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Regional age structure and economic growth: an econometric study for German regions

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Regional Age Structure and Economic Growth: An Econometric Study for German Regions.

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Abstract:

This paper analyses the impact of the regional age structure on growth of German regions. Based on a neoclassical growth model an augmented Solow model was derived and estimated in a spatial econometric approach. Besides labor and human capital, public spendings and urbanisation measures are controlled for. Adding the age structure of the employed labor force, which we use as proxy for the age pattern of human capital, improves the regression model significantly. Spatial autocorrelation is controlled for and supports OLS results. To get deeper insights in the effectiveness of the age structure quantile regression techniques are applied to distinguish the effects between various levels of growth rates. The results of the different estimation approaches provide evidence that the age structure matters for growth.

JEL-Classification: J 1, R 11, R 53

Keywords: age structure, growth, public spending

1 Introduction

There is a tremendous number of studies on the empirics of economic growth of countries or regions. Most are referring to the neoclassical growth model. Basically, a deviation from long-run steady state values generates growth or shrinkage in neoclassical growth models as in the augmented Solow-Swan model of Mankiw, Romer and Weil (1992), as from now MRW. As a consequence, many empirical studies examine the idea of absolute or conditional convergence across countries and regions thereby also controlling for other determinants of economic growth (see the meta study of Abreu, de Groot and Florax 2005). Regardless of which type of model is applied the major determinants used are usually population growth, depreciation, investment, education or learning, investment in or the level of human capital or technological progress. In particular, the role of human capital often approximated by educational attainment of the labour force is considered to be crucial. That applies also to German regions. Evidence on convergence and growth is given by Herz and Röger (1995), Seitz (1995), Schalk/Untied (1996), Bohl (1998) or Niebuhr (2001) for West German regions. Further evidence for unified Germany is provided by Barrell and te Velde (2000), Funke and Strulik (2000), and Kosfeld et al. (2005). Some, but not all studies control for spatial autocorrelation and human capital. However, all of these studies do not control for the regional age structure although there are several reasons for doing so.

The consideration of the age of individuals can be motivated by the theory of human capital, which was introduced by Becker (1964) and Schultz (1962). Individual human capital depends not only on formal qualification and schooling but also on experience and the ability to adopt new knowledge or technologies or by obsolescence and depreciation of knowledge. Empirical studies find a hump-shaped age dependency on those variables (see the overview of Skirbek 2004). If individual productivity depends on human capital and the stock of human capital changes during the life cycle, then differences in productivity can be indirectly explained by age. With the help of a Mincer (1974) wage equation one can determine productivity changes due to changes in age. Based on the theory of human capital and its empirical evidence, one might conclude that individual labour productivity depends on age.

Since growth models are based on some aggregate production function one might, therefore, expect that regional differences in the composition of the labor force with respect to age changes labor productivity (i.e. the effective worker). This deviation could change growth perspectives. Thus, the age structure of a region should be considered as well in growth equations. The literature on that topic is rather short. The aim of that paper is to fill this gap. We are closely related to the work of Lindh and Malmberg (1999) and Brunow and Hirte (2006). Both studies adopt an augmented Solow model based on the work of MRW (1992). Furthermore we enrich the growth model by the work of Crihfield and Panggabean (1995a, b). They introduce public spending, motivated by the work of Aschauer (1989) and following debate on the impact of public capital. The literature provides evidence that public spending and the public capital stock have some positive impact on productivity.

To sum up, this paper analyses the impact of regional age pattern on economic growth, controlling for human capital formation in the sense of MRW (1992) and public spending. Urbanization and location measures are considered as well in order to capture regional externalities. We apply a cross-section study for 180 German labour market regions for the time period 1996-2005. The research field Germany is chosen for the following reasons: first, variation of the age structure between regions is quite strong. Based on the theory of human capital, these differences might lead to variation in growth rates. Second, the distribution of the gross domestic product per capita is uneven, such that one can test the hypothesis of β - convergence. A third reason is German unification and the consequences of economic integrating a traditional capitalistic economy with a transition economy.

The structure of the paper is as follows. The next section briefly derives the regression equation and introduces control variables. The following part describes the data and gives descriptive statistics, followed by the regression analysis where the results are discussed. The paper closes with a conclusion.

