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Vocational education and productivity in the Swiss business sector: An analysis based on firm-level and industry-level panel data

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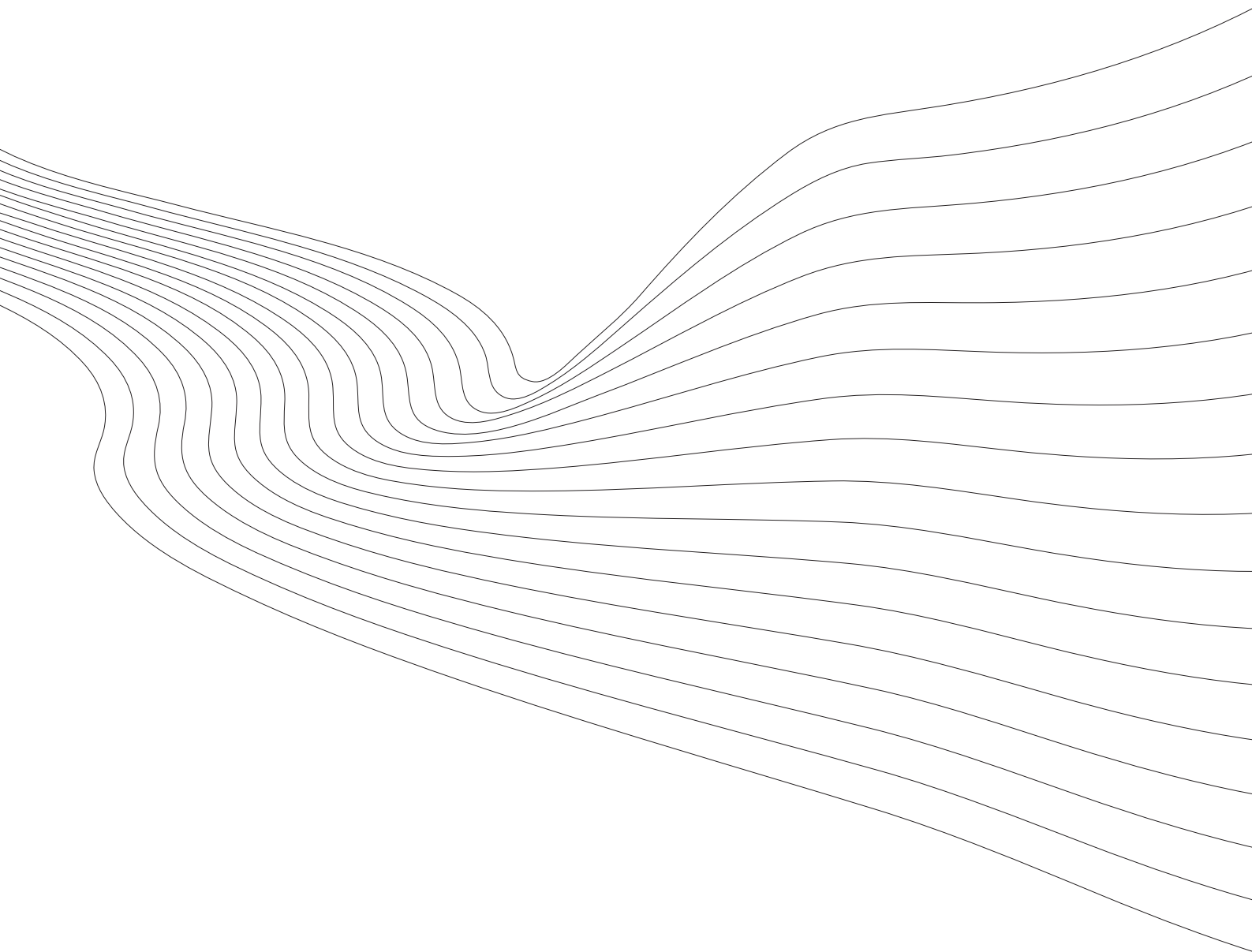
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Vocational Education and Productivity in the Swiss Business Sector –

An Analysis Based on Firm-level and Industry-level Panel Data

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Vocational Education and Productivity in the Swiss Business Sector – An Analysis Based on Firm-level and Industry-level Panel Data*

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Summary

In this study we investigate the effects of three categories of employees with different levels of formal education (upper secondary level (“Berufslehre”); tertiary level other than academic university (“Fachhochschulen”, etc.); and academic university level) on average labour productivity in an “augmented production function” framework (a) at *firm* level for the period 1994-2005 and (b) at *industry* level for the period 1991-2005.

Throughout our firm-level estimations we find a significant positive effect for the share of employees with academic education on labour productivity at the firm level. A significant positive effect is also found for the share of the employees of employees with tertiary education (without academic university) for all firms but this effect can be traced back primarily to manufacturing firms.

Less clear is the situation for “middle-educated” employees that build in most firms the largest part of employees. In the estimates with lagged right-hand variables (our preferred version) we find no significant effect of the share of this important category of employees on productivity. We obtain a significant positive effect only in the estimates for all firms without lags. Quantile regressions reveal that there are discernible differences between low-productivity and high-productivity firms with respect to the contribution of this employee category to productivity; these differences seem to be quite sector-specific.

At industry level we obtain a somewhat more positive picture with respect to the contribution of the share of middle-educated employees (who are measured at exactly the same way as firm level; referenced group is also in this case is the group of employees without formal vocational education) to productivity. The coefficient of the respective variable is significantly positive. A possible explanation for this positive effect could be that our sample of industries contains relatively few service industries as compared to manufacturing industries (56 out of totally 73 industries are manufacturing industries).

Key words: medium-educated employees; high-educated employees; competition; R&D; average labour productivity

JEL-Classification: J2; L1; O3

1. Introduction

Firm-funded training of apprentices covering a wide spectrum of skills from construction to information technologies and banking is the most important source of “middle-level” human capital for the Swiss economy.¹ The employees with such “middle-level” vocational education build the largest group among employed persons. Moreover, having such a (nationally organized) vocational qualification is a precondition for the acquisition of every other type of higher tertiary-level education (with the exception of academic education). Thus, it is quite reasonable that both economists and economic policy-makers are greatly interested (a) in better understanding the factors influencing positively or negatively the willingness of private enterprises to offer apprenticeships; and, even more important, (b) in measuring the contribution of employees with such “middle-level” vocational education to economic performance, particularly productivity (at firm or industry level). Of particular interest is the productivity contribution of technologically advanced enterprises that are frequently also the most productive. There is long-term empirical evidence that both the number and the employment share of high-skilled (or high-educated) workers have grown over time in many OECD countries. Most observers think that this effect is attributable primarily to skill-based technical change (see, e.g., Machin and Van Reenen 1998; see also Acemoglu 2001 for a survey of this empirical literature). Thus, technical change is expected to further shift labour demand in favour of high-qualified persons. This accentuates the question concerning the role and importance of “middle-educated” employees in the Swiss economy.

Some of the above topics, particularly the factors explaining the training propensity of firms have been analyzed for the Swiss business sector in a series of KOF studies financed by the Federal office for Professional Education and Technology (OPET) that investigate primarily the determinants training propensity of Swiss firms (Arvanitis 2008; Arvanitis and Stucki 2008; Hollenstein and Stucki 2008). Some other studies analyze related topics, e.g. the impact of ICT on the demand for employees of different education levels (see Arvanitis 2005a). We know of no study in Switzerland and only a few studies in other countries that deal with the contribution of middle-educated employees to firm or industry productivity.

In this study we investigate the effects of three categories of employees with different levels of formal education (upper secondary level (“Berufslehre”); tertiary level other than academic university (“Fachhochschulen”, etc.); and academic university level) on average labour productivity in an “augmented production function” framework (a) at *firm* level for the period 1994-2005 and (b) at *industry* level for the period 1991-2005.

¹ Within contemporary advanced economies “apprenticeship typically denotes employer-sponsored programmes which integrate part-time schooling with part-time training and work experience [in a firm]... within an externally defined curriculum which contains mandatory part-time schooling and leads to a nationally recognized vocational qualification and takes at least two years to complete” (Ryan 1998, p. 290). This is exactly the definition of apprenticeship as it is used also in Switzerland.

The study is structured as follows: in section 2 we present some basic theoretical thoughts and a summary of related empirical literature. In section 3 we present the data and the methodology applied in this study. The specification of the models estimated in this study is presented in section 4. In section 5 the results are discussed. Section 6 summarizes our conclusions.

2. Theoretical framework and selected empirical literature

2.1 Preliminary remarks

The literature about vocational education can be broadly categorized into two branches. The first deals with education that is offered as an alternative to more general educational programmes. On the level of secondary education, there are a large number of countries that have implemented schools that offer vocational education. In addition to such programmes, Swiss firms offer the possibility of apprenticeships. It is a combination of learning-by doing at the workplace and school education. While Germany and Austria know a similar system, it is rather seldom in the larger context. At the level of tertiary education, vocational education is offered in Switzerland in the universities of applied sciences that have been up-graded since the mid-nineties and a series of other tertiary-level technical and business schools (“Fachschulen”; “Technikerschulen”, etc.). The literature about the relevance of tertiary vocational education is scant though. The second branch of literature about vocational education analyzes training possibilities that are attended parallel to working and usually have a shorter duration. In this literature review, we focus on the first kind, the institutionalized vocational education.

There is a substantial literature that analyzes the impact of vocational education on the earnings of individuals (for a summary, see, e.g., Blundell et al. 1999, Ananiadou, Jenkins and Wolf 2003). While the interpretation of these effects on productivity is valid from the perspective of an employee, it is not clear to what extent these results hold for the productivity on the firm-level (Backes-Gellner 2006). Individual wage increases do not necessarily go together with increases of firm productivity. Furthermore, complementarity effects are not taken into account (see Huselid and Becker 1998 for an overview). Potential sources of such complementarities include human resource management practices (see, e.g., Ichniowski and Shaw 2003), organisational change (see e.g. Caroli and van Reenen 2001), ICT (see, e.g., Bresnahan et al. 2002; for Switzerland: Arvanitis 2005b) and selling market volatility (see, e.g., Backes-Gellner 1996). Due to these difficulties, we concentrate the literature review on those studies that provide direct evidence of the impact of vocational education on the productivity of firms.

We first summarize some theoretical thoughts on vocational education before discussing the existing evidence of the relation between productivity and apprentices and apprenticeship graduates.

2.2 Economics of Education: Basic theoretical thoughts

Building on Becker (1964), the economic literature argues that firms invest in specific, non-transferable skills of their workers but not in general ones. However, in practice we can observe that there are firms that bear a significant fraction of the costs of training, even if this training contains general skills. For example, according to empirical studies for Germany and to a lesser extent for Switzerland, a significant share of firms offers apprenticeships even if they incur net costs. The explanation of this seemingly economically irrational behaviour became the subject of a substantial amount of theoretical literature; see, e.g., Franz und Soskice (1995); Harhoff and Kane (1997); Acemoglu and Pischke (1998); Acemoglu and Pischke (1999b); Dustmann and Schönberg (2004); and Lülfelsmann and Kessler (2006). These contributions discuss the impact of various market imperfections on the willingness of firms to provide general training to their workers.

