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Human Capital and Regional Growth in Switzerland

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Abstract

This paper develops a regional production function model for Swiss cantons that incorporates human capital together with spatial effects. Within a spatial panel framework we find that controlling for time effects the spatial spillover effect becomes insignificant. Our results are sensitive with respect to the human capital proxy. We find that the share of academics in the workforce is the main component of human capital driving productivity growth in Swiss cantons. This is in line with findings of previous studies suggesting that mostly highly skilled workers matter for productivity growth in technologically advanced economies.

Keywords
Production function with human capital, spatial panel, regional growth

JEL Classification
C21, C23, I22, J23, R11, R12

Comments
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Contents

1. Introduction

Human capital is recognized as one of the key determinants of growth today (see OECD, 2001). This especially applies to modern developed economies such as Switzerland, as industries with a large share of unskilled labour have moved to other countries of the world as a consequence of their comparative advantage. Even though this has been a known fact for years, there are not many empirical studies focusing on the effect of human capital that have investigated the impact of human capital solely for developed economies. Most cross-country and cross-regional studies have the problem that they are mixing developed and non-developed countries or regions (see e.g. Mankiw, Romer, and Weil (1992) for countries or Badinger and Tondl (2005) for regions).

Given the higher labour productivity and higher capital intensity, human capital accumulation potentially plays a much more significant role for developed economies than for non-developed countries. One of the reasons for mixing economies at various stages of development appears to be the need to gather a sufficiently large dataset.

Human capital can be defined as the skills and knowledge of workers obtained through education and experience. It was already described by Adam Smith as one of the four main inputs for production, next to useful machines, buildings and the improvements of land. Modern macroeconomics has intensified research in this area since the seminal work of Gary Becker (1964). The problem of measuring human capital is still unsolved and depends on the type of research focus. Following Becker, the human capital literature often distinguishes between "specific" and "general" human capital. Specific human capital refers to skills or knowledge that is useful only to a single employer or industry, whereas general human capital (such as literacy) is useful to all employers.

We try to proxy human capital by some available macro variables which reflect the cumulated education of the workers.[1] The problem with this approach is that it is a one-dimensional concept and does not take into account the many possibilities to use human capital optimal in production. Human capital needs an efficient combination with the other input factors of production to yield the best outcome in terms of growth. A good example is the human capital of East German workers after unification in 1990. Most of their acquired human capital was not useful anymore, because it had to be used in conjunction with new production technologies and physical capital from the West, meaning a lot of write-offs of old human capital and the build up of new human capital in the new production process. This shows that the right combination of input factors in the production is responsible for optimal growth, given the same endowment of input factors.

[1] We leave out medical care, as proposed by Becker (2008), because for the Swiss Cantons there is no reason to believe that this indicator shows much variation.

Essentially, the supply and demand for human capital is strongly intertwined with the production facilities of an economy. In cross-country studies the production facilities can vary substantially and therefore the effect of human capital will be blurred because of the varying circumstances. Therefore it is more interesting to study the pure effects of human capital in an economic setting where the other factors of production stay approximately constant. These considerations give rise to the question if the effects of human capital could be larger within a country because the other factors of production are more constant. Switzerland is a good study object, because it has a highly developed economy (specialized in financial services, pharmaceuticals and hi-tech products), but the educational and cultural politics across the 26 cantons is rather independent and diversified. Thus, economic growth across cantons might be dependent on the successful supply of human capital.

Finally we want to mention that an extension of the concept of human capital is "social capital", a term used to describe the characteristics of social organization such as trust, norms, and networks (Coleman, 1990). Clearly, the empirical measurement of social capital is even more demanding than human capital and will be a topic for future analysis of growth.

Previous studies on growth and human capital (see Sianesi and Van Reenen (2003) or Krueger and Lindahl (2001) for an overview) have shown a connection between human capital and growth, but in cross-country studies. Only a few studies have addressed the problem of regional growth and human capital as in Vanhoudt et al. (2000), Badinger and Tondl (2005) or Turner et al. (2006).

This paper is organised as follows: Section 2 discusses the effects of human capital on growth in the modern growth literature and discusses some empirical results. Section 3 discusses data issues and the econometric model used for this analysis and shows the estimation results. Section 4 concludes.