2 Model description and control variables

Model description The derivation of the regression model is based on the work of the following studies. The basic underlying neoclassical growth model is that of MRW (1992). The age structure is implemented as suggested by Lindh and Malmberg (1999). Brunow and Hirte (2006) adopt this study but additionally control for labour market effects, i.e. the participation and unemployment rate. Furthermore, the work of Crihfield and Panggabean (1995a, b) introduces public spending.

Aggregate production Y can be described by a function with constant returns to scale, using private capital K , labour L, human capital H and public capital G as input

$$Y = AK^{\alpha}G^{\beta}(MH)^{\gamma}(ML)^{1-\alpha-\beta-\gamma}$$

where A is the total factor productivity and M is an index of the decomposition of the labour force with respect to age, given by

$$M = \prod_{i}^{k} m_i^{\delta_i},$$

where m_i is the share of age cohort i. The production function is transformed in per capita terms by division with regional population B. Applying the decomposition as described in Brunow and Hirte (2006), it follows

$$y = Ak^{\alpha}g^{\beta}h^{\gamma}M^{1-\alpha-\beta}\left[p(1-u)\right]^{1-\alpha-\beta-\gamma} \tag{1}$$

where p is the participation and u is the unemployment rate. Both rates are exogenously given and do not vary over time.

s_k, s_g and s_h are the fractions of output invested in capital formation for private, public and human capital, respectively. For simplicity, the depreciation rate δ is common for all types of capital. Regional population grows by an exogenous rate n. Applying the approximation around the steady state as outlined in Barro and Sala-i-Martin (1995), the growth rate of per-capita output can be derived (see appendix). It is given by

$$\begin{aligned}\frac{g}{n+\delta} &= \ln A - (1-\alpha-\beta-\gamma)\ln y - (\alpha+\beta+\gamma)\ln(n+\delta) + (1-\alpha-\beta)\ln M \\ &\quad + \alpha\ln s_k + \beta\ln s_g + \gamma\ln s_h + (1-\alpha-\beta-\gamma)\ln\left[p(1-u)\right].\end{aligned}$$

Adding an error term ε yields the regression equation

$$\begin{aligned}\frac{g}{n+\delta} &= \alpha_0 + \alpha_1\ln y + \alpha_2\ln(n+\delta) + \alpha_3\ln M \\ &\quad + \alpha_4\ln s_k + \alpha_5\ln s_g + \alpha_6\ln s_h + \alpha_7\ln\left[p(1-u)\right] + \varepsilon.\end{aligned} \tag{2}$$

If the age pattern and the labour market decomposition is not considered, α_3 and α_7 are equal to zero and the model reduces to that of Crihfield and Pangabean (1995 a).

Control Variables The derived model motivates determinants of growth. So far, total factor productivity A was held constant for all regions. Branch specific agglomeration forces and externalities suggested by Marshall (1920), Arrow (1962) and Romer (1986)[1] but also regional diversity

[1] This type of externality is often referred as MAR-externalities.

of industries as suggested by Jacobs (1969) should be considered as well[2]. In the presence of externalities A might differ between regions. From a theoretical point of view, externalities would lead to differences in growth rates and regions tend to converge to distinct steady states[3]. Bräuninger and Niebuhr (2008) give a broad overview of related literature on that topic. Therefore, one should control for regional differences and characteristics. However, imputing these forces into A implies that these effects are Hicks-neutral.

Combes et al. (2004) suggest to use a diversity measure of employment over regional industries / branches to capture the effect of urbanization externalities. They apply a Herfindahl-index. Furthermore they suggest to control for the total number of industries and the logarithm of the working force. However, the former is highly correlated with the diversity measure, because this proxy increases if the number of branches increases as well. The latter variable is indirectly affiliated by the per capita normalization and is captured in the participation-unemployment-rate part of the model. Thus, we control for urbanization measures using a diversity index DIV_N which is defined over the distribution of firms within industries. The reason is that the distribution of firms is closer related to the industrial structure of a region and captures not only diversity but also production externalities such as vertical linkages[4]. Martin et al. (2008) note that externalities does not necessarily have a linear affect on productivity. As they suggest we therefore add a squared value of DIV_N to the regression equation.