Early explanations focus on the difficulty to observe the training quality and the resulting information asymmetry (Katz and Ziderman 1990; Chang and Wang 1996). With respect to the dual vocational educational system an alternative explanation for a firm's willingness to provide general training could be explained by asymmetric information about the characteristics of apprentices (Elbaum and Sing 1995; Franz and Soskice 1995; Acemoglu and Pischke 1998). Both kinds of information asymmetries have the effect that the apprentices cannot signal their productivity to outside firms perfectly. As a consequence the training firms can pay graduated apprentices below their productivity and recoup their losses from the apprenticeship period. A similar effect is created by search and matching frictions by restraining worker mobility (Acemoglu 1997; Acemoglu and Pischke 1999a, Wasmer 2006). Imperfect labour mobility might also be due to unions (Harhoff and Kane 1997; Dustmann and Schönberg 2004). Bishop (1996) suggests an explanation by differentiating between the specificity degree of a skill and the skill mix. If the required mix of general skills is firm-specific, investment in general skills is rational as it provides the workforce the mix that is optimal for the firm.

To our knowledge, there is no theoretical literature dealing specifically with the relationship between vocational education (e.g., as provided by the Swiss dual educational system) and firm economic performance. Recent studies referring to the concept of the technological frontier (see Acemoglu et al. 2006) yield indirectly useful insights to this topic. For example, Vandenbussche et al. (2006) develop a model, in which the relevance of education depends on the distance to the technological frontier. They argue that workers with primary or secondary education are able to induce growth by imitation but do not contribute to the innovation

process. In this model innovation-induced growth is driven by workers holding tertiary education. The authors do not refer specifically to the concept of apprenticeship-based vocational education as established in German-speaking countries, but workers with formal vocational education based on apprenticeship as the highest education fall implicitly in the category of employees that do not contribute to innovation. Therefore, their model predicts that workers holding such vocational education are relatively more productive the further away from the technological frontier the firm operates.

Finally, there is a literature strand that analyzes the impact of general and specific training on macroeconomic growth rates in situations of slow and fast technological progress (Krueger and Kumar, 2003, 2004). They argue that the European education system which focuses on vocational education has worked well during the 60s and 70s, but not in the information age when the technological progress sped up. Due to the specificity of knowledge, the workers adapted slower to the new technological opportunities, resulting in a technology adoption lag compared to the US. Similarly, Gervais et al. (2007) argue that specific human capital is more valuable in relatively stable environments while general human capital appears to suit better under high uncertainty. Complementing these papers, Mukoyama (2004) develops a model that explains technology diffusion as a function of the adoption costs. Krueger and Kumar (2004) provide macroeconomic evidence for the causal relationship between education specificity, technological progress and growth. At the microeconomic level, the argument is supported for Germany by the study of Ludwig and Pfeiffer (2005) who show that the depreciation rate of (specific) vocational education capital is higher than that of general education capital. No direct evidence on this issue exists for Switzerland. Indirect indication is provided by the increasing share of apprentices that choose to supplement the vocational education by a voluntary general education programme called “Berufsmaturität”² This indicates that the valuation of general education as part of human capital is increasing, thereby supporting the thesis that general education is relatively valuable under conditions of rapid technological progress.

2.2. Selected empirical literature

Apprentices

Zwick (2007) estimates a productivity equation for Germany, where productivity is measured by the profit per employee. His OLS estimates indicate a negative correlation between the share of apprentices and productivity. The reference group consists of unskilled workers. A potential explanation is that the negative correlation is due to the fact that it is mostly relatively unproductive firms that train apprentices. In order to account for this unobserved heterogeneity, he uses a fixed effect estimator which yields a negative but insignificant

² See <http://www.bfs.admin.ch/bfs/portal/de/index/themen/15/04/ind4.indicator.40804.408.html?open=1#1>).

coefficient. Worried about a potential endogeneity bias, Zwick (2007) further estimates a two-step dynamic panel system GMM. In this specification, the coefficient share of apprentices turns positive though not significant.

Mohrenweiser and Zwick (2008) refine the analysis by distinguishing three different sectors, in which apprentices are employed: “Commercial and Trade”, “Manufacturing” and “Crafts and Construction”. Furthermore they use both the value added and gross profits as measures for profitability. The empirical strategy is similar as in Zwick (2007). The reference group contains the unskilled workers. The OLS estimates indicate that while the share of apprentices has a positive effect in “Commercial and Trade” it is negative in the “Manufacturing” and “Crafts and Construction”. The fixed effect methodology results in insignificant coefficients for all three sectors. Using system GMM to account for endogeneity renders the negative impact for “Manufacturing” and “Crafts and Construction” insignificant while the positive impact in “Commercial and Trade” remains significant. These findings indicate that there is substantial heterogeneity within the apprenticeships.

Prskawetz et al. (2005) estimate a productivity equation for the mining and manufacturing sector in Austria (cross-section of employer-employee matched data for the year 2001). They analyze the determinants of the log of value-added per employee, including the share of apprentices, where the reference category is again the share of unskilled workers. They find a significantly negative relationship for the share of apprentices for both large and small firms. Using a similar setup, Prskawetz et al. (2008) (also based on a cross-section of employer-employee matched data for 2001) confirm that these results hold for the whole economy including the service sector.

The results for Switzerland are similar to those for Austria. Arvanitis (2008), Arvanitis and Stucki (2008) and Hollenstein and Stucki (2008) find a negative relationship between firm productivity and the share of apprentices working in the firm. They use the workers holding a primary or secondary education (no formal vocational education) as the reference group.

Besides of this direct evidence on the effect of training apprentices on productivity, there are a number of studies that calculate the net costs. Schweri et al. (2003) analyze the costs and the benefits of apprentice training for Switzerland. While they find that for most firms the benefits exceed the costs, they also show that a substantial number of firms have net costs. Similarly, Wolter et al. (2003) and Wolter (2008) find that the average net costs of apprentices are negative, but firms incurring positive net costs are observed as well. Furthermore, Wolter et al. (2003) show that the decision not to train apprentices reflects rational decision-making as these firms would incur relatively high net costs compared to those that are observed to provide training. The difference between the two types of firms is mainly due to lower benefits while the gross costs are comparable. Wolter and Schweri (2002) show that on average the net costs per apprentice are higher in large firms. They recoup these costs by

higher benefits stemming from apprenticeship graduates that remain in the firm after graduation.

Early evidence of net costs in Germany can be found in Noll et al. (1983), von Bardeleben et al. (1991, 1995, 1996 and 1997). They find that while some firms with negative net costs exist, most have positive net costs during the apprenticeship. More recently, Beicht et al. (2004) and Wenzelmann et al. (2009) show that the average net cost are positive for all sectors and firm sizes. They further estimate average savings for recruitment and adjustment to the new job and find that they are sizable in comparison to the net costs of an apprentice. They conclude that including long-term benefits such as lower fluctuation rates, access to qualified personnel and image gains would render the apprenticeship institution profitable for firms. Similarly, Walden (2007) reports positive average values of net direct cost (€3310), but huge standard deviations (€7039). His analysis of long-term benefits reveals that the most important benefits are the savings of recruitment costs, savings of introductory costs, avoidance of wrong hiring choices, avoidance of staff turnover, access to qualified staff in tight labour market situations and training of young workers in line with company requirements. In sum, the net cost analysis reveals that a larger fraction of firms profits from training apprentices in Switzerland as compared to Germany.

Using a production function approach, Fougère and Schwerdt (2002) find that apprentices participate in the production process of medium sized firms but not otherwise. They interpret this as a stronger presence of the substitution strategy in medium sized firms than in small and large firms where the investment strategy is dominant.

Dionisius et al. (2008) analyze the gap that exists in respect to the net costs between Germany and Switzerland. Average net costs per apprentice per year amount to €7528 in Germany compared to (minus) -€913 in Switzerland. They find that the main reason for this difference is the difference in the share of time the apprentices work in productive tasks. Furthermore relative wages are shown to be of relevance too.

Finally, Mohrenweiser and Backes-Gellner (2008) provide indirect evidence on the net costs of an apprenticeship. They differentiate between the investment strategy and the substitution strategy (implicating the substitution of “normal” workers for apprentices) by using retention rates. They find that nearly 20% of firms follow a substitution strategy and around 45% an investment strategy. The remaining firms use a mixture of both.

Apprenticeship Graduates

To our knowledge, there is no study that focuses on the effects of apprenticeship-based education on the productivity of firms and discusses the results. But controlling for human capital in a productivity equation is fairly standard and therefore some studies exist that allow

some conclusions with respect to the relevance of workers who have accomplished an apprenticeship.

For Austria, Prskawetz et al. (2005) estimate a productivity equation that includes the shares of four education classes, one of which refers to workers whose highest education is a completed apprenticeship. The reference group are workers with a primary education. In the overall sample, the share of vocationally educated workers affects productivity positively. Differentiating between small and large firms reveals though, that this effect is driven by small firms, while the coefficient is not significant for large firms.

Prskawetz et al. (2008) estimate a similar equation but include the service sector in the sample as well. They find a significantly positive influence of the share of workers that have completed an apprentice for both small and large firms, the reference group being unskilled workers again.

Zwick (2007) includes a number of human capital measures in his productivity equation, productivity being measured as profit per employee. The reference category consists of workers that hold a university entrance degree ('Abitur'), but have not finished an apprenticeship. His OLS estimates indicate that within the share of workers holding a secondary education, those without a university entrance degree are inferior. But holding the attainment of this degree constant, having completed an apprenticeship has a positive impact on the firm productivity. These results are robust to the correction of unobserved firm heterogeneity and endogeneity in respect to the share of apprentices.

Similarly, the OLS estimates of Mohrenweiser and Zwick (2008) indicate that in relation to the share of workers holding a university entrance certificate but not an apprentice, the share of workers having completed only an apprenticeship have a negative impact on firm productivity, measured as value added per employee profits. Workers who have completed both an apprenticeship and have a university entrance certificate on the other hand are more productive than those who only hold a university entrance certificate. This finding is not robust to the correction for unobserved heterogeneity and endogeneity though. Adjusting for these in the econometric specification renders all coefficients insignificant. This indicates that the kind of secondary education is less important than having obtained a secondary education degree.

Euwals and Winkelmann (2004) provide indirect evidence for the total net costs of training an apprentice by comparing wages of apprenticeship graduates that stay in the firm and those that leave it. They do not find any significant effect.

Finally, the paper of Addison et al. (2000) based on German data use a measure for the share of skilled, manual labour input in productivity estimates for Germany, but the authors do not specify the measurement exactly. They also include the share of workers with tertiary education in the regression, implying that the reference group is the share of unskilled

workers. They differentiate between small and large firms but do not find any significant impact on productivity in either case.

