma_e	0.299	0.299	0.299	0.299	0.296		0.299
Rho	0.553	0.552	0.549	0.546	0.544		0.536

* p<0.1, ** p<0.05, *** p<0.01

APPENDIX TO CHAPTER 4:

Table A.4.1a: Descriptive statistics; manufacturing

Variables	N	Average	Standard Deviation
LQL	8706	11.827	0.426
LNICT	3385	8.693	1.866
LICT	3390	6.585	1.901
LRDL	5883	4.513	4.212
LHC	8625	2.510	1.043
LEMPL	8701	4.100	1.430
IPC	5729	0.718	0.450
NIPC	5356	0.377	0.485
FOREIGN	6678	0.153	0.360
STRUCT	3149	0.339	0.473
INTER			
1-20%	6204	0.397	0.489
21-40%	6204	0.243	0.429
41-60%	6204	0.154	0.361
61-80%	6204	0.096	0.294
81-100%	6204	0.069	0.254
ERP	3385	0.593	0.491
SCM	3385	0.136	0.342
CRM	3385	0.323	0.468
OPEN	504	0.315	0.654
SOCIAL	512	0.459	1.103
INSTANT	518	0.654	1.038
COLL	507	0.434	0.912
CLOUD	502	0.301	0.917
VOIP	512	0.625	1.114

Table A.4.1b: Descriptive statistics; services

Variables	N	Average	Standard Deviation
LQL	6680	11.911	0.527
LNICT	2680	8.141	2.242
LICT	2687	6.656	2.181
LRDL	4507	1.581	3.177
LHC	6609	2.524	1.307
LEMPL	6679	3.801	1.595
IPC	4046	0.673	0.469
NIPC	4007	0.408	0.492
FOREIGN	5338	0.136	0.343
STRUCT	2260	0.375	0.484
INTER			
1-20%	5051	0.313	0.464
21-40%	5051	0.146	0.353
41-60%	5051	0.119	0.324
61-80%	5051	0.090	0.287
81-100%	5051	0.272	0.445
ERP	2688	0.380	0.485
SCM	2688	0.107	0.309
CRM	2688	0.323	0.468
OPEN	406	0.352	0.668
SOCIAL	409	0.929	1.476
INSTANT	412	0.471	0.908
COLL	413	0.496	0.984
CLOUD	402	0.284	0.879
VOIP	410	0.624	1.088

Table A.4.2a: Correlation matrix; manufacturing

	LQL	LNICT	LICT	LRDL	LHC	LEMPL	IPC	NIPC	FO-REIGN	STRUCT	ERP	SCM	CRM	OPEN	SOCIAL	IN-STANT	COLL	CLOUD	VOIP
LQL	1.000																		
LNICT	0.284	1.000																	
LICT	0.245	0.685	1.000																
LRDL	0.163	0.072	0.131	1.000															
LHC	0.242	0.041	0.136	0.318	1.000														
LEMPL	0.184	0.162	0.110	0.253	0.273	1.000													
IPC	-0.071	-0.045	-0.094	0.063	-0.033	0.062	1.000												
NIPC	0.098	0.108	0.103	0.125	0.121	0.052	-0.092	1.000											
FOREIGN	0.183	-0.034	-0.072	0.050	0.085	0.110	0.011	-0.036	1.000										
STRUCT	0.082	-0.003	0.066	0.138	0.105	0.275	-0.031	-0.077	0.073	1.000									
ERP	0.119	0.057	0.151	0.255	0.245	0.274	0.007	0.048	0.098	0.183	1.000								
SCM	0.135	0.070	0.066	0.263	0.237	0.355	-0.057	-0.018	-0.018	0.133	0.241	1.000							
CRM	0.160	0.067	0.096	0.196	0.188	0.240	-0.010	-0.050	0.030	0.075	0.305	0.391	1.000						
OPEN	0.028	0.077	0.121	0.089	0.212	0.173	0.048	0.106	-0.050	0.067	0.051	0.067	0.006	1.000					
SOCIAL	-0.002	0.052	0.108	0.046	0.019	0.095	0.059	0.111	-0.033	0.067	0.085	0.136	0.057	0.103	1.000				
INSTANT	0.000	0.026	0.020	0.167	0.197	0.179	0.021	0.036	0.041	0.020	0.120	0.113	-0.067	0.059	0.106	1.000			
COLL	0.136	0.002	0.004	0.104	0.195	0.299	-0.006	0.007	0.057	0.073	0.177	0.171	-0.004	0.151	0.089	0.282	1.000		
CLOUD	0.103	-0.010	0.072	0.078	0.015	0.167	0.031	0.013	-0.009	0.073	0.104	0.058	0.146	0.126	0.135	0.039	0.056	1.000	
VOIP	0.086	-0.010	0.031	0.115	0.160	0.205	0.052	0.067	0.073	0.072	0.118	0.175	0.080	0.138	0.180	0.180	0.155	0.196	1.000