2. The effects of human capital on growth

2.1. Human capital models

Since the 1980s two models formalised the idea how human capital influences economic performance more explicitly. Lucas (1988), drawing on Uzawa (1965), defined human capital as a factor of production, which can be measured by the general skill levels of persons in an economy. It is therefore a private good, rivalrous and excludable in consumption. His model consists of two sectors, a production sector and an education sector. The production sector uses the human capital for production, which is the product of the education sector. It can be shown that for this class of models the equilibrium growth rate depends on the rate of human capital growth. The equilibrium growth rate of this economy is given by

$$\frac{\dot{y}}{y} = \frac{1-\alpha+\gamma}{1-\alpha}\frac{\dot{h}}{h}, \tag{1}$$

where α and γ are the elasticities of output with respect physical and human capital respectively.

Romer (1990) formulated a different model, which divides the economy into three sectors, a production sector, a technology sector and intermediary goods sector. Human capital has two functions in the Romer model, it is a production input for the production sector and it is also used to generate technological progress by research in the technology sector. Solving for the equilibrium growth rate it can be shown that the level of human capital drives the growth rate of the economy in equilibrium,

$$\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{A}}{A} = \sigma H_A, \tag{2}$$

where σ is the elasticity of technological progress with respect to human capital employed on the technology sector (H_A).

A third interesting approach focusing on the regional impact of human capital is provided by Ciccone (2002). Contrary to the national level, he explicitly considers the role of spatial spill-overs in a regional production function with human capital, which is also estimated and finds evidence that spatial spillovers are significant in Germany, France and the UK. In our approach we follow his line of reasoning in developing our empirical model.

2.2. Empirical Estimation of human capital effects

The role of human capital for production has been explored in many empirical macro-economic studies on the country and regional level.

A commonly mentioned publication is by Mankiw, Romer and Weil (1992), in which they estimated the effects of human capital in a Lucas-type specification for a cross-country sample between 0.23 and 0.37. As a measure of human capital they used the percentage of the working-age population that is in secondary school. The implication for regions in a high developed country might be limited.

Vanhoudt et al. (2000) conducted a study for European NUTS 2 regions and estimated the elasticity of human capital on output to be around 0.18 for the level regression. They used an index of the fraction of workers in basic, secondary and higher education.

Another example for a regional human capital augmented growth analysis is Badinger and Tondl (2005), who have investigated the influence of human capital, proxied by the share of higher educated population (ISCED-97 sectors 5 and 6), on value added growth in a Lucas-type specification. The authors found rather low elasticities for human capital on output: 0.05 to 0.07.

Their explanation for these results is the low data quality on a regional level. Estimating the equation in growth rates they found elasticities in the range of 0.03 to 0.04.

Turner et al. (2006) estimated the effects of an additional year of schooling on output per worker for the States of the USA between 11 and 15%. They used historical enrollment and population data to construct the average years of schooling for each state for the years 1840 to 2000.

Recently, Fischer et al. (2009) estimated the effects of human capital on output per worker for European regions in a Spatial Durbin framework, employing the neighboring human capital as an additional regressor. They found a direct output-elasticity with respect to human capital of 0.13, however, when taking into account the negative spatial feedbacks of human capital (due to the Spatial Durbin term) the total effects aren't statistically different from zero.

Among the regional studies for more advanced countries, Bronzini and Piselli (2009) estimated the social returns to human capital for Italian regions in a cointegration framework. They included regional and time fixed effects as well as spatial spillovers. In conclusion, a one percent increase in human capital – measured by the average years of schooling – increases productivity by approximately 0.38 percent.[2] Additionally, they found that human capital is exougenous in the long run and exerts the strongest impact on productivity.

Brunow and Hirte (2009) analyzed the impacts of human capital on German regions. They defined two measures of human capital: 1) the share of persons with university degree on the labour force and 2) the share of people in highly-skilled jobs or people who worked in a high skilled job before entering short-term unemployment. Depending on the definition their estimated productivity elasticities with respect to human capital lie in the range between 0.08 and 0.11.[3]

3. Estimating a regional production function for Switzerland

3.1. The econometric model

Our empirical model specifies the output of a Swiss canton determined by technological progress in Switzerland (A_t), the amount of human capital employed ($N_{it}H_{it}$), physical capital (K_{it}) and a weighted average of the output in other cantons $\left(\overline{Y_{Jt}}\right)$

$$Y_{it} = a_i A_t \left(N_{it} H_{it}^{\gamma}\right)^{\alpha} K_{it}^{1-\alpha} \left(\overline{Y_{Jt}}\right)^{\delta} \quad (3)$$