Comparing the results for Austria and Germany indicates that the effect of the share of workers having completed an apprenticeship is ambiguous and rather weak in both countries. The effect appears to be more positive in Austria though.

Tertiary Education

Barely any empirical evidence exists on the relationship between firm productivity and the share of workers holding a vocational tertiary education. The exceptions are Zwick (2007) as well as Mohrenweiser and Zwick (2008) who find a positive impact of the share of this category of employees on economic performance for OLS estimates; the significance of this effect disappears though when they correct for heterogeneity and endogeneity by using fixed effect estimators and GMM.

With respect to the effect of general tertiary education including university education, the literature shows in general a positive effect on the productivity of firms. For Germany, see, e.g. example Zwick (2005, 2007), Mohrenweiser and Zwick (2008), Addison et al. (2000). It should be noted though, that the correction for firm heterogeneity and endogeneity reduces the impact of the share of workers with tertiary education substantially. Evidence for a positive influence in Austria is provided by Prskawetz et al. (2005) and Prskawetz et al. (2008). Arvanitis (2008) as well as Hollenstein and Stucki (2008) confirm the findings for Switzerland, while Arvanitis and Stucki (2008) find no effect of the share of workers holding a tertiary education for start-up firms.

In sum, existing literature finds mostly no clear-cut effect of vocational education on economic performance (see table with a summary of relevant empirical literature on the next page).

Summary of Empirical Literature on the Impact of Vocational Education on Economic Performance at Firm-level

<i>Authors</i>	<i>Country</i>	<i>Estimation Technique</i>	<i>Apprenticeship</i>	<i>Vocational Secondary Education</i>	<i>Vocational Tertiary Education</i>	<i>Tertiary Education</i>
Zwick (2007)	Germany	OLS, FE, GMM (ref.: primary education)	-,-,+)	-,-,-)	+,-,+)	+ ,+ ,+)
Mohrenweiser/Zwick (2008)	Germany	OLS, FE, GMM (ref.: primary education)	Commercial: +,-,+ Manufacturing: -,-,- Crafts: -(+),+	With school degree: +,(+),(+) Without school degree: -, (-), (-)	+,-,+)	+,-,-)
Addison et al. (2000)	Germany	OLS (ref.: primary education)		Small firms: (+) Large firms: (-)		Small firms: + Large firms: +
Prskawetz et al. (2008)	Austria	OLS (ref.: primary education)	small firms: - large firm: -	Small firms: + Large firms: (+)		+
Prskawetz et al. (2005)	Austria	OLS (ref: primary education)		(+)		+
Euwals/Winkelmann (2004)	Germany	Wage-comparison stayers and leavers		+		
Wolter et al. (2003)	Switzerland	Cost-Benefit Analysis	+			
Schweri et al. (2003)	Switzerland	Cost-Benefit Analysis	+			
Noll et al. (1983)	Germany	Cost-Benefit Analysis	-			
Von Bardeleben et al. (1991, 1995, 1996, 1997)	Germany	Cost-Benefit Analysis	-			
Beicht et al. (2004)	Germany	Cost-Benefit Analysis	-			
Wenzelmann et al. (2009)	Germany	Cost-Benefit Analysis	-			
Walden (2007)	Germany	Cost-Benefit Analysis	-			
Fougère/Schwerdt (2002)	Germany & France	Indirect Evidence through Significance in Production Function	Small firms: - Medium firms: + Large firms -			
Mohrenweiser/Backes Gellner (2008)	Germany	Retention Rates used for the identification of pure strategy	20% Substitution 45% Investment			
Dionisius et al. (2008)	Germany & Switzerland	Cost-Benefit Analysis	Germany: - Switzerland: +			

3. Data and Method

3.1 Data

Firm level

The data used in this study were collected in the course of three surveys among Swiss enterprises (defined as legal entities) in the years 1996, 1999, 2002 and 2005 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) and 38.7% (2005) 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 8757 enterprises from all fields of activity and size classes and may be considered as representative of Swiss business sector (see table A.1 in appendix for the structure of the used data set by industry, firm size class and year respectively).

Table A.2 in the appendix shows the average share of middle-educated employees holding a degree of vocational education ('Berufslehre') by industry in our sample. In order to assess the relative importance of the industries with above-average intensity of middle skills also the shares of total value added of these branches is included in Table A.2. In manufacturing the industries with the highest shares of middle-educated employees are printing, chemicals, vehicles and machinery. Chemicals (about 5% of total value added) and machinery (share of total value added of 8.4% in KOF-sample versus 3.8% in the National Accounts, thus over-represented in the KOF-sample) are the two industries that are relatively larger in the Swiss economy than in other advanced economies. In the service sector the three industries with the highest shares of middle-educated employees are transport, trade and banking/insurance. Banking/insurance is the industry with above-average intensity of middle skills that also has a very high share of total value (9.4% in the KOF-sample versus 16.7% in the National Accounts, thus under-represented in the KOF-sample) in international comparison.

Finally, Table A.3 in the appendix contains some information on the average share of the two categories of high-educated employees as well as the middle-educated employees for the SMEs and for larger firms by sector. According to these data the differences between the sectors with respect to the share of middle-educated employees is considerably larger as the differences for the same variables between SMEs and larger firms.

Industry level

The data for the 73 3-digit manufacturing and service industries used in this study were calculated based on several data sources (see table A.4 in the appendix for a list of the industries taken into consideration in this study; see Arvanitis et al. 2008 for details with respect to the construction of the industry-level data):

(a) Data on value added, employment, book value of capital, equity share of total capital, etc. for 3-digit industries for the period 1991-2005 from the official statistics of the Swiss Federal Statistical Office (SFSO).

(b) Data on export intensity, share of employees with different levels of education, R&D intensity, etc. based on firm data from the Swiss Innovation Surveys 1990, 1993 1996, 1999, and 2002.

(c) Data on market characteristics (market concentration, measures of market mobility) calculated on the basis of data of the Federal Enterprise Census 1991, 1995, 1998, 2001 and 2005.

3.2 Method

Firm level

We do not assume a concrete functional form for the theoretical production function underlying the productivity equation we estimate because our data would not allow an identification of this functional form. We use as in most studies a linear logarithmic specification for the empirical study. In order to avoid problems of endogeneity of some of the right-hand variables in case they are contemporaneous to the dependent variable we estimate productivity equations with lagged right-hand variables (lag of a period of 3 years in our dataset). By using lagged variables the data set is reduced from 8758 observations to 3179 observation, i.e. to about 36% of the available observations. In this case any inference from the smaller sample could imply serious selection bias. In order to test the robustness of our estimates with respect to this potential bias we also estimate productivity equations without lags that allow us to exploit all available data.

The use of 3-digit market concentration and market mobility data that are matched with firm data leads to a further reduction of the number of observations to 2744 observation for the estimates with these variables.

We use GLS random effects (RE) regression as estimation method (software: STATA IC10) throughout this study.³ Tests with first difference equations and fix effects as alternative panel

³ 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

estimation method led to unstable and or counterintuitive results presumably due to the fact that we dispose only of four points of time with a distance of three years between each of them. This characteristic gives our panel rather the character of a series of (almost independent) consecutive cross-sections. For this reason we also estimated OLS pooled regressions with year dummies (see table 2 and table 4a), whose results are close to those of the RE estimates. A further possible reason for the weak performance of the FE estimator could be the existence of selectivity bias due the fact that our firm panel is highly unbalanced. Finally, to get some idea of dynamic implications we also test a model version that includes the lagged productivity variables as an additional right-hand variable. Given these restrictions, we consider our estimates rather descriptive than causal. Since unobserved heterogeneity is not controlled for, our results should be generally interpreted as descriptive rather than causal.

Preliminary tests showed that there is considerable heterogeneity in the data referring to vocational education due to differences between sectors. This is the reason, why we estimate the education-focused productivity equations separately for manufacturing and services. In addition, we conduct also quantile regressions to capture differences of high- and low-productivity segments with respect to the impact of human capital, particularly of middle-educated employees, on productivity.

Finally, we considered firm size as a further source of heterogeneity by estimating separately a productivity equation for SMEs (firms with up to 249 employees) and for larger firms (250 and more employees). The results of these estimations show that the overall results for all firms are dominated by the results for the SMEs (see also table A.3 in the appendix). Due to the fact that only 474 observations for larger firms are available, the estimates for this category have to be considered with much caution, thus we refrain here from presenting these results.

Industry level

We use three estimation methods for the industry-level estimates of the productivity equation in order to test their robustness: simple OLS regressions with pooled data, GLS random effects and GLS fixed effects regressions (balanced panel!). The inclusion of time dummies led to instable results in many cases, so we decided to drop them. Finally, the problem of possible endogeneity of right-hand variables is to a large extent avoided by using pre-determined right-hand variables (e.g., the productivity 2005 is explained by the export intensity or the R&D intensity 2002 and so on).

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).

4. Specification of the empirical model

4.1 Firm level

We specified at firm level productivity equations (dependent variable: logarithm of value added per employee) that contained measures for physical capital (variable $\ln((C/L))$), for human capital (share employees with university education: $\ln(HQUAL1)$; share of employees with tertiary-level education other than university (i.e. universities of applied science and tertiary vocational education): $\ln(HQUAL2)$; share of employees with formal vocational education : $\ln(MQUAL)$), for R&D intensity ($\ln(R\&D/S)$), for market competition (market structure: $\ln(CONC5)$; NCOMPET; market mobility: net market entry rate (N-ENTRY_L; N_ENTRY_L); entry (ENTRY_L; ENTRY_L) and exit market rates (EXIT_L; EXIT_L) (see table 1 for the variable description). In addition, we included controls for foreign-owned firms, firm size, industry affiliation (2-digit industries) and time.

In a first step we focused on the role of *education* and specified a productivity equation containing the three human capital variables and three firm-level competition variables, thus leaving out the industry-level measures for market concentration and market mobility that would further reduce the number of observations used in the estimations due to restrained availability of these industry-level measures. A formal expression of the equation (for lagged right-hand variables) is as follows:

$$\ln(Q/L)_{it} = \alpha_0 + \alpha_1 \ln(C/L)_{it-1} + \alpha_2 \ln(R\&D/S)_{it-1} + \alpha_3 \ln(HQUAL1)_{it-1} + \alpha_4 \ln(HQUAL2)_{it-1} + \alpha_5 \ln(MQUAL)_{it-1} + \alpha_6 NCOMPET_{it-1} + \alpha_7 IPC_{it-1} + \alpha_8 INPC_{it-1} + \alpha_9 FOREIGN_{it-1} + \alpha_{10} \ln(L)_{it-1} + \text{industry and time dummies} + e_{it} \quad (\text{for firm } i) \quad (1)$$

In a second step we focused on the effects of *competition*, hence taking into consideration also the industry-level variables for market concentration and market mobility. A formal expression of this second specification (for lagged right-hand variables) is as follows:

$$\ln(Q/L)_{it} = \beta_0 + \beta_1 \ln(C/L)_{it-1} + \beta_2 \ln(R\&D/S)_{it-1} + \beta_3 \ln(HQUAL)_{it-1} + \beta_4 \ln(CONC5)_{it-1} + \beta_5 N_ENTRY_L_{it-1} + \beta_6 IPC_{it-1} + \beta_7 INPC_{it-1} + \beta_8 FOREIGN_{it-1} + \beta_9 \ln(L)_{it-1} + \text{industry and time dummies} + e_{it} \quad (\text{for firm } i) \quad (2)$$

(N_ENTRY_N; ENTRY_L; ENTRY_N; EXIT_L; and EXIT_L are used alternatively to N_ENTRY_L).