Table A.4.2b: Correlation matrix ; services

	LQL	LNICT	LICT	LRDL	LHC	LEMPL	IPC	NIPC	FO-REIGN	STRUCT	ERP	SCM	CRM	OPEN	SOCIAL	IN-STANT	COLL	CLOUD	VOIP
LQL	1.000																		
LNICT	0.036	1.000																	
LICT	0.374	0.388	1.000																
LRDL	0.210	0.079	0.255	1.000															
LHC	0.364	-0.192	0.280	0.297	1.000														
LEMPL	0.121	0.158	0.196	0.127	0.038	1.000													
IPC	0.020	-0.081	0.017	-0.011	0.158	0.051	1.000												
NIPC	0.128	0.093	0.079	0.102	0.077	0.126	0.038	1.000											
FOREIGN	0.122	-0.117	-0.031	0.138	0.060	0.082	0.088	0.098	1.000										
STRUCT	0.057	0.104	0.105	0.072	0.126	0.325	0.042	0.072	0.110	1.000									
ERP	0.077	0.011	0.109	0.199	0.144	0.427	0.034	0.135	0.201	0.137	1.000								
SCM	0.139	0.062	0.143	0.068	0.022	0.260	-0.038	0.198	0.088	0.134	0.413	1.000							
CRM	0.256	0.029	0.180	0.242	0.197	0.278	0.053	0.264	0.122	0.087	0.425	0.405	1.000						
OPEN	0.105	-0.071	0.048	0.138	0.065	0.176	-0.005	-0.016	0.076	-0.013	0.264	0.093	0.204	1.000					
SOCIAL	-0.054	0.047	-0.067	0.038	-0.027	0.198	0.037	0.028	0.066	0.057	0.102	0.021	0.067	0.040	1.000				
INSTANT	-0.056	-0.064	-0.057	0.132	0.018	0.106	0.052	0.010	0.002	0.012	0.145	0.063	0.089	0.160	0.224	1.000			
COLL	0.125	0.027	0.131	0.213	0.162	0.221	-0.059	0.024	0.085	0.135	0.262	0.132	0.195	0.193	0.076	0.093	1.000		
CLOUD	0.082	-0.002	0.040	0.155	0.106	0.178	-0.053	0.051	0.190	0.078	0.133	0.139	0.114	0.148	0.116	0.135	0.199	1.000	
VOIP	0.219	0.061	0.125	0.156	0.163	0.291	0.122	0.120	0.158	0.172	0.130	0.070	0.200	0.161	0.100	0.197	0.232	0.186	1.000

Table A.4.3: Endogeneity test for LICT (Rivers and Vuong 1988) ;

	LICT Instrument equation	LQL Bootstrapped (100 replications)	LICT Instrument equation	LQL Bootstrapped (100 replications)
	manufacturing		services	
OBSTACLE_FUNDS	-0.196***		-0.134	
	(0.071)		(0.109)	
EBUY	0.169***		0.135	
	(0.059)		(0.083)	
ESELL	0.189**		0.148*	
	(0.077)		(0.088)	
LNICT	0.657***	-0.025	0.561***	-0.103
	(0.026)	(0.054)	(0.035)	(0.077)
LICT		0.083		0.194
		(0.079)		(0.136)
RES_LICT		-0.086		-0.171
		(0.081)		(0.135)
LRDL	0.023***	0.005	0.016	-0.002
	(0.009)	(0.004)	(0.013)	(0.006)
LHC	0.175***	0.043***	0.182***	0.036
	(0.043)	(0.016)	(0.053)	(0.028)
LEMPL	0.013	0.017	0.04	-0.003
	(0.029)	(0.011)	(0.035)	(0.011)
IPC	-0.033	-0.011	-0.06	-0.019
	(0.066)	(0.020)	(0.093)	(0.031)
INPC	-0.081	0.043**	-0.025	0.054**
	(0.058)	(0.022)	(0.084)	(0.027)
FOREIGN	-0.022	0.159***	0.136	0.102**
	(0.080)	(0.031)	(0.120)	(0.052)
STRUCT	0.102	0.019	0.127	-0.003
	(0.066)	(0.023)	(0.087)	(0.031)
Industry controls	YES	YES	YES	YES
Year controls	YES	YES	YES	YES
Const.	-0.01	11.882***	1.592***	10.733***
	(0.359)	(0.099)	(0.420)	(0.274)
N	2305	2305	1589	1589
R2 overall	0.445	0.245	0.418	0.369
R2 within	0.378	0.023	0.338	0.024
R2 between	0.468	0.276	0.446	0.391
Wald chi2	1132.545	1145.087	745.631	1551.921
Sigma_u	0.82	0.291	0.955	0.332
Sigma_e	1.025	0.259	1.27	0.295
Rho	0.39	0.558	0.361	0.558