[2] The OLS results for Italian regions of Sterlacchini (2008) point to a similar magnitude of the effect of human capital on GDP per capita.
[3] Comparable human capital effects are found in Kosfeld et al. (2006).

where a_i is a cantonal fixed effect to capture all institutional differences not accounted for by the other production factors, such as taxation. It appears to be crucial to account for other institutional difference across Swiss cantons, as they have a larger degree of autonomy in terms of taxation than comparable regions in other European countries. Not taking into account these institutional differences would lead to a misspecification of the model. Furthermore regional spillovers should be considered as cantons considerably differ in size and population, which implies that production as well as mobility of the work force is highly interdependent between cantons.

As we have no data on the physical capital stock[4] on a cantonal level, we follow Ciccone's (2002) line of reasoning and assume that in the long run the free movement of physical capital across cantons assures that the rental price of physical capital across cantons is the same, i.e. $r_t = r_{it}$. Using this and substituting out capital by the capital demand function

$$K_{it} = \frac{(1-\alpha)}{r_t} Y_{it}, \tag{4}$$

yields

$$Y_{it} = f(a_i, A_t, H_{it}, N_{it}, \overline{Y_{jt}}). \tag{5}$$

Rearranging and taking logs we derive

$$\ln \frac{Y_{it}}{N_{it}} = \mu_i + \tau_t + \gamma \ln H_{it} + \rho W ln\, (\frac{Y_{jt}}{N_{jt}}) + u_{it}, \tag{6}$$

where $\mu_i = \frac{\ln(a_i)}{\alpha}$, $\tau_t = \frac{1}{\alpha}\left(\ln(A_t) + (1-\alpha)\ln\frac{(1-\alpha)}{r_t}\right)$, $\rho = \frac{\delta}{\alpha}$ and u_{it} being an i.i.d error term. For the specification of the spatial effects we use a row-normalized matrix (see Anselin, 1988) of the inverse driving times between Swiss cantons. We limit the spatial neighborhood by setting all entries to 0 that are above 120 minutes. We tested different thresholds (60, 90, 120, 180, 210 and no restriction) and this cut-off point showed the smallest log likelihood statistics of most models considered in this paper.

Model (6) is a SAR (=spatial autoregressive) panel model with regional and period fixed effects. The model is estimated by the maximum likelihood estimator proposed by Elhorst (2003).

3.2. Data

Regional output was measured by the cantonal regional income, which is calculated annually by the Swiss statistical office (BfS: Bundesamt für Statistik) since 1965. Furthermore we used the population census data for the years 1970, 1980, 1990 and 2000. They contain the employment data per canton and for groups of educational attainment. The educational types are primary

[4] In an earlier version of this paper, we estimated the effects of human capital on productivity in a cross-sectional setting, approximating the physical capital stock by the number of firms at the Cantonal level. However, we obtained implausibly high human capital elasticities which could be due to a poor approximation of the physical capital stock and/or the omission of time and regional fixed effects (compare Polasek et al. 2008).

(e1), lower secondary (e2), upper secondary (e3), post-secondary (e4), and tertiary education (e5). The duration of these studies are made available for each study course (or educational program) and is published on the homepage of the Swiss educational conference (see Table 1).

Table 1: Average duration of educational by categories

Type of education	Av. Duration
no education	0
mandatory schooling	9
High school with diploma	11.5
Vocational schooling	12.5
Graduate school	13
Teacher seminars	13
Higher vocational schooling	15
Higher diploma schools	16
Applied University (polytechnique)	16.5
University	18

Source: Swiss conference of cantonal education (http://www.edk.ch/)

The average year of schooling of employed persons has been calculated as the weighted sum of the 5 educational types of the population census data using the average years of schooling. We use two types of indicators for the approximation of human capital, average years of schooling of the employed population in a given canton in a given year, and the number of employed in secondary, post-secondary and tertiary education.

3.3. Results

The summary of results of equation (6) is given in Table 2. The first three columns (1-3) show the results for the human capital indicator 'average years of schooling' in the workforce of the Swiss cantons, whereas the second 3 columns (4-6) show the results for the share of workforce with secondary, post-secondary and tertiary education as a human capital measure.