4.2 Industry level

The productivity equation (dependent variable: logarithm of value added per employee) at industry level contains measures for the following three main groups of determining factors (see table 1 for the description of the variables): (a) Endowment with production factors: physical capital (variable $\ln(C/L)$); human capital ($\ln(HQUAL)$; $\ln(MQUAL)$); knowledge capital ($\ln(R\&D/S)$); and equity capital as share of total capital ($\ln(FIN)$); (b) market conditions: market concentration ($\ln(CONC5)$); market mobility (N_ENTRY_N ; $ENTRY_N$); market behaviour: intensity of price (IPC) and non-price competition (INPC); and (c) exposure to international competition and degree of international integration: sales share of exports ($\ln(EXP/S)$); share of foreign-owned firms (FOREIGN). A formal expression of the main specification is as follows:

$$\ln(Q/L)_{it} = \alpha_0 + \alpha_1 \ln(C/L)_{it} + \alpha_2 \ln(R\&D/L)_{it} + \beta_3 \ln(EXP/S)_{it} + \beta_4 \ln(HQUAL)_{it} + \beta_5 \ln(FOREIGN)_{it} + \beta_6 \ln(FIN)_{it} + \beta_7 N_ENTRY_N_{it} \text{ control variables for time} + e_{it}$$

(industry i) (3)

($ENTRY_N$; $\ln(CONC5)$) and IPC; INPC are used alternatively to N_ENTRY_N).

Table 1
Definition of variables

Variable	Description
Ln(Q/L)	Natural logarithm of value added per employee; industry level: at constant prices
Ln(L) Ln(C/L) Ln(EXP/S) Ln(R&D/S) Ln(R&D/L) LN(FIN)	Natural logarithm of the number of employees (in full-time equivalents) Firm level: natural logarithm of capital income per employee (capital income = value added minus labour costs divided by value added); Industry level: natural logarithm of book value of equipment and buildings (at constant prices) per employee Industry level: natural logarithm of exports divided by sales Firm level: natural logarithm of R&D expenditures divided by sales Industry level: natural logarithm of R&D expenditures per employee Industry level: equity capital as share of total capital
<i>Vocational education</i> Ln(HQUAL) Ln(HQUAL1) Ln(HQUAL2) Ln(MQUAL)	(Firm level as well as industry level) Natural logarithm of employment share of employees with tertiary-level education (HQUAL = HQUAL1 + HQUAL2) Natural logarithm of employment share of employees with university education (excl. universities of applied sciences - Fachhochschulen) Natural logarithm of employment share of employees with tertiary-level education other than university education Natural logarithm of employment share of employees with formal vocational education (as defined in the Swiss dual educational system; Berufslehre)
<i>Competition</i> N_ENTRY_N N_ENTRY_L ENTRY_N ENTRY_L EXIT_N EXIT_L Ln(CONC5) IPC INPC NCOMPET	Industry level: net market entry rate (with respect to the number of firms) Industry level: net market entry rate (with respect to employment) Industry level: market entry rate (with respect to the number of firms) Industry level: market entry rate (with respect to employment) Industry level: market exit rate (with respect to the number of firms) Industry level: market exit rate (with respect to employment) Industry level: concentration ratio C5 (employment share of the five largest firms in a market) Firm level: values 1 to 5 on a five-point Likert scale assessing the intensity of <i>price</i> competition (ordinal variable); Industry level: share of firms reporting high intensity of <i>price</i> competition (values 4 or 5 on a five-point Likert scale) Firm level: values 1 to 5 on a five-point Likert scale assessing the intensity of <i>non-price</i> competition (ordinal variable); Industry level: share of firms reporting high intensity of <i>non-price</i> competition (values 4 or 5 on a five-point Likert scale) Firm level: number of main competitors in a firm's most important (worldwide) product market (interval variable: 1: up to 5 competitors; 2: 6 to 10; 3: 11 to 15; 4: 16 to 50; 5: more than 50)
FOREIGN	Firm level: foreign-owned firm yes/no (dummy variable) Industry level: share of foreign-owned firms

Industry level: 3-digit industries.

5. Results

5.1 Firm level

Education

Table 2 to table 7 contain the econometric estimates that are focused on the variables for vocational education (variables HQUAL1; HQUAL2; and MQUAL). Table 2 to table 5 show the results for lagged right-hand variables, table 5 to table 7 present the estimates for contemporaneous right-hand-variables.

Table 2 shows the results with right-hand lagged variables for all firms, table 4 presents the separate estimates with right-hand lagged variables for manufacturing and services respectively. We estimated two versions of the productivity model, one without lagged productivity (see, e.g., column 1 in table 2) and a second one with lagged productivity as an additional right-hand variable (dynamic version; see, e.g. column 2 in table 2). Also the OLS pooled regression estimates in column 3 show for the education variables results similar to those of the RE estimates.

We comment first the results in table 2. The variable for physical capital shows the expected positive sign, also the variable for R&D intensity but in the latter case the respective coefficient is not statistically significant. We obtain positive and statistical significant coefficients for the two categories of high-educated employees (tertiary-level education); the coefficient for the middle-educated employees is not statistically significant.

The economic interpretation of the coefficient (in this case: elasticity), e.g., for the variable for university-educated employees ($\ln(\text{HQUAL1})$) is as follows: an increase of 1% of the share of this employee category (e.g., from 10% to 10.1%, i.e. for a firm with 1000 employees an increase of 100 to 101 academics) is positively correlated with an increase of average labour productivity of 0.02%. Further, a chi2-test on the difference of the coefficients of the variables $\ln(\text{HQUAL1})$ and $\ln(\text{HQUAL2})$ shows that the coefficient of the variable $\ln(\text{HQUAL1})$ is not significantly larger than that of $\ln(\text{HQUAL2})$ in column 1 and column 3 in table 2.

The three variables for competition are not significant (with the exception of a rather weak negative effect of the intensity of price competition; we discuss this effect later). Finally, we find a positive effect for foreign-owned firms and a positive, non-linear effect of firm size. The second model version shows practically the same results. As expected the positive coefficient of the lagged productivity variable is rather low indicating a weak correlation between the productivity levels in two points of time with a distance of three years. Additional quantile regression estimates yield some evidence that middle-educated employees show a significantly positive effect in the low-productivity segment up to Q30 (lowest 30%) and a negative effect at the highest level (Q90) (see table 3).

A comparison with the separate estimates for manufacturing and services in table 4 and table 5 reveal some interesting additional findings: (a) the effect of university-educated employees

(HQUAL1) is stronger in service firms than in manufacturing firms but the effect of employees with tertiary education other than university is more prominent in manufacturing than in the service sector; (b) the contribution of the middle-educated employees is significantly positive for the lower productivity segment up to Q50 in manufacturing (see table 5; at least for the model version without lagged productivity) but not in the service sector.⁴ Further differences between the sectors refer to the competition variables. The estimates in table 4 (columns 1 and 2) yield some evidence that there is a negative effect of the number of competitors (the higher the number of competitors the lower the productivity) and a negative effect of the intensity of price competition (the higher the intensity of price competition the lower the productivity) (we comment later on these effects). Finally, we find no (qualitative) differences between sectors with respect to physical capital, R&D intensity, foreign-owned firms and firm size.

Table 6 and table 7 present the estimates without lagged right-hand variables that allow the exploitation of the entire available information for 8757 firms. The pattern of results is qualitatively the same but some effects become more clearly statistically significant. This is particularly the case for the variables for the high-educated employees in both sectors (see table 6). We even obtain a positive effect for the middle-educated in the estimates for all firms. In addition, the quantile estimates show that positive effects of middle-educated employees are found up to Q60 in both sectors. Also the effects of the competition variables are somewhat accentuated in manufacturing (negative effect of the number of competitors but positive effect of the intensity of non-price competition). There are no differences with respect to physical capital, R&D intensity and foreign-owned firms but with respect to firm size. The positive, nonlinear effect disappears when no lag is used, and as a consequence much more observation can be exploited in the estimations.

⁴ The OLS pooled regression results for the education variables in table 4a are similar to those for the RE estimates in table 4 with the exception of a significantly positive effect for middle-educated employees in manufacturing (column 1 in table 4a).

Table 2**Average labour productivity and vocational education 1994-2005; lagged right-hand variables; all firms**

	Ln(Q/L) _t	Ln(Q/L) _t	Ln(Q/L) _t
Ln(Q/L) _{t-1}		0.189*** (0.026)	
Ln(C/L) _{t-1}	0.011*** (0.003)	0.030*** (0.010)	0.026*** (0.004)
Ln(R&D/S) _{t-1}	0.004 (0.041)	0.008 (0.039)	-0.015 (0.042)
Ln(HQUAL1) _{t-1}	0.020*** (0.005)	0.015*** (0.005)	0.021*** (0.005)
Ln(HQUAL2) _{t-1}	0.013** (0.005)	0.011** (0.005)	0.014*** (0.005)
Ln(MQUAL) _{t-1}	-0.011 (0.011)	-0.016 (0.011)	-0.001 (0.011)
NCOMPET _{t-1}	-0.009 (0.006)	-0.008 (0.006)	-0.011* (0.006)
IPC _{t-1}	-0.014* (0.008)	-0.012 (0.008)	-0.015* (0.008)
INPC _{t-1}	0.005 (0.008)	0.003 (0.008)	0.010 (0.008)
FOREIGN _{t-1}	0.169*** (0.029)	0.151*** (0.028)	0.177*** (0.026)
Ln(L) _{t-1}	0.032*** (0.008)	0.030*** (0.008)	0.029*** (0.007)
Industry dummies (27)	Yes	Yes	Yes
Time dummies (2)	Yes	Yes	Yes
N	3179	3179	3179
R2 overall	0.239	0.311	
R2 within	0.011	0.008	
R2 between	0.256	0.344	
R2			0.245
Wald chi2	452.4***	531.0***	
F-test			16.9***
Root MSE			0.447
Rho	0.441	0.422	

Random effects GLS estimates (column 1 and 2); OLS pooled regression estimates (column 3); ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. All variables with the exception of the variables measuring market mobility refer to the period (t-1); the market mobility variables refer to changes between (t-1) and t. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Table 3
Average labour productivity and vocational education 1994-2005;
lagged right-hand variables; quantile estimates; all firms

	Ln(Q/L) _t Ln(MQUAL)	Ln(Q/L) _t ; Ln(Q/L) _{t-1} Ln(MQUAL)
Q10	0.034 (0.025)	0.008 (0.012)
Q20	0.024** (0.011)	0.009 (0.010)
Q30	0.020* (0.012)	-0.001 (0.010)
Q40	<i>0.005</i> (0.013)	-0.002 (0.010)
Q50	-0.001 (0.011)	-0.006 (0.010)
Q60	-0.004 (0.010)	-0.006 (0.009)
Q70	-0.008 (0.010)	-0.005 (0.010)
Q80	-0.006 (0.010)	-0.017 (0.012)
Q90	-0.041* (0.024)	-0.062** (0.032)

Simultaneous quantile regression (bootstrap standard errors); only the coefficients of the variable ln(MQUAL) are presented. The specification of all other variables is as in Table 2; ***, ** and * resp. denote statistical significance at the 1%-, 5% - and 10%-level resp. The figures in italics indicate the quantile for which the variable Ln(MQUAL) becomes statistically insignificant.