* p<0.10, ** p<0.05, *** p<0.01

5. Start-ups in Switzerland

Many studies find evidence for the importance of start-ups. The idea is that start-ups positively impact economic growth and development (see e.g., Audretsch et al., 2006; Gries and Naudé, 2008). This is especially true for knowledge-intensive start-ups. They contribute to growth in two ways, first, *directly* through the development of fundamentally new problem solutions. R&D in established firms is much more restricted to less risky projects that are in line with the main strategic directions of the firms, so that new technological solutions are not their main goal. Second, start-ups contribute *indirectly* to growth as they increase competition and thus force established firms to keep high their level of innovation activities or even increase it (see Aghion et al., 2009).

In the following we describe the state of start-up activities in Switzerland on the basis of publically available data in a first step. In a second step, we present the results of studies dealing with the development of a cohort of Swiss "greenfield" start-ups which we observed during ten years after their foundation. The studies refer (a) to the financial restrictions start-ups are confronted with and (b) the factors (including characteristics of the founding persons) that determine the innovativeness of start-ups and thus the possibility that new firms contribute to economic growth.

5.1 Descriptive statistics: What do we know about start-ups in Switzerland?

An international comparison of the rate of new entrepreneurial activity measured by the share of adult population that owns a new firm shows that Switzerland has one of the largest rates of new businesses among the eleven countries in our sample (see table 5.1). The figure with respect to survival probability (column 2 in table 5.1) is even more impressive. Switzerland has the highest rate of established business ownership among all eleven countries.

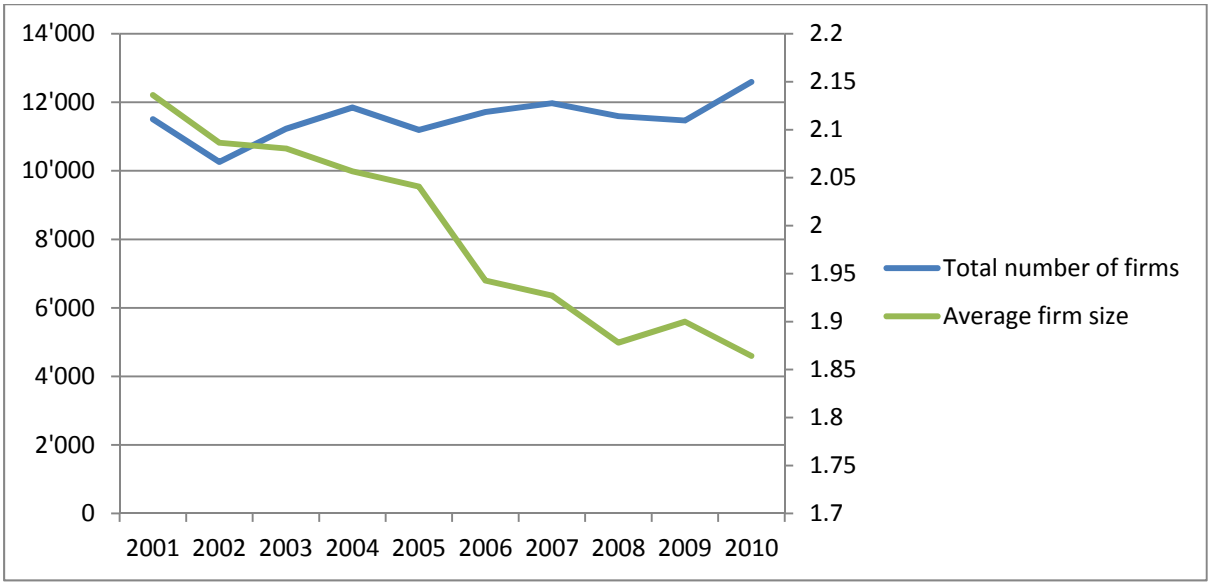
Table 5.1: Entrepreneurial activity by country, 2011
(Percentage of adult population between 18-64 years)