The specification in column (1) shows the human capital model without regional and period fixed effects. The human capital coefficient and the spatial spillover are positive and statistically significant. An increase in average years of schooling of 10% increases cantonal productivity by 1.6%. The LM test statistics (see Elhorst, 2009) clearly indicates that we can reject the null hypothesis of no spatial lag or no spatial error.

Column (2) shows the results for the specification including regional fixed effects. The human capital coefficient increases to 1.01 and is still highly significant. The spatial spillover marginally increases from 0.9 to 0.91 and retains its significance. The LM tests point to significant spatial spillovers.

Table 2: Summary of spatial panel regressions (Equation 6)

Dependent variable: ln (Y/N)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
ln(H)	0.16***	1.01***	0.96	-	-	-
	(0.05)	(0.32)	(0.58)			
ln(se2+se3)	-	-	-	-0.24**	0.17***	-0.01
				(0.11)	(0.06)	(0.08)
ln(se4)	-	-	-	-0.07*	-0.01	0.06
				(0.04)	(0.02)	(0.04)
ln(se5)	-	-	-	0.10***	0.14***	0.25***
				(0.03)	(0.05)	(0.09)
W*ln(Y/N)	0.90***	0.91***	0.15	0.98***	0.84***	0.08
	(0.04)	(0.02)	(0.22)	(0.01)	(0.04)	(0.22)
regional fixed effects	No	Yes	Yes	No	Yes	Yes
period fixed effects	No	No	Yes	No	No	Yes
number of observations	104	104	104	104	104	104
R^2	0.89	0.99	0.99	0.89	0.99	0.99
LM, H0: no spatial lag	514.27	177.15	0.356	352.35	126.02	0.1102
p-value	0.00	0.00	0.55	0.00	0.00	0.74
LM, H0: no spatial error	136.37	217.67	0.456	31.725	41.472	0.0506
p-value	0.00	0.00	0.50	0.00	0.00	0.82

Notes: All equations were estimated using a spatial panel estimator (cross-section and time fixed effects suppressed); standard errors in parentheses; ***,**,* denote significance at the 1, 5, 10 percent level; Y is cantonal income, N is the number of employees, H is the average years of schooling of employees, se2, se3, se4 and se5 are the share of employees in lower and upper secondary, post-secondary and tertiary education and W is the inverse driving time between Swiss cantons, with a threshold value of 120 minutes.

Source: Own calculations.

Including regional and period fixed effects (see column (3)) does not result in significant coefficients for the human capital measure and the spatial spillovers. From LM test statistics, we cannot reject the null hypotheses of no spatial lag or error. This is in line with Elhorst (2009) pointing out that applied researchers often only find weak evidence in favor of spatial interaction terms when controlling for period fixed effects. One explanation of Elhorst (2009) is that most variables tend to increase and decrease together in different spatial units along the national evolution of these variables over time. The correlation over time is thus of a much higher degree than among spatial units.

For the share of workforce with a certain educational background we find that the pooled SAR-model without regional or period fixed effects (column (4)) shows positive and highly significant economic rents for tertiary education and negative and moderately significant rents for secondary and post-secondary education. The specification yields very high and significant spatial spillover, which might be due to not accounting for unobserved heterogeneity (e.g. by adding regional and period fixed effects). Column (5) where regional fixed effects are included, shows an increase in the rents for tertiary education, positive and highly significant rents for secondary education and no effect of post-secondary education. The degree of spatial spillovers decreases from nearly one to 0.84 and is still highly significant. The LM statistics reject the null of no spatial lags or errors.

Adding period fixed effects (see column (6)) increases the tertiary education rent further to 0.25. As in the average years of schooling model, the spatial lag turns out insignificant when accounting for period fixed effects and the LM test results do not favor spatial interaction effects anymore. However, unlike in the average years of schooling models, the tertiary education coefficient retains its significance.

Table 3: Summary of non-spatial panel regression

Dependent variable: ln (Y/N)		
Variables	(1)	(2)
ln(H)	0.93	-
	(0.60)	
ln(se2+se3)	-	-0.01
		(0.06)
ln(se4)	-	0.06
		(0.07)
ln(se5)	-	0.25**
		(0.10)
number of observations	104	104
R^2	0.98	0.98

Notes: All equations were estimated using a regional and time fixed effects panel estimator (cross-section fixed effects suppressed); standard errors in parentheses; ***,**,* denote significance at the 1, 5, 10 percent level; Y is cantonal income, N is the number of employees, H is the average years of schooling of employees, se2, se3, se4 and se5 are the share of employees in lower and upper secondary, post-secondary and tertiary education.