Table 4**Average labour productivity and vocational education 1994-2005; lagged right-hand variables**

	Manufacturing		Services	
	Ln(Q/L) _t	Ln(Q/L) _t	Ln(Q/L) _t	Ln(Q/L) _t
Ln(Q/L) _{t-1}		0.296*** (0.036)		0.129*** (0.040)
Ln(C/L) _{t-1}	0.009* (0.005)	0.015*** (0.003)	0.013** (0.006)	0.068*** (0.022)
Ln(R&D/S) _{t-1}	0.056 (0.047)	0.050 (0.044)	-0.092 (0.064)	-0.084 (0.063)
Ln(HQUAL1) _{t-1}	0.012* (0.006)	0.005 (0.006)	0.019* (0.010)	0.018* (0.010)
Ln(HQUAL2) _{t-1}	0.015** (0.007)	0.011* (0.006)	0.010 (0.009)	0.010 (0.009)
Ln(MQUAL) _{t-1}	0.023 (0.014)	0.013 (0.012)	-0.026 (0.018)	-0.029 (0.018)
NCOMPET _{t-1}	-0.014* (0.007)	-0.006 (0.007)	-0.004 (0.012)	-0.008 (0.012)
IPC _{t-1}	-0.015 (0.010)	-0.017* (0.009)	-0.019 (0.015)	-0.015 (0.015)
INPC _{t-1}	-0.001 (0.010)	-0.006 (0.010)	0.022 (0.016)	0.022 (0.016)
FOREIGN _{t-1}	0.177*** (0.032)	0.149*** (0.029)	0.124** (0.061)	0.120** (0.062)
Ln(L) _{t-1}	0.037*** (0.009)	0.030*** (0.008)	0.033** (0.016)	0.035** (0.017)
Industry dummies (17; 9)	Yes	Yes	Yes	Yes
Time dummies (2)	Yes	Yes	Yes	Yes
N	1735	1735	1132	1132
R2 overall	0.227	0.355	0.244	0.295
R2 within	0.014	0.001	0.029	0.002
R2 between	0.241	0.381	0.256	0.322
Wald chi2	265.5***	364.1***	178.4***	198.1***
Rho	0.566	0.484	0.330	0.265

Random effects GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. All variables with the exception of the variables measuring market mobility refer to the period (t-1); the market mobility variables refer to changes between (t-1) and t. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Table 4a
Average labour productivity and vocational education
1994-2005; lagged right-hand variables

	Manufacturing	Services
	Ln(Q/L) _t	Ln(Q/L) _t
Ln(C/L) _{t-1}	0.031*** (0.006)	0.026*** (0.006)
Ln(R&D/S) _{t-1}	0.054 (0.050)	-0.120** (0.061)
Ln(HQUAL1) _{t-1}	0.016*** (0.006)	0.017* (0.009)
Ln(HQUAL2) _{t-1}	0.023*** (0.007)	0.010 (0.008)
Ln(MQUAL) _{t-1}	0.042*** (0.014)	-0.016 (0.016)
NCOMPET _{t-1}	-0.016** (0.007)	-0.007 (0.012)
IPC _{t-1}	-0.020* (0.010)	-0.017 (0.015)
INPC _{t-1}	0.003 (0.011)	0.023 (0.016)
FOREIGN _{t-1}	0.190*** (0.028)	0.133** (0.057)
Ln(L) _{t-1}	0.033*** (0.007)	0.029** (0.014)
Industry dummies (17; 9)	Yes	Yes
Time dummies (2)	Yes	Yes
N	1735	1132
R2	0.240	0.247
F-test	14.5***	12.0***
Root MSE	0.384	0.549

OLS pooled regression estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. All variables with the exception of the variables measuring market mobility refer to the period (t-1); the market mobility variables refer to changes between (t-1) and t.

Table 5**Average labour productivity and vocational education 1994-2005; lagged right-hand variables; quantile estimates**

	Manufacturing		Services	
	Ln(Q/L) _t	Ln(Q/L) _{t-1}	Ln(Q/L) _t	Ln(Q/L) _{t-1}
	Ln(MQUAL)	Ln(MQUAL)	Ln(MQUAL)	Ln(MQUAL)
Q10	0.118*** (0.023)	0.050** (0.023)	0.013 (0.017)	0.005 (0.012)
Q20	0.046** (0.019)	<i>0.019</i> (0.014)	0.012 (0.014)	0.007 (0.012)
Q30	0.043*** (0.016)	0.012 (0.013)	0.019 (0.016)	0.012 (0.018)
Q40	0.033* (0.019)	0.009 (0.011)	0.004 (0.018)	-0.001 (0.018)
Q50	0.031* (0.018)	0.013 (0.012)	0.001 (0.015)	-0.009 (0.017)
Q60	<i>0.022</i> (0.014)	0.008 (0.014)	-0.003 (0.013)	-0.007 (0.014)
Q70	0.013 (0.016)	0.005 (0.015)	0.012 (0.009)	-0.004 (0.020)
Q80	0.006 (0.013)	-0.004 (0.012)	-0.004 (0.031)	-0.013 (0.033)
Q90	0.026 (0.017)	0.016 (0.021)	-0.083 (0.059)	-0.087 (0.055)

Simultaneous quantile regression (bootstrap standard errors); only the coefficients of the variable Ln(MQUAL) are presented. The specification of all other variables is as in Table 3; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. The figures in italics indicate the quantile for which the variable Ln(MQUAL) becomes statistically insignificant.

Table 6
Average labour productivity and vocational education 1994-2005

	Manufacturing	Services	All firms
	Ln(Q/L) _t	Ln(Q/L) _t	Ln(Q/L) _t
Ln(C/L) _t	0.079*** (0.004)	0.141*** (0.011)	0.100*** (0.004)
Ln(R&D/S) _t	0.030 (0.028)	-0.041 (0.054)	0.014 (0.026)
Ln(HQUAL1) _t	0.022*** (0.004)	0.020*** (0.006)	0.022*** (0.003)
Ln(HQUAL2) _t	0.010*** (0.004)	0.011* (0.005)	0.009*** (0.003)
Ln(MQUAL) _t	0.012 (0.008)	0.013 (0.009)	0.012** (0.006)
NCOMPET _t	-0.014*** (0.004)	-0.005 (0.007)	-0.012*** (0.004)
IPC _t	0.006 (0.005)	0.002 (0.009)	-0.003 (0.005)
INPC _t	0.012** (0.006)	-0.003 (0.010)	0.008 (0.005)
FOREIGN _t	0.104*** (0.019)	0.147*** (0.034)	0.127*** (0.018)
Ln(L) _t	0.000 (0.006)	-0.001 (0.008)	0.001 (0.005)
Industry dummies (17; 9)	Yes	Yes	Yes
Time dummies (3)	Yes	Yes	Yes
N	4516	3371	8757
R2 overall	0.356	0.399	0.359
R2 within	0.233	0.228	0.200
R2 between	0.368	0.424	0.384
Wald chi2	945.0***	771.9***	1531.2***
Rho	0.467	0.312	0.421

Random effects GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. All variables with the exception of the variables measuring market mobility refer to the period t; the market mobility variables refer to changes between (t-1) and t. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Table 7**Average labour productivity and vocational education 1994-2005; quantile estimates**

	Manufacturing	Services	All Firms
	Ln(Q/L) _t	Ln(Q/L) _t	Ln(Q/L) _t
	Ln(MQUAL)	Ln(MQUAL)	Ln(MQUAL)
Q10	0.036*** (0.009)	0.016** (0.007)	0.024*** (0.005)
Q20	0.036*** (0.007)	0.011* (0.007)	0.021*** (0.005)
Q30	0.026*** (0.009)	0.012*** (0.004)	0.014*** (0.003)
Q40	0.016*** (0.006)	0.013*** (0.005)	0.014*** (0.003)
Q50	0.017*** (0.004)	0.014*** (0.005)	0.014*** (0.004)
Q60	0.018*** (0.007)	0.011** (0.006)	0.012*** (0.005)
Q70	<i>0.007</i> (0.008)	<i>0.008</i> (0.007)	0.012*** (0.006)
Q80	0.010 (0.011)	0.002 (0.013)	<i>0.003</i> (0.008)
Q90	-0.004 (0.018)	0.003 (0.019)	0.003 (0.011)

Only the coefficients of the variable Ln(MQUAL) are presented. The specification of all other variables is as in Table 6; simultaneous quantile regression (bootstrap standard errors); ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. The figures in italics indicate the quantile for which the variable Ln(MQUAL) becomes statistically insignificant.

Competition

In the estimates in table 8 and 9 we concentrate on the competition variables. To control for human capital we use in this case only one variable, the logarithm of high-educated employees ($\ln(\text{HQUAL})$). In this model specification we take into consideration several aspects of competition: market structure (as measured by market concentration), market mobility (as measured by market entry and exit rates), and market behaviour (as measured by the intensity of price and non-price competition). We present here the estimates for lagged-right-hand variables for all firms and for two model versions (with and without lagged productivity variable as an additional right-hand variable). The results with respect to physical capital, R&D intensity, employment share of high-educated, foreign-owned firms and firm size are quite similar and compatible with those presented in table 2, hence we focus on the effects of the competition variables.

The market concentration effect is significantly positive throughout in table 8. High-productive firms are found in more concentrated markets. This result is compatible with the finding of a negative coefficient for the number of competitors in an estimate in table 2. It is also quite compatible with the result for the variable for market mobility (net market entry rate with respect to employment; column 1 and 2 in table 8). The coefficient for the net market entry rate as to the number of firms is also negative but not significant. Throughout the estimates in table 8 we find a negative correlation of the intensity of price competition and no significant correlation for the intensity of non-price competition. Markets with strong price competition are often not concentrated (but not exclusively; for example, one can find fierce price competition in a duopoly). Thus, this effect is accordance with the findings for the other competition variables. In a last step we investigate whether the overall market mobility effect of *net* market entry is primarily entry-driven or exit-driven. The results in table 9 show that the market mobility effect is primarily driven by the entry of new firms independent of their relative size.