Country	New business ownership rate (running business for more than three months, but not more than 42 months)	Established business ownership rate (running business for more than 42 months)
Switzerland	2.9	10.1
Germany	2.4	5.6
France	1.7	2.4
Great	2.6	7.2
Netherlands	4.1	8.7
Sweden	2.3	7.0
Finland	3.3	8.8
Denmark	1.6	4.9
Ireland	3.1	8.0
Japan	2.0	8.3
USA	4.3	9.1

Source: GEM (2012).

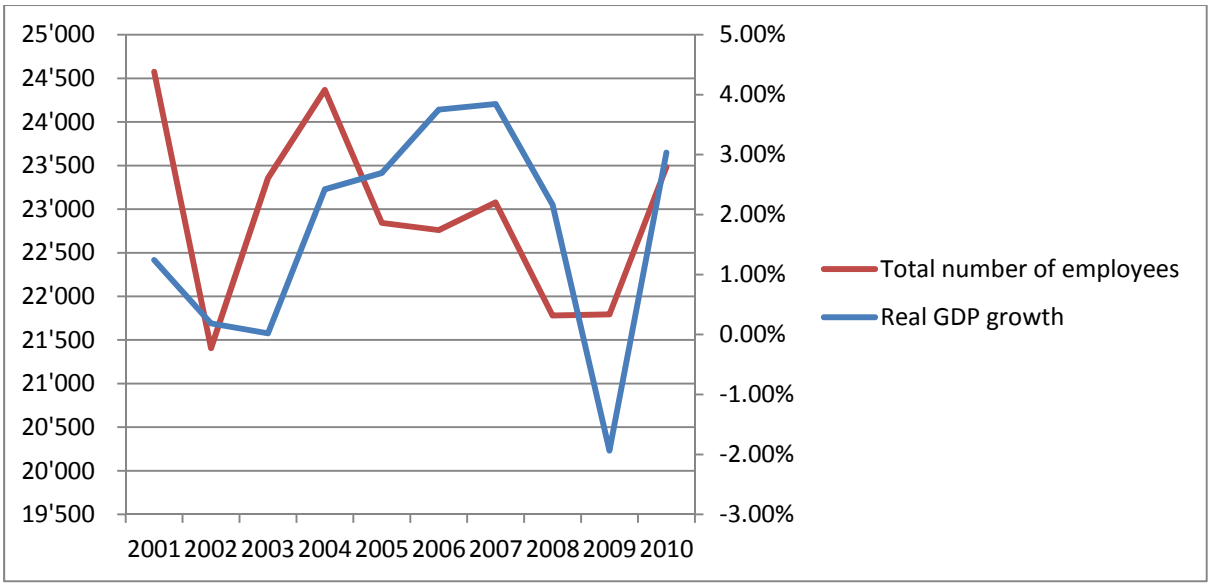
Figure 5.1 presents the development of entrepreneurial activity for Switzerland over time. The figure shows that the total number of new firms ("greenfield" new firms) has slightly increased in the period 2001-2010. At the same time, the average number of employees decreased. In 2010, 12'596 new firms with an average firm size of 1.9 employees were founded in Switzerland. The total number of employees that is engaged in these start-ups is strongly related to the general economic development of the country (see figure 5.2). In the period 2001-2010, the start-ups engaged about 23'000 employees per year on average.

Figure 5.1: Number of firms and average firm size over time



Source: SFSO (2012b).

Figure 5.2: Total number of employees and economic development



Source: SFSO (2012b).

Table 5.2 presents the number of start-ups by sector and industry. The distribution among sectors remained almost constant over time. Most of the start-ups are firms in the service sector. They represent about 83% of the start-ups. About 11% belong to the construction sector, the remaining 6% to the manufacturing sector. In the service sector the sub-sector of knowledge-intensive service industries (e.g., banking and insurance, information technology, telecommunication, engineering) has a share of about 40%. In the manufacturing sector, about 30% of the start-ups belong to high-tech manufacturing (e.g., chemicals, machinery, electronics/instruments). The share of high-tech remained quite stable over time. The share of knowledge-intensive service industries slightly decreased between 2001 and 2005 primarily due to the decrease of start-ups in the software industry. Furthermore, in each period about 95% of the start-ups employed less than five employees (measured in full-time equivalents).