To control for localization measures is rather complicated. If a location has some advantages for a particular type of industry then this industry could be concentrated within this region. Thus, one way would be to look at each single industry and evaluate the distribution over space. The shortcoming of that approach is that it does not control for regional size. To make it more clear if the relative share of employees to total population is constant then one would not say that this industry is concentrated. However, looking on the distribution of intraindustry shares would imply that large regions tend to have some agglomeration. Therefore, some normalization is necessary. We employ the localization coefficient over the employment to identify regions which are specialized in some industries and call it $No.\ spec.\ ind.$. This proxy counts the number of industries which are relatively strong specialized in a region.

Two further measures are introduced, the density of infrastructure area $infradens$ as a proxy

[2] See e.g. Glaeser et al. (1992), Henderson et al. (1995), Henderson (1997), Henderson (2003), Combes and Overman (2004) or Rosenthal and Strange (2004) for a discussion and empirical investigation of externalities.

[3] See Martin and Ottaviano (1999) or Baldwin et al. (2001).

[4] See Brunow and Hirte (forthcoming).

for urbanization[5] and the average plant age N_{age}.

3 Data and descriptive statistics

Data Regional information on Gross domestic product, population, total employment and public spending is taken from the GENESIS-Regional data base provided by the German Federal Statistical Office. The age structure of the labour force, the number of firms and employment separated by industries and firms age are taken from the Establishment History Panel (BHP) provided by the Institute of Employment Research (IAB) and the German Federal Employment Agency (BA).

We employ a cross section study on 180 labour market regions as suggested by Eckey (2001). The assignment of NUTS3 regions to Eckeys classification is based on commuting flows and should overcome strong regional autocorrelation.

The annual growth rates of g and n are calculated using the geometric mean of data from 1996 and 2005. The participation and unemployment rate are taken from the year 1996. The share of public spending s_g is calculated as the ratio of public impersonal spending to total public spending. This variable has some short-comings because it does not include regional spending of the Federal State which are partially invested in the transport network.

Kosfeld et al. (2005) suggest a common depreciation rate of 0.048. Typically a value of 0.05 is assumed, which we will apply as well.

There is a discussion on the proxy variable of human capital. Originally MRW suggest to use school enrollment rate. However, this variable does not control for "learning by doing" and "on the job training". As Acs et al (2006) argue, it is not just the stock or accumulation of knowledge but also the transfer and implementation of new knowledge, that counts. Thus, enrollment rates do not represent accumulation of knowledge well[6].

Another possibility to capture the effect of human capital is to use some measures of the human capital stock. Then, not the accumulation of human capital promotes growth but the initial stock, as Romer (1990) suggests. Thus, our definition of s_h is to use the regional share of employed high-

[5] Infrastructure density is highly correlated with population density. The latter we do not use because of collinearity.

[6] We adopt the enrollment approach and define s_h as the share of population attending school. Regional variation is in a range of 0.12-0.20 with mean 0.154 and a standard deviation of 0.016. In all models the estimated coefficient was insignificant at a high level such that we did not follow this approach. A reason might be the common educational system. The variation in the data is due to population characteristics.

skilled person, i.e. person with a university degree relative to total regional employment. Data is taken from the Establishment History Panel of 1996.

Descriptive Statistics A descriptive statistics of variables is given in table 1. To get a better overview, they are not reported in logs. The average annual growth rate is 2% and ranges from zero to almost 5%. The worst performing region is Celle which suffers under shrinkage, however the growth rate is very close to zero. The fastest growing region is Salzwedel, which is the fifth poorest region. As one can see the income distribution of GDP per capita is very uneven.

Table 1: Descriptive statistics of model variables

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
g	0.020	(0.009)	-0.004	0.049
GDP per capita	20.237	(4.479)	11.324	35.713
$n+\delta$	0.049	(0.006)	0.033	0.062
$p\,(1-u)$	0.389	(0.057)	0.245	0.537
s_g	0.211	(0.067)	0.064	0.383
s_h	0.059	(0.029)	0.017	0.183
$infradens$	0.048	(0.015)	0.022	0.112
No. spec. ind.	3.239	(1.679)	0	8
N_{age}	0.000	(0.838)	-6.178	1.643
DIV_N	3.235	(0.141)	2.827	3.655

N=180

Considering the investment shares on capital one can see a huge range of regional public spending. It is worth to note that almost every Eastern German region has public investment shares which are higher than the sample mean, which indicates that not necessarily richer regions have higher investment rates. However, these high values are also due to some political process.