Table 8
Average labour productivity and competition 1994-2005; lagged right-hand variables;
all firms

	Ln(Q/L) _t	Ln(Q/L) _t	Ln(Q/L) _t	Ln(Q/L) _t
Ln(Q/L) _{t-1}		0.251*** (0.029)		0.255*** (0.030)
Ln(C/L) _{t-1}	0.017*** (0.004)	0.033*** (0.011)	0.017*** (0.004)	0.032*** (0.011)
Ln(R&D/S) _{t-1}	0.050 (0.052)	0.043 (0.049)	0.047 (0.052)	0.040 (0.049)
Ln(HQUAL) _{t-1}	0.016*** (0.006)	0.013** (0.006)	0.016*** (0.006)	0.014** (0.006)
Ln(CONC5) _{t-1}	0.068** (0.029)	0.068** (0.028)	0.064** (0.028)	0.062*** (0.026)
N_ENTRY_L _t	-0.012*** (0.004)	-0.012*** (0.004)		
N_ENTRY_N _t			-0.008 (0.006)	-0.009 (0.005)
IPC _{t-1}	-0.019** (0.009)	-0.016* (0.008)	-0.019** (0.009)	-0.015* (0.008)
INPC _{t-1}	0.002 (0.009)	-0.000 (0.009)	0.003 (0.009)	0.000 (0.009)
FOREIGN _{t-1}	0.177*** (0.030)	0.150*** (0.029)	0.181*** (0.030)	0.153*** (0.029)
Ln(L) _{t-1}	0.038*** (0.008)	0.033*** (0.008)	0.038*** (0.008)	0.033*** (0.008)
Industry dummies (27)	Yes	Yes	Yes	Yes
Time dummies (2)	Yes	Yes	Yes	Yes
N	2744	2744	2744	2744
R2 overall	0.240	0.320	0.239	0.319
R2 within	0.004	0.011	0.001	0.017
R2 between	0.264	0.369	0.239	0.371
Wald chi2	444.3***	552.3***	446.7***	557.0***
Rho	0.308	0.269	0.305	0.265

Random effects GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%- level resp. All variables with the exception of the variables measuring market mobility refer to the period (t-1); the market mobility variables refer to changes between (t-1) and t. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Table 9
Average labour productivity and competition; 1994-
2005. all firms; alternative measures of market mobility

	$\ln(Q/L)_t$	$\ln(C/L)_t$; $\ln(Q/L)_{t-1}$
ENTRY_L _t	-0.013** (0.006)	-0.014** (0.005)
ENTRY_N _t	-0.016* (0.009)	-0.016* (0.009)
EXIT_L _t	-0.001 (0.001)	0.010 (0.008)
EXIT_N _t	-0.001 (0.013)	0.003 (0.012)
NCOMPET _{t-1}	-0.008 (0.007)	-0.007 (0.007)

The variables ENTRY_L, ENTRY_N, EXIT_L and EXIT_N are alternative measures for N_ENTRY_L; NCOMPET is an alternative measure for $\ln(\text{CONC5})$. Only the coefficients of the alternative variables for market mobility are presented. The specification of all other variables is as in Table 8. Random effects GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp.

5.2 Industry level

Education

Table 10 shows the estimates of a first version of eq. (3) focusing on the education variables. Besides positive effects for physical capital power employee (C/L; as in the estimates at firm level), R&D expenditures per employee (R&D/L; no significant effect at firm level) and export intensity (EXP/S) we find clearly significantly positive effects for both categories of employees (HQUAL; employees with tertiary-level education; MQUAL; employees with formal vocational education).⁵ The latter effect is not clear at firm level, where we find a positive effect only for low-productivity firms. Thus, there is a discernible difference between firm-level and industry-level estimates with respect not only to the middle-educated employees but also to R&D expenditures per employee. The results at industry level have to be considered with some caution because we had to leave out time dummies in order to obtain stable estimates. Time dummies control for differences in the cyclical position of the economy, in this sense dropping them might cause considerable distortions of the estimated coefficients.

Competition

Table 11 presents the results of a further version of eq. (3) concentrating in this case on the competition variables. We omit the human capital variable because of multicollinearity with the R&D variable (the coefficients of the R&D variable are considerably larger in table 11 than in table 10 and significant even in the fixed effects estimates). Once more we find significantly positive effects for capital, export intensity and R&D intensity. Moreover, the estimates in table 11 yield a clearly negative effect of both market mobility variables (used alternatively: net entry market rate and entry market rate) as well as a positive effect for – alternatively – the market concentration. These competition effects are compatible not only to each other but also to the findings at firm level. Finally, table 12 shows the estimates with the market behaviour variables IPC and INPC. For IPC we find a negative but statistically insignificant coefficient, for INPC a positive and statistically significant coefficient; these effects tend to be at least partially in accordance to the results at firm level.

For the data at industry level that build a balanced panel we tested also first difference equations.⁶ Unfortunately the first difference equations yielded few significant results (see

⁵ We estimated the productivity equation separately for high-educated and middle-educated employees in order to avoid multicollinearity of these two variables. Table 10a shows the results when we include both variables in the estimates. In this case the positive coefficient for the middle-educated employees is significantly positive in the RE estimates and becomes statistically insignificant in the FE estimates. Further, a chi2-test on the difference of the coefficients of the variables $\ln(\text{HQUAL})$ and $\ln(\text{MQUAL})$ shows that the coefficient of the variable $\ln(\text{HQUAL})$ is not significantly larger than that of $\ln(\text{MQUAL})$ in column 2 in table 10a.

⁶ In addition to eq. (3) we also specified the following first difference equation:

table 13). However, there is clear evidence also in this case for the positive contribution of physical capital, the (level of) export intensity and market concentration. Also here holds the reservation with respect to the time dummies already mentioned in the paragraph for education.

$$\Delta \ln(Q/L)_{it} = \alpha_0 + \alpha_1 \Delta \ln(C/L)_{it} + \alpha_2 (\Delta) \ln(R\&D/L)_{it} + \beta_3 (\Delta) \ln(EXP/S)_{it} + \beta_4_ENTRY_N_{it} \text{ [alternatively: } \ln(CONC5)_{it}] + \text{control variables for time} + e_{it} \quad (\text{industry } i) \quad (3a)$$

Table 10**Average labour productivity and vocational education at industry level; 1991-2005**

	ln(Q/L) _t			Ln(Q/L) _t		
	pooled	FE	RE	pooled	FE	RE
Ln(C/L) _t	0.249*** (0.025)	0.229*** (0.038)	0.251*** (0.030)	0.245*** (0.026)	0.222*** (0.038)	0.236*** (0.031)
ln(R&D/L) _t	0.005 (0.010)	0.013 (0.010)	0.014* (0.008)	0.032*** (0.009)	0.017* (0.090)	0.024*** (0.008)
ln(HQUAL) _t	0.235*** (0.029)	0.083** (0.033)	0.146*** (0.028)			
ln(MQUAL) _t				0.180*** (0.046)	0.059 (0.050)	0.103** (0.044)
ln(EXP/S) _t	0.029*** (0.011)	0.041*** (0.016)	0.039*** (0.013)	0.033** (0.015)	0.036** (0.016)	0.036*** (0.016)
Time dummies (4)	Yes	No	No	Yes	No	No
N	360	360	360	360	360	360
R2 overall	0.454	0.357	0.390	0.341	0.281	0.295
R2 within		0.163	0.157		0.148	0.146
R2 between		0.445	0.498		0.281	0.366
F	33.8***	13.8***		16.2***	12.3***	
Wald chi2			116.9***			85.3***
Root MSE	0.294			0.322		
Rho		0.584	0.489		0.614	0.561

Random-effects (RE) and fixed-effects (FE) GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Table 10a
Average labour productivity and vocational education
at industry level; 1991-2005

	ln(Q/L) _t FE	ln(Q/L) _t RE
ln(C/L) _t	0.228*** (0.038)	0.245*** (0.029)
ln(R&D/L) _t	0.013 (0.010)	0.014* (0.008)
ln(HQUAL) _t	0.088** (0.033)	0.150*** (0.027)
ln(MQUAL) _t	0.072 (0.049)	0.119*** (0.043)
ln(EXP/S) _t	0.041*** (0.016)	0.041*** (0.013)
Time Dummies (4)	No	No
N	360	360
R2 overall	0.387	0.421
R2 within	0.169	0.163
R2 between	0.487	0.421
Wald chi2	11.5***	129.1***
Rho	0.567	0.474

Random-effects (RE) and fixed-effects (FE) GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Table 11
Average labour productivity and vocational education at industry level (2); 1991-2005

	Ln(Q/L) _t			Ln(Q/L) _t			Ln(Q/L) _t		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
Ln(C/L) _t	0.257**** (0.027)	0.204*** (0.039)	0.233*** (0.032)	0.247*** (0.027)	0.204*** (0.039)	0.220*** (0.031)	0.246*** (0.027)	0.218*** (0.038)	0.238*** (0.031)
Ln(EXP/S) _t	0.033** (0.014)	0.034** (0.016)	0.034*** (0.013)	0.030** (0.013)	0.034** (0.016)	0.028** (0.014)	0.013 (0.016)	0.034** (0.016)	0.028** (0.014)
Ln(R&D/L) _t	0.027*** (0.009)	0.017* (0.009)	0.023*** (0.008)	0.028**** (0.010)	0.017**** (0.009)	0.022*** (0.008)	0.029**** (0.010)	0.017* (0.008)	0.022*** (0.008)
N_ENTRY_N _t	0.003*** c (0.001)	-0.002** (0.001)	-0.001 (0.001)						
ENTRY_N _t				0.004*** (0.001)	-0.002** (0.001)	-0.004*** (0.001)			
Ln(CONC5) _t							0.045* (0.024)	0.121** (0.060)	0.055* (0.030)
Time dummies (4)	Yes	No	No	Yes	No	No	Yes	No	No
N	360	360	360	360	360	360	360	360	360
R2 overall	0.332	0.213	0.244	0.331	0.163	0.193	0.318	0.212	0.262
R2 within		0.163	0.157		0.236	0.243		0.156	0.151
R2 between		0.236	0.284		0.213	0.226		0.237	0.309
F	16.9***	13.8***		17.3***	13.8***		19.5***	13.1***	
Wald chi2			80.5***			89.9***			81.2***
Root MSE	0.325			0.325			0.328		
Rho		0.646	0.571		0.646	0.599		0.645	0.591

Random-effects (RE) and fixed-effects (FE) GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Table 12
Average Labour Productivity and Intensity of Price and Non-price Competition

	Ln(Q/L) _t Pooled	FE	RE
Ln(C/L) _t	0.259*** (0.025)	0.225*** (0.038)	0.243*** (0.031)
Ln(EXP/S) _t	0.027** (0.013)	0.037** (0.016)	0.037*** (0.013)
Ln(R&D/L) _t	0.024** (0.010)	0.016* (0.010)	0.022*** (0.008)
Ln(IPC) _t	-0.080 (0.050)	-0.055 (0.056)	-0.059 (0.053)
Ln(INPC) _t	0.133*** (0.034)	0.024 (0.027)	0.046* (0.026)
Time dummies (4)	Yes	No	No
N	360	360	360
R2 overall	0.347	0.271	0.284
R2 within		0.149	0.148
R2 between		0.327	0.349
F	20.0***	10.0***	
Wald chi2			84.5***
Root MSE	0.321		
Rho		0.617	0.552

Random-effects (RE) and fixed-effects (FE) GLS estimates; ***, ** and * resp. denote statistical significance at the 1%-, 5%- and 10%-level resp. Rho: fraction of variance due to firm heterogeneity (individual residual u_i).