In sum, only a small share of the start-ups belong to knowledge-intensive industries. As a consequence only a relatively small number of the new firms has a high potential for stimulating general innovation activities and growth.

Table 5.2: Swiss start-ups by industry and firm size

Year	2001	2005	2010
Industry/sector			
Manufacturing/energy	7.0%	7.1%	4.9%
- Chemicals, pharmaceuticals	5.1%	5.2%	5.6%
- Electrical machinery, electronics	10.5%	12.7%	7.4%
- Machinery, vehicles	14.4%	14.7%	17.5%
- Total high-tech manufacturing	30.0%	32.5%	30.5%
Construction	10.5%	11.4%	11.2%
Services	82.6%	81.5%	83.8%
- Publishing, media	1.4%	1.9%	1.2%
- Telecommunication	0.2%	0.2%	0.2%
- Information technology/services	14.0%	8.6%	8.9%
- Banks, insurance	4.1%	5.1%	6.9%
- Legal/tax advice, auditing	5.0%	4.5%	3.6%
- Business administration/consultancy	11.0%	10.1%	10.1%
- Technical commercial services	8.8%	7.0%	7.3%
- Advertising, market research	2.1%	1.8%	1.7%
- Total modern services	46.5%	39.3%	39.9%
Firm size (number of employees)			
less than 5	95%	96%	97%
5-10	4%	4%	3%
more than 10	1%	1%	1%

Source: SFSO (2012b).

5.2 Empirical evidence for Switzerland: Financial constraints and innovativeness

5.2.1 Dataset

Based on information about "greenfield" start-ups that was collected by the Swiss Federal Statistical Office, the KOF Swiss Economic Institute constructed a unique survey data set. The population used for this data refers to the cohort of all Swiss enterprises that were founded between 1996 and 1997. In the beginning the cohort included 7'112 firms. In 2000, we checked which firms of this cohort still existed. 3'288 (46.2%) of these start-ups were still in business in 2000. Among the firms that still existed by that time, data were collected by means of a postal survey. The questionnaire was answered by 49.4% (1625) of the firms. 1'339 (82.4%) of these firms survived over the next three years. In 2003 a follow-up survey was conducted among these firms. Answers were received from 70.6% (945) of the firms. In 2006, nine to ten years after firm foundation, 857 (90.7%) of the participants of the 2003 survey still existed. 73.5% (630) of them were willing to fill out a third questionnaire. For some firms we thus have data at different points in time.

The questionnaire covered questions about basic firm characteristics, firm success and activity level, resource endowment, innovative activities, the market environment and financial constraints.[10] In 2000, the questionnaire included some additional questions about the founder characteristics (e.g., gender, age, education, experience and the wealth of the firm founders). For detailed descriptive information on this data see Marmet (2004).

Based on this data, several studies were performed that either analyse the determinants of innovation activities or the economic performance of these firms. In the following we will present two of them. The first one focuses on the impact of financial constraints on firm success (Stucki, 2013). The second study deals with the impact of founder characteristics on innovation activities of the firms (see Arvanitis and Stucki, 2012).

5.2.2 The role of financial constraints for economic performance

A main topic in the literature dealing with start-up success is the impact of financial constraints. Financial constraints are often seen as an important reason for their failure. Accordingly, many studies deal with the question of how access to financial resources could be promoted (e.g., OECD 2004, 2005, World Bank 2004, 2006, European Commission 2007). However, to draw adequate policy implications, it is important to know whether firms need help only in their first years after their establishment or whether financial constraints are a persistent problem. While previous empirical studies provide some evidence that financial constraints do negatively affect the economic performance of start-ups during the first few years of existence, it is not well understood how the impact of financial constraints on

[10] The questionnaires are available in German, French and Italian at www.kof.ethz.ch/surveys/ structural/panel.

economic performance changes with increasing firm age. Based on the KOF cohort data, this question is analysed in Stucki (2013).

Estimation results indicate that financial constraints are not only a problem of the first years. While the negative impact of financial constraints on *firm survival* disappears with increasing age of the firms, *profits* are persistently negatively affected by financial constraints. Ten years after firm foundation, financially constrained firms still had problems to break even.