Source: Own calculations.

Since the spatial specification of our model including regional fixed and period fixed effects does not seem to be justified (see LM statistics in Table 2), we additionally estimate a non-spatial model specification for our two human capital measures, by simply dropping the SAR term from equation (6). The results of these estimations are given in Table 3. The insignificant SAR term does not seem to influence the results. Still, the average years of schooling measure is insignificant and the coefficient on the share of workers with tertiary education is 0.25. The size of the coefficient is within the band of estimates found in previous studies (see Table 4 in the Appendix).

Summing up the results from the empirical estimates, we conclude that for the Swiss cantons only highly skilled human capital seems to influence productivity growth. This result is in line with distance to the frontier theories (see Vandenbussche et al. 2006) suggesting that medium-skilled human capital is essential in developing regions for adapting existing technologies from higher advanced regions. By contrast technologically more advanced regions benefit from highly skilled human capital. This seems plausible for Swiss cantons.

The analysis also shows the importance of controlling for unobserved heterogeneity over space and time. A panel data approach permits the inclusion of common regional and period effects. Spatial spillovers do not seem to matter when capturing common movements of variables over time.

4. Conclusion

This paper promotes the hypothesis that skilled labour in particular in combination with the demands of a highly developed economy plays a key role in regional growth. It remains to be seen if such results are only true for small open and specialised economies and can be found in larger or developed countries as well. Thus the paper promotes the hypothesis that smart educational policies are a good growth strategy for small open economies in a globalised world.

We analysed the effects of human capital on productivity in Swiss cantons using a spatial panel framework. We find that controlling for time effects the spatial spillover effect becomes insignificant. This is in line with Elhorst (2009) pointing out that applied researchers often only find weak evidence in favor of spatial interaction terms when controlling for period fixed effects. This is because most variables tend to increase and decrease together in different spatial units along the national evolution of these variables over time. The correlation over time is thus of a much higher degree than among spatial units.

We approximated human capital by two distinct measures, average years of schooling of the workforce and the shares of workers with secondary, post-secondary and tertiary education. Our results are sensitive with respect to the human capital proxy. For the average years of schooling measure we do not find robust evidence for productivity enhancing effects. Using our second measure for human capital we find that the share of academics in the workforce is the main component of human capital driving productivity growth in Swiss cantons. This is in line with findings of previous studies suggesting that mostly highly skilled workers matter for productivity growth in technologically advanced economies.

As some authors note (see Barro 2001 or Hanoushek and Kimko 2000), human capital might be better measured using quality (test scores) not quantity (average years of schooling) measures, a topic that should be further investigated at the regional level for highly advanced economies like Switzerland. On different stages of development, different skills are demanded, effecting growth heterogeneously among skill groups sharing the same education in terms of years. Such measures could shed some light on the effects of specialised educational policies as in the case of the Swiss ETH.

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Appendix

Table 4: Comparison of human capital elasticities

Study	Level	Human capital proxy	Elasticity	Method
Mankiw, Romer and Weil (1992)	national	% of the working-age pop in secondary school	0.23-0.37	cross-section
Vanhoudth et al. (2000)	Europe (NUTS-2)	weighted average in education per employee	0.18	panel
Badinger and Tondl (2005)	Europe (NUTS-2)	average years in education per employee	0.05-0.07	cross-section/spatial
Turner et al. (2006)	USA (States)	average years in education	0.11-0.15	panel
Fischer et al. (2009)	regional (NUTS-2)	share of active population with tertiary education	0.13	cross-section/spatial
Bronzi and Piselli (2009)	Italy (regions)	average years in education per employee	0.38	panel cointegration
Sterlacchini (2008)	Italy (regions)	share of adults with tertiary education	0.34-0.39	cross-section
Brunow and Hirte (2009)	Germany (regions)	share of tertiary educated and share of people in high-skilled jobs	0.08-0.11	cross-section/spatial
Kosfeld et al. (2006)	Germany (regions)	share of tertiary educated workers	0.12-0.15	cross-section/spatial
Polasek, Schwarzbauer and Sellner (this study)	Switzerland (NUTS-3)	share of workers with tertiary education	0.25	spatial panel

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