Tabelle 13
Average productivity; Differences equations

	$\Delta \ln(Q/L)$	$\Delta \ln(Q/L)$	$\Delta \ln(Q/L)$	$\Delta \ln(Q/L)$
$\Delta \ln(C/L)_t$	0.116* (0.065)	0.108* (0.062)	0.107* (0.063)	0.112* (0.066)
$\Delta \ln(R\&D/L)_t$	-0.010 (0.015)			-0.008 (0.015)
$\Delta \ln(EXP/S)_t$	0.013 (0.010)			0.014 (0.010)
$\ln(R\&D/L)_t$		-0.002 (0.003)	-0.002 (0.003)	
$\ln(EXP/S)_t$		0.009*** (0.003)	0.009*** (0.003)	
$N_ENTRY_N_t$	-9.8E-05 (2.1E-04)		-3.9E-05 (2.1E-04)	
$\ln(CONC5)_t$				0.007** (0.003)
Time dummies	Yes	Yes	Yes	Yes
N	288	288	288	288
R2	0.107	0.095	0.096	0.076
F	1.7*	4.3***	3.7***	4.0***
Root MSE	0.064	0.063	0.063	0.064

OLS estimates; ***, ** and * denote statistical significance at the 1%-, 5%- and 10%-level resp.

6. Conclusions

6.1 Role of human capital

Firm level

Human capital is measured in this study by the share of employees (a) with (academic education); (b) with tertiary education other than university; and (c) with upper secondary vocational education (“Berufslehre”). As implicit reference group we use employees with no formal vocational education.

Throughout our firm-level estimations we find a significant positive effect for the share of employees with academic education on labour productivity at the firm level. A significant positive effect is also found for the share of the employees of employees with tertiary education (without academic university) for all firms but this effect can be traced back primarily to manufacturing firms. In manufacturing, particularly in machinery, electrical machinery and electronics/instruments (less in chemical and pharmaceutical industry) there is in Switzerland a long tradition of employing engineers and technicians of this category that are mostly occupied in production and marketing activities.

Less clear is the situation for “middle-educated” employees that build in most firms the largest part of employees. In the estimates with lagged right-hand variables (our preferred version) we find no significant effect of the share of this important category of employees on productivity. We obtain a significant positive effect only in the estimates for all firms without lags. Quantile regressions reveal that there are discernible differences between low-productivity and high-productivity firms with respect to the contribution of this employee category to productivity; these differences seem to be quite sector-specific. In manufacturing for the 50% lower-productivity firms a positive effect of the share of middle-educated employee is estimated, but no such threshold can be found for service industries where throughout no significant effects can be estimated. The threshold with respect to the middle-educated effect between low-productivity and high-productivity moves up to higher levels of productivity when contemporaneous right-hand variables are used: 60% of lower-productivity firms show in this case a positive effect; even for service industries we find such an effect up to the same threshold as in manufacturing. Thus, the (partially) positive effect up to some threshold for manufacturing appears to be more robust than that for services. These results are in accordance with the (scarce) similar studies for other countries.

In order to assess adequately these results we have to take into consideration that there may exist some measurement error due to the fact that this employee category is much broader than the other two, thus much more heterogeneous than these: besides, e.g., so-called “poly-mechanics” (with a multi-functional vocational education) we find in the same aggregate of middle-educated employees also much simpler occupations, e.g., of shop-assistants. Distinguishing between categories of occupations with different technological profiles would presumably have led to more differentiated results. Unfortunately no such data are available. However even if we keep this in mind, it is still undeniable that our estimates show a difference between high-productivity firms (that are mostly also the most innovative and technologically advanced) and low-productivity firms with respect to the engagement of middle-educated employees. This result seems also to be in accordance with the technological frontier approach of Vandebussche et al. (2006) as described shortly in section 2 (middle-educated employees are relatively less productive the nearer to the technological frontier the firm operates).

Industry level

At industry level we obtain a somewhat more positive picture with respect to the contribution of the share of middle-educated employees (who are measured at exactly the same way as firm level; referenced group is also in this case is the group of employees without formal vocational education) to productivity. The coefficient of the respective variable is significantly positive. A possible explanation for this positive effect could be that our sample

of industries contains relatively few service industries as compared to manufacturing industries (56 out of totally 73 industries are manufacturing industries).

Role of competition

We investigate competition effects based on three types of indicators measuring different aspects of competition: market structure (market concentration); market mobility (market entry and exit rates); market behaviour (intensity of price and non-price competition). The competition effects at firm and industry level are quite compatible to each other. We find a negative effect of market entry rates and a (complementary to it) positive effect of market concentration. The effect of the intensity of price competition is negative in some estimates at firm level, while the effect of non-price competition is positive in some estimate at industry level.

On the whole, the emerging pattern is one of specialized “niche” markets (some kind of monopolistic competition) where firms develop new products and new production techniques that lead to high productivity that keeps entry lower and concentration higher than in markets with low productivity.

Finally, it is difficult to say anything about the influence of macroeconomic conditions on these effects because the reference period is characterized by both troughs and peaks of economic activity the impact of which cannot be identified based on information of only four firm cross-sections and four industry cross-sections respectively. However, the results at industry level have to be considered with some caution because we had to leave out time dummies in order to obtain stable estimates as already mentioned in section

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Appendix

Table A.1
Composition of the dataset at firm level

Industry	N	Percentage of firms
<i>Manufacturing</i>		
Food, beverage, tobacco	348	4.0
Textiles	138	1.6
Clothing, leather	61	0.7
Wood processing	196	2.2
Paper	108	1.2
Printing	276	3.2
Chemicals	279	3.2
Plastics, rubber	219	2.5
Glass, stone, clay	196	2.2
Metal	107	1.2
Metalworking	638	7.3
Machinery	733	8.4
Electrical machinery	210	2.4
Electronics, instruments	449	5.2
Watches	156	1.8
Vehicles	91	1.0
Other manufacturing	188	2.2
Energy	123	1.4
<i>Construction</i>	870	9.8
<i>Services</i>		
Wholesale trade	747	8.4
Retail trade	558	6.4
Hotels, restaurants	343	3.9
Transport, telecommunication	433	5.0
Banking, insurance	359	4.1
Leasing, real estate	60	0.7
Computer services	180	2.1
Other business services	613	7.0
Personal services	78	0.9
<i>Firm size</i>		
5 to 49 employees	4409	50.3
50-249 employees	3080	35.2
250 employees and more	1268	14.5
Year 1996	1863	21.3
Year 1999	2012	23.0
Year 2002	2412	27.5
Year 2005	2470	28.2
Total	8757	100.0

Table A.2
Value added and share of middle-educated employees by industry 2005

Industry	Share of nominal value added (National Accounts)	Share of nominal value added (KOF-sample)	Share of middle-educated employees
<i>Manufacturing</i>			
Food, beverage, tobacco	2.6	4.9	38.3
Textiles	0.3	1.1	27.9
Clothing, leather	0.1	0.3	34.6
Wood processing	1.0	1.4	46.1
Paper	0.5	0.9	42.2
Printing	1.5	2.3	56.8
Chemicals	5.1	4.7	56.1
Plastics, rubber	0.8	1.7	39.1
Glass, stone, clay	0.7	1.8	38.8
Metal	0.5	0.9	38.7
Metalworking	2.5	4.9	44.1
Machinery	3.8	8.4	52.5
Electrical machinery/electronics/watches	5.9	10.0	34.0
Vehicles	0.5	1.0	54.8
Other manufacturing	0.8	1.2	34.2
Energy	2.8	3.3	51.5
<i>Construction</i>	7.9	7.9	48.1
<i>Services</i>			
Wholesale/retail trade	18.8	15.4	58.6
Hotels, restaurants	3.3	2.1	39.7
Transport	5.0	4.8	67.4
Telecommunication	4.3	0.9	36.9
Banking, insurance	16.7	9.4	50.7
Computer services/R&D	3.3	8.0	31.6
Leasing/real estate/other business services	11.3	2.6	36.9

Share of business sector total value added (71% of total value added of the entire economy).

Table A.3
Average share of high-educated and middle-educated employees for SMEs and larger firms by sector

	SMEs	Large firms
<i>All firms</i>		
HQUAL1	4.5	5.6
HQUAL2	12.5	13.9
MQUAL	47.4	45.0
<i>Manufacturing</i>		
HQUAL1	3.3	5.3
HQUAL2	12.2	13.5
MQUAL	45.0	41.8
<i>Services</i>		
HQUAL1	7.1	7.2
HQUAL2	13.3	15.2
MQUAL	51.1	51.2

Table A.4**Industries; matching of industries for two classification systems; deflators**

B_Ind	NOGA 1995	Industry General Classification 1985 (until 1996)		Deflator (Index; reference year: 1990)
1	151	211	Schlachten und Fleischverarbeitung	PPI Food
2	153	214	Verarbeitung und Konservierung von Gemüse	PPI Food
3	155	212	Verarbeitung von Milch	PPI Food
4	156+157	213	Mahl- und Schälmaschinen/Stärke + Futtermittel	PPI Food
5	158	215+216+217	sonstige Nahrungsmittel	PPI Food
6	159	22	Herstellung von Getränken	PPI Food
7	16	23	Tabakverarbeitung	PPI Food
8	171	241	Textilgewerbe	PPI Textiles, clothing
9	172	242	Weberei	PPI Textiles, clothing
10	173	246	Textilveredlung	PPI Textiles, clothing
11	174	254	Herstellung von konfektionierten Textilwaren	PPI Textiles, clothing
12	175	245+247	sonstiges Textilgewerbe	PPI Textiles, clothing
13	176+177	252	Herstellung von gewirktem und gestricktem Stoff	PPI Textiles, clothing
14	182	251+253	Herstellung von Textilbekleidung	PPI Textiles, clothing
15	192	292	Herstellung von Reiseartikeln, Leder, Sattelwaren	PPI Textiles, clothing
16	193	293	Herstellung von Schuhen	PPI Textiles, clothing
17	201+202	261	Säge, Hobel, Holzimprägnierung, Holzplattenwerke	PPI Wood
18	203+204	264	Herst. von Konstruktionsteilen/Verpackung aus Holz	PPI Wood
19	211	271	Herstellung Holzstoff, Papier, Karton und Pappe	PPI Paper
20	212	272	Waren aus Papier Karton Pappe	PPI Paper
21	221	284	Verlagsgewerbe	PPI Paper
22	222	282	Druckgewerbe	PPI Paper
23	241	311+3122+3128	Chemische Grundstoffe	PPI Chemicals
24	243	3123+3124	Anstrichmittel, Druckfarben, Kitt	PPI Chemicals
25	244	3121	Pharmazeutische Industrie	PPI Chemicals
26	245	3125+3127	Seifen, Waschmittel, Körperpflege	PPI Chemicals
27	246	313+3126	Sonstige Chemische Erzeugnisse	PPI Chemicals
28	251	322	Gummiwaren	PPI Plastics
29	252	321	Kunststoffwaren	PPI Plastics
30	261	336	Glas und Glaswaren	PPI Glass, stone, clay