5.2.2 Innovation capability of firm founders

Most start-ups are not growth-drivers (Shane, 2009). Innovative start-ups and not start-ups in general are considered to be important drivers of innovation in existing industries (Aghion et al., 2009; Schumpeter, 1934) and also contribute to the creation of new industries (Acs and Audretsch, 1990). It is thus especially important for policy makers to be able to identify the innovative firms. However, only a few studies analyse how such firms look like. As activities of start-ups are strongly related to firm founders, Arvanitis and Stucki (2012) investigate this topic focusing on the innovation capability of firm founders. This study is, again, based on the data set for the start-up cohort 1996/97. One important feature of this data set is that it includes detailed information on the characteristics of up to three individual firm founders per firm. The richness of the data makes it possible to describe the characteristics of the whole founding team in detail.

Estimation results show that a combination of different founder characteristics such as university education (at best a combination of technical and commercial education), prior experience in R&D, and strong motivation to realize own innovative ideas increase innovative activities of start-ups by more than 40%. Hence, estimation results indicate that founder characteristics contain important information to identify innovative start-ups.

This finding show that the total entrepreneurial activity as measured by the number of new start-ups is not a good measure to describe the quality of founding activities and focusing on knowledge-intensive firms also yields a too optimistic picture. Firms with a high probability of growth perspectives have very specific characteristics. Accordingly, simply encouraging more people to become entrepreneurs does not seem to be the best policy for stimulating economic growth. As shown in Arvanitis and Stucki (2012), knowing the founder characteristics would help policy makers identify the innovative start-ups right from the beginning and thus increase efficiency of start-up subsidies, given that such a promotion policy is pursued.

6. Summary and Conclusions

Development of productivity 1990-2010

The most striking feature of Switzerland is that – as the only of the countries considered here – it experienced *negative productivity growth from 1990 to 1995*, both in MFP and labour productivity. This period was marked by a severe recession in the aftermath of a real estate bubble in Switzerland that burst in the late 80s. During the remainder of the period, productivity growth remained comparatively slow in Switzerland, albeit of positive sign in all sub-periods. Switzerland's productivity growth in the latest sub-period 2005-2010 *was not hit by the financial crisis* as badly as in other countries, especially when MFP is considered. Even after taking into consideration a recent study that showed that average labour productivity growth figures of the official statistics need *to be corrected upwards by about one percentage point*, the overall finding of *comparatively weak productivity growth* in Switzerland when compared to other OECD countries still holds.

On sectoral level, the contribution of the *financial sector* – both banking and insurance – to labour productivity growth in the 1990s appears to have been remarkable, both of these branches exhibiting more than 6% average productivity growth. This is, however, overshadowed by very low (insurance) and even negative (banking) growth in the subsequent decade. A more moderate, yet still substantial growth over the entire reference time period can be found in manufacturing (around 2.5%) and wholesale and retail trade (around 2%). In construction and the remaining branches belonging to the service sector, growth has been lower than on average (even negative in some instances) and more erratic.

For all three potential determinants of productivity that are considered in this study Switzerland shows on country level an above-average performance (R&D intensity, patents per capita, ICT investment as share of total gross investment).

Determinants of labour productivity on firm level 1995-2010: the role of innovation

In the estimates for both sectors the variables for physical capital and human capital show the expected positive sign; both elasticities are statistically significant and of the same magnitude in both sectors. The negative sign of the variable for the lack of qualified personnel indicates that personnel shortage might have been a hindrance for the improvement of labour productivity, primarily in manufacturing. In manufacturing, positive and statistically significant elasticities are found for R&D intensity and patent applications but not for the share of innovative products and process innovation. In the estimates for the service sector only the sales share of innovative products is positive and statistically significant. Separate estimates not presented here for the sales shares of *new* products and *significantly modified* products for both sectors did not bring out additional insights. However, firms with patent applications, an intermediate form of innovation output, seem to be more productive than firms without patent applications. Additional quantile regression estimates yield some

evidence that R&D intensity in manufacturing shows a significantly positive effect from Q30 upwards. The estimates indicate also an increase of the positive R&D intensity effect between Q50 and Q60, further between Q80 and Q90. The effect of the share of innovative products in the service sector seems to be concentrated to the high productivity quantiles (Q80).

There are differences between the two sectors with respect to the effects of market conditions productivity. For manufacturing, we find a negative effect for the number of competitors (NCOMP), that is a positive effect of market concentration (if we interpret the variable NCOMP as reverse to market concentration). High-productive firms are found in more concentrated markets. In the estimates for the service sector the respective variable shows also a negative sign but the respective coefficient is not statistically significant. Obviously, the concentration effect is less relevant for the service sector. Throughout the estimates for both sectors we find a positive effect of non-price competition and no significant effect for price competition. Thus, high-productive enterprise operate in concentrated markets with high non-price competition, in case of many Swiss SMEs these are “niches” for highly specialized high-tech products.