The school enrollment rates do not vary much while this is the case for the share of employed high-skilled person. There are no data on private capital investment s_k. Kosfeld et al. (2005) do not use investment rates of some sector since they are not representative. They use a proxy based on establishment formation. We, however, refrain from using this data for the following reasons. First, it does not capture firm-intern investment decision. Second, there are several reasons to found an establishment: individuals might get back in a job and get self-employed. Those micro-firm formations are typically not capital intensive and branch specific. E.g. Fritsch and Mueller (2004) find evidence that regions will have a higher rate of establishment formation when the service sector is relatively large in size and well developed. Theoretical work on firm formation focuses on the special role of human capital[7]. Models of endogenous growth typically assume that research activity promotes growth. New developed products which would be more complex in its structure, will cause investments in physical capital. Only if this investment is undertaken together with a firm start-up then the approach of Kosfeld et al. (2005) would not be misleading. However, it is hard to believe that this is the dominant motive for firm start-ups.

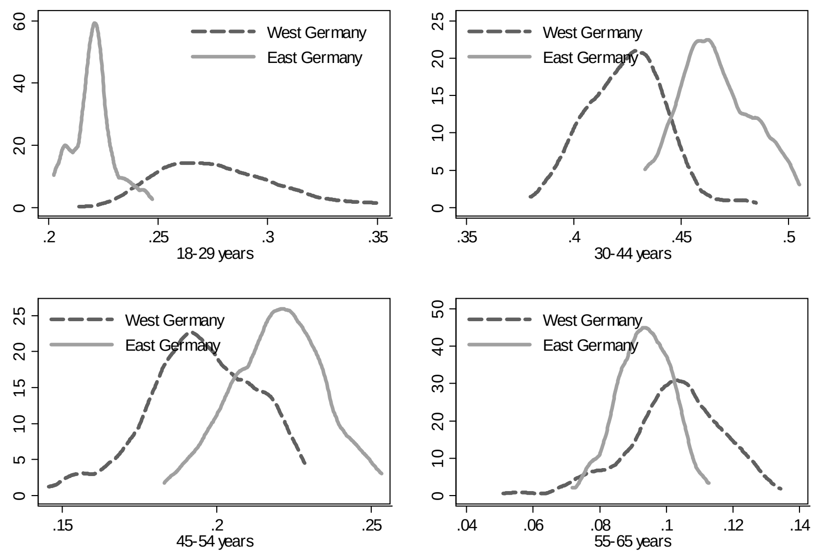
Leaving out information on private capital could bias the results because of an omitted variable problem. Of course, one can argue that capital flows adjust quickly, such that the rental rate is equal over all regions, but because of capital market imperfections this assumption does not necessarily hold. In our robustness-check we carry out a Panel analysis with two 5 year periods in order to rule out unobserved heterogeneity, which would reduce the problem of omitting a measure of private capital investment.

Table 2: Descriptive statistics of the age pattern of the employment

	m_{18-29}	m_{30-44}	m_{45-54}	m_{55-65}
Mean	0.263	0.435	0.202	0.100
Std. Dev.	0.034	0.026	0.020	0.014
Min	0.202	0.380	0.146	0.051
Max	0.352	0.505	0.253	0.134
Correlation Table				
m_{18-29}	1.000			
m_{30-44}	-0.650	1.000		
m_{45-54}	-0.826	0.219	1.000	
m_{55-65}	-0.082	-0.575	0.201	1.000
N=180				

Table 2 reports descriptive statistics and a correlation matrix of the age structure (shares) of employees in 1996. Again, there is a relatively large variation within the data. Unfortunately, the second age cohort comprises a large group of person aged 30 to 44. This large range is due to limitations of the Establishment history panel. Interestingly, the oldest cohort is the one with the smallest standard deviation indicating that there seems to be some filtering which can be explained with labour market arguments. There might be some selection that only those are (still) employed who are fit enough.