B_Ind	NOGA	Industry General Classification 1985 (until 1996)		Deflator (Index; reference year: 1990)
31	262+263+264	335	Keramische Erzeugnisse, Fliesplatten, Ziegel	PPI Glass, stone, clay
32	265+266	333	Zement, Kalk, Gips, Erzeugnisse daraus	PPI Glass, stone, clay
33	267	331	Natursteinverarbeitung	PPI Glass, stone, clay
34	268	334	Sonstige Produkte aus nichtmetallischen Mineralien	PPI Glass, stone, clay
35	271	341	Erzeugung von Roheisen, Stahl und Ferrolegierungen	PPI Metal
36	274	342	Erzeugung und Erstverarbeitung von Metallen	PPI Metal
37	275	343	Giesserei	PPI Metal
38	281	345	Stahl und Leichtmetallbau	PPI Metal
39	286	346	Schneidwaren, Werkzeugen etc.	PPI Metal
40	291	3522+ 3523	Herstellung von Maschinen etc.	PPI Machinery
41	292	3521+ 3525	Sonstige Maschinen für unspezifische Verwendung	PPI Machinery
42	294	3514	Werkzeugmaschinen	PPI Machinery
43	295	3512+3513+3515+3518+3519	Sonstige Maschinen	PPI Machinery
44	297	3618	Haushaltsgeräte	PPI Machinery
45	311	3611	Elektromotore, Generatoren etc.	PPI Electrical machinery
46	312	3612	Elektrizitätsverteilung etc.	PPI Electrical machinery
47	321	3622	Elektronische Bauelemente	PPI Electrical machinery
48	322	3617	Radio- , Fernseh-, Nachrichtentechnik-Geräte	PPI Electrical machinery
49	331	3634	Medizinische und chirurgische Geräte	PPI Electrical machinery
50	332	3616+3633	Mess- und Kontrollinstrumente	PPI Electrical machinery
51	334	3631+3632	Optische und photographische Geräte	PPI Electrical machinery
52	335	371	Uhren	PPI Electrical machinery
53	341+342	3541	Automobile, Karosserien und Anhänger	PPI Vehicles
54	352	3545	Schienenfahrzeugbau	PPI Vehicles
55	361	263	Möbelherstellung	PPI Wood
56	362	372	Schmuck und ähnliches	PPI Total Manufacturing
57	452	41	Hoch- u. Tiefbau	VGR Construction
58	453	421	Bauinstallation	VGR Construction
59	454	422	Ausbaugewerbe	VGR Construction
60	51	51+52+53+54	Handelsvermittlung und Grosshandel	VGR Trade
61	52	55+56	Detailhandel, Reparatur	VGR Transport/Telecommunication
62	551+553+555	57	Hotels, Restaurants, Kantinen	VGR Hotels, restaurants
63	60	61+62	Landverkehr	VGR Transport/Telecommunication

B_Ind	NOGA	Industry General Classification 1985 (until 1996)		Deflator (Index; reference year: 1990)
64	61	63	Schifffahrt	VGR Transport/Telecommunication
65	62	64	Luftfahrt	VGR Transport/Telecommunication
66	63	65	Hilfs- und Nebentätigkeiten für den Verkehr, Reisebüros	VGR Transport/Telecommunication
67	641+642 (64)	66	Nachrichtenübermittlung	VGR Transport/Telecommunication
68	70	73	Immobilienwesen	VGR Real estate, leasing, computer services, R&D services
69	71	74	Vermietung beweglicher Sachen	VGR Real estate, leasing, computer services, R&D services
70	72	755	Informatikdienste	VGR Real estate, leasing, computer services, R&D services
71	73	82	FuE	VGR Real estate, leasing, computer services, R&D services
72	741+742+743+744+745+748	751+752+753+754+383	Geschäftsdienstleistungen	VGR Other services
73	65	71	Kreditgewerbe	VGR Banking
74	66	72	Versicherungsgewerbe	VGR Insurance

PPI: Producer Price Index; VGR: Deflator of National Accounts. Source: SFSO, authors' calculations.

Table A.5: Descriptive statistics; firm data

Variable	Manu- facturing		Services		All firms	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	N=4516		N=3371		N=8757	
L(Q/L)	11.811	0.445	11.940	0.687	11.842	0.555
Ln(L)	4.100	1.414	3.961	1.586	3.951	1.483
Ln(C/L)	10.493	2.248	10.753	2.274	10.526	2.332
Ln(R&D/S)	-2.167	0.235	-2.248	0.214	-2.211	0.220
Ln(HQUAL)						
Ln(HQUAL1)	-0.263	2.004	-0.230	2.335	-0.345	2.124
Ln(HQUAL2)	1.836	1.673	1.581	2.070	1.734	1.836
Ln(MQUAL)	3.576	0.964	3.552	1.353	3.572	1.132
FOREIGN	0.142	0.349	0.130	0.336	0.128	0.334
NCOMPET	2.588	1.408	2.994	1.595	2.823	1.504
IPC	4.017	1.018	3.813	1.115	3.956	1.079
INPC	3.242	0.933	3.243	1.003	3.194	0.980
					N=2744	
Ln(CONC5)					2.059	1.161
N_ENTR_N					-0.656	2.227
N_ENTRY_L					-0.437	2.479
ENTRY_N					2.793	1.939
ENTRY_L					4.785	1.656
EXIT_N					3.114	1.263
EXIT_L					5.205	1.275

Table A.6: Descriptive statistics; industry data

Variable	Mean	Standard deviation
	N=365	
L(Q/L)	4.730	0.419
Ln(C/L)	4.298	0.671
Ln(R&D/S)	-0.831	2.036
Ln(HQUAL)	2.688	0.688
Ln(MQUAL)	3.652	0.406
FOREIGN	2.204	1.003
IPC	4.254	0.292
INPC	3.614	0.556
Ln(CONC5)	2.988	1.036
N_ENTRY_L	-0.457	4.512
ENTRY_L	5.057	2.554
EXIT_L	5.185	1.865

Table A.7: Correlations; firm level; all firms; education-focused model

	Ln(L)	Ln(C/L)	LN (R&D/S)	Ln (HQUAL1)	Ln (HQUAL2)	Ln (MQUAL)	FOREIGN	NCOMP ET	IPC
Ln(L)	1.000								
Ln(C/L)	0.062	1.000							
Ln(R&D/S)	0.075	-0.031	1.000						
Ln(HQUAL1)	0.284	0.036	0.278	1.000					
Ln(HQUAL2)	0.256	0.023	0.141	0.245	1.000				
Ln(MQUAL)	0.113	0.047	-0.069	-0.125	-0.082	1.000			
FOREIGN	0.137	0.054	0.071	0.138	0.113	0.007	1.000		
MCOMPET	-0.138	-0.005	-0.142	-0.109	-0.079	-0.015	-0.108	1.000	
IPC	0.133	-0.005	-0.161	-0.012	0.056	0.046	0.029	0.114	1.000
INPC	0.066	0.042	0.097	0.056	0.035	0.018	0.082	0.050	0.106

Table A.8: Correlations; firm level; all firms; competition-focused model

	Ln(L)	Ln(C/L)	LN (R&D/S)	Ln (HQUAL)	FOREIGN	LN (CONC5)	N_ENTRY _N	N_ENT RY_L	ENTRY _N	ENTRY _L	EXIT_N	EXIT_L	IPC
Ln(L)	1.000												
Ln(C/L)	0.046	1.000											
Ln(R&D/S)	0.103	-0.010	1.000										
Ln(HQUAL)	0.215	0.109	0.226	1.000									
FOREIGN	0.119	0.042	0.069	0.108	1.000								
Ln(CONC5)	0.211	0.060	0.301	0.129	0.131	1.000							
N_ENTRY_N	-0.072	0.035	0.075	0.024	-0.034	-0.093	1.000						
N_ENTRY_L	-0.028	0.011	0.080	0.071	-0.004	-0.241	0.410	1.000					
ENTRY_N	-0.047	0.016	0.077	0.122	0.019	-0.196	0.371	0.510	1.000				
ENTRY_L	-0.066	0.011	0.044	0.035	-0.035	-0.201	0.669	0.407	0.696	1.000			
EXIT_N	0.009	-0.001	0.022	0.058	0.007	-0.028	0.051	-0.232	0.640	0.466	1.000		
EXIT_L	-0.074	-0.023	-0.028	0.026	-0.022	-0.226	-0.298	0.053	0.510			1.000	
IPC	0.157	-0.039	-0.005	0.032	0.032	0.036	-0.123	-0.041	-0.072	-0.094	-0.035	0.014	1.000
INPC	0.088	0.051	0.117	0.051	0.090	0.097	0.027	0.021	0.048	0.040	0.036	0.036	0.101

Table A.9: Correlations; industry level

	Ln(C/L)	Ln(R&D/L)	Ln(HQUAL)	Ln(MQUAL)	Ln(FIN)	Ln(EXP/S)	FOREIGN	Ln(CONC5)	N_ENTR Y-N	ENTRY_ N	EXIT_N	IPC
Ln(C/L)	1.000											
Ln(R&D/L)	-0.104	1.000										
Ln(HQUAL)	-0.016	0.384	1.000									
Ln(MQUAL)	0.134	-0.092	0.071	1.000								
LN(FIN)	-0.118	0.207	-0.210	-0.034	1.000							
LN(EXP/S)	-0.210	0.443	0.135	-0.130	0.186	1.000						
FOREIGN	-0.170	0.116	0.339	0.035	0.008	0.339	1.000					
Ln(CONC5)	-0.040	0.313	0.072	-0.268	0.149	0.520	0.187	1.000				
N_ENTRY_N	-0.060	0.008	0.321	0.138	-0.132	-0.090	0.125	-0.253	1.000			
ENTRY_N	0.020	0.106	0.374	0.093	-0.076	-0.045	0.105	-0.158	0.573	1.000		
EXIT_N	0.105	0.035	0.104	-0.090	0.038	0.001	0.014	0.071	-0.259	0.485	1.000	
IPC	-0.083	0.110	-0.048	0.102	-0.043	0.048	0.036	0.036	-0.077	-0.084	-0.016	1.000
INPC	-0.081	0.227	0.259	0.166	0.186	0.128	0.200	0.053	0.105	0.126	0.014	0.035