Finally, we find a positive non-linear effect for firm size and a positive effect for foreign-owned firms.

Determinants of labour productivity on firm level 2004-2010: the role of ICT

Due to high multicollinearity we examine the effects of ICT investments and non-ICT investments separately. For manufacturing, we find the expected significantly positive elasticities for both ICT and non-ICT investments. For the services sector, there is a significantly positive elasticity only for ICT investments. This difference between manufacturing and services might indicate that ICT investments are more important in the services sector compared to the manufacturing sector where investments in machines and equipment might be more important.

In an alternative specification based on the share of ICT investments, we find a significantly positive effect only for services, whereas the elasticity of gross investments is significantly positive for both sectors. This result supports the notion that investments in machines and equipment might be a more important driver of labour productivity in manufacturing compared to ICT investments.

The use of internet has a significantly positive effect on labour productivity only for higher user rates (for user rates > 40%) and for firms in the manufacturing sector. An additional test of equality of coefficients of user shares higher than 40% shows that the effect on productivity increases with increasing share of internet users. Interestingly, such effects cannot be found in the services sector.

Further, the use of CRM has a significantly positive effect for both manufacturing and services firms. ERP only has a significantly positive effect for manufacturing. We do not find empirical evidence of an effect of SCM on labour productivity. A positive effect of ERP in the manufacturing sector clearly indicates the need to have a IT system for steering of the whole production process in manufacturing. It points to the importance of coordination of different automated tasks in a production line that is not needed in services.

Finally, we tested the relevance for productivity of several modern computer-based methods and tools for communication and data exchange (OPEN, SOCIAL, INSTANT, COLL, CLOUD, VOIP). We find weak evidence only for an effect of cloud computing on labour productivity in the manufacturing and of instant messaging in the services sector. The impact of cloud computing might point to positive effects of more efficient data storage and data exchange. The impact of instant messaging might refer to a positive effect of more efficient forms of communication within a firm.

Start-ups in Switzerland

The total number of new firms ("greenfield" new firms) has slightly increased in the period 2001-2010. At the same time, the average number of employees decreased. In 2010, 12'596 new firms with an average firm size of 1.9 employees were founded in Switzerland. In the period 2001-2010, the start-ups engaged about 23'000 employees per year on average. Only a small share of the start-ups belong to knowledge-intensive industries. As a consequence only a relatively small number of the new firms have a high potential for stimulating general innovation activities and growth.

An international comparison of the rate of new entrepreneurial activity measured by the share of adult population that owns a new firm shows that Switzerland has one of the largest rates of new businesses among the eleven countries in our sample.

Econometric estimates based on data on a cohort of Swiss start-ups for the time period between foundation and maturity (i.e. during about 10 years) indicate that financial constraints are not only a problem of the first years. While the negative impact of financial constraints on *firm survival* disappears with increasing age of the firms, *profits* are persistently negatively affected by financial constraints. Ten years after firm foundation, financially constrained firms still had problems to break even.

Further estimation results show that a combination of different founder characteristics such as university education (at best a combination of technical and commercial education), prior experience in R&D, and strong motivation to realize own innovative ideas increase innovative activities of start-ups by more than 40%. Hence, estimation results indicate that founder characteristics contain important information to identify innovative start-ups.

References

Acs, Z.J., Audretsch, D. (1990). *Innovation and small firms*. London: The MIT Press.

Aghion, P., Blundell, R., Griffith, R., Howitt, P. and Prantl, S. (2009). The Effects of Entry on Incumbent Innovation and Productivity, *The Review of Economics and Statistics,* vol. 91(1), pages 20-32.

Arvanitis, S. (2005): Computerization, Workplace Organization, Skilled Labour and Firm Productivity: Evidence for the Swiss Business Sector, *Economics of Innovation and New Technology,* 14(4), 225-249.

Arvanitis, S. (2008a): Innovation and Labour Productivity in the Swiss Manufacturing Sector: An Analysis Based on Firm panel Data, in C. van Beers, A. Kleinknecht, R. Ortt and R. Verburg (eds.), *Determinants of Innovative Behaviour: A Firm's Internal Practices and Its External Environment*, Palgrave, London, pp. 188-216.

Arvanitis, S. (2008b): Determinanten der Innovationsneigung und Beitrag der Innovation zur Unternehmensleistung, *KOF Analysen*, 71 (Frühjahr), 71-84.

Arvanitis, S und J. von Arx (2004): Bestimmungsfaktoren der Innovationstätigkeit und Einfluss der Innovation auf Beschäftigung und Produktivität: Eine mikroökonometrische Untersuchung anhand von Unternehmenspaneldaten, *KOF-Arbeitspapiere/Working Papers Nr. 91*, Oktober, Zurich.

Arvanitis, S. and H. Hollenstein (2007): Determinants of Swiss Firms' R&D Activities at Foreign Locations: An Empirical Analysis Based on Firm-level Data, in G.R.G. Benito and H.R. Greve (eds.), *Progress in International Business Research*, Volume 1, Elsevier, Amsterdam, pp. 61-90.

Arvanitis, S. and H. Hollenstein (2011): How Do Different Drivers of R&D Investment in Foreign Locations Affect Domestic Firm Performance? An Analysis Based on Swiss Panel Micro data, *Industrial and Corporate Change*, 20(2), 605-640.

Arvanitis, S. and J.-E. Sturm (2008): Innovation and Labour Productivity Growth in Switzerland: An Analysis Based on Firm Level Data, in: OECD (ed.), *Productivity Measurement and Analysis,* Paris, pp. 101-112.

Arvanitis, S. and T. Stucki (2012): What Determines the Innovation Capability of Firm Founders?, *Industrial and Corporate Change*, 21(4), 1049–1084.

Audretsch, D.B., Keilbach, M.C. and Lehmann, E.E. (2006): *Entrepreneurship and Economic Growth*. Oxford University Press, Oxford.

European Commission (2007). Seed Finance for High-Growth SMEs Active in Eco-Innovation: Summary Report. European Commission, Brussels.

GEM (2012): Global Entrepreneurship Monitor: Key indicators, available at: www.gemconsortium.org/key-indicators (accessed January 2013).

Gries, T. and Naudé, W. (2008): Entrepreneurship and Regional Economic Growth: Towards A General Theory of Start-ups. *World Institute for Development Economic Research, Working Papers RP2008/70*.

Hall, B. H., Mairesse, J., Mohnen, P. (2009): Measuring the returns to R&D, *NBER Working Papers*, 15622, Cambridge MA

Hsiao, C. (2003): Analysis of Panel Data, Cambridge University Press, Cambridge.

Marmet, D. (2004): Growth of New Firms. Which Factors Influence Post-Entry Performance? An Empirical Analysis Based on Swiss Firm Data, KOF-Arbeitspapiere/Working Papers No. 97, December, Zurich.

OECD (2004). Financing Innovative SMEs in a Global Economy. OECD, Paris.

OECD (2005). OECD SME and Entrepreneurship Outlook: 2005 Edition. OECD, Paris.

Schumpeter, J.A. (1934). *The theory of economic development*, Cambridge: Harvard University.

SFSO (2011): Internationale Aspekte der Schweizer Forschung und Entwicklung 2008, *Swiss Federal Statistical Office*, Neuchâtel

SFSO (2012a): Öffentliche Finanzierung der Forschung in der Schweiz 2000-2010, *Swiss Federal Statistical Office*, Neuchâtel

SFSO (2012b): Unternehmensdemografie: Neugründungen, *Swiss Federal Statistical Office*, Neuchâtel, available at: www.bfs.admin.ch/bfs/portal/de/index/themen/06/02/blank/key/02/ueberlebensraten.html (accessed January 2013).

Shane, S. (2009). Why encouraging more people to become entrepreneurs is bad public policy, *Small Business Economics*, Springer, vol. 33(2), pages 141-49.

Siegenthaler, M. (2012): A view on the long-run evolution of hours worked and labor productivity in Switzerland (1950–2010), *KOF Working Papers*, 300

Stucki (2013): Success of Start-up Firms: The Role of Financial Constraints, *Industrial and Corporate Change*, forthcoming.

Wooldrige, J.M. (2002): Econometric Analysis of Cross Section and Panel Data, The MIT Press Cambridge, Mass.

World Bank (2004). *World Development Report: A Better Investment Climate for Everyone*. World Bank, Washington DC, Oxford University Press.

World Bank (2006). *Expanding Access to Finance: Good Practices and Policies for Micro, Small, and Medium Enterprises*. World Bank, Washington DC.