[7] See, for example, Romer (1990) or Baldwin et al. (2001).



N=180, Data for computation is taken from the Establishment History Panel.

Kernel density of the different age cohorts

To get a better overview of the distribution of the age groups a kernel density plot is given in figure 3 separated by East and West. While the distribution of the youngest cohort is very broad within the West, there is little variation within the East. Less employment chances and a higher willingness to migrate probably push the youth of East to migrate to western regions and thus, lowers the relative share of employees the eastern regions. Besides the means the distribution for the 30-44-cohort obviously differs not much. Child care services for preschool children and an associated higher participation rate of women might offer an explanation for the higher mean of the share in the East. This result is supported by a t-test of the population shares - both, East and West, have similar mean values of the share of population in age 30-44 but the employment is significant higher in the East. Because of the observed outflow of the youth the labour force is older and the share of the 45-54 year old employees is higher in the East.

Concerning the for other age cohorts employment chances are better for the youngest cohort and the elderly in the West while they are better for the two middle aged groups in the East. Thus, concerning regional differences the term $p(1-u)$ is correlated with the age structure.

Table 6 contains the correlation matrix of the regression model and can be found in the appendix. Remark, most of the variables are in log form as they enter the regression equation.

After exploring the data, the next section focuses on the regression.

4 Regression Analysis

The regression equation (2) is estimated. Table 3 contains OLS estimates, where model 1 represents the unconditional model without the age structure including agglomeration and urbanization measures. In Model 2 the age structure of the employees is added. Because of a relatively high level of multicollinearity between $\ln y_0$, $\ln (n + \delta)$ and $\ln [p (1 - u)]$ a reduced model 3 was estimated without structural parameters. The presence of collinearity is detected by the variance inflation factor and can be seen by the highly reduced standard error of $\ln y$. Reported standard errors in the OLS models are White adjusted. Model 4 is robust against outliers using weighted regression techniques[8]. Model 5 reports the results of a spatial lag model using a distance based and row standardized weighting matrix which moderately discounts distance[9]. Again there are robust standard errors.

The F-test rejects the hypothesis of coefficients equal to zero. Also, adding the age structure improves the model significantly[10]. Furthermore, dropping the structural parameters does not worsen the model. The estimates of the robust regression approach in Model 4 and 5 do not change the interpretation compared to the results of its OLS counterparts of Models 2 and 3. Based on the F-test and the information criteria, Model 3 of the OLS regression seems to be the best. These estimates, however, do not control for spatial autocorrelation. To identify spatial processes a spatial weights matrix is essential. We applied four different matrices, which are all row standardized. In addition to a neighborhood matrix as suggested by Kosfeld et al. (2005) we use distance based matrices. Their construction is described in Brunow and Hirte (2006).

With the help of (robust) lagrange multiplier tests one can determine whether a spatial lag or a spatial error model should be applied in the presence of a spatial structure[11]. Following the procedure of (spatial) model selection as suggested by Florax et al. (2003) the spatial lag model is the appropriate one for all distance based weighting matrices. Stressing the information criteria

[8] See Berk (1990), Goodall (1983) and Rousseeuw and Leroy (2003) for a description of the method.

[9] See Brunow and Hirte (2006), the parameter γ is chosen to be equal 0.5, the average distance to neighboring regions is 52km in that case.

[10] The test value of the F-Test is 4.85. The improvement is significant at a 99%-level.

[11] Spatial models based on this growth regression are outlined in detail in Brunow and Hirte (2006) or in Kosfeld et al. (2005). For spatial tests see Anselin and Florax (1995) and Anselin and Moreno (2003).

again, the model improves when distance is less strong discounted. This finding is consistent with the findings of Kosfeld et al. (2005) who consider spatial processes of higher order based on a neighborhood weighting matrix. In their case, not only the surrounding regions determine spatial correlation but also regions further away. This effect is accounted for in the case of a distance based matrix as well. However, we can not control for the strength of the coherence.

A Ramsey test of omitted variables rejects the hypothesis of omitted variables applying Model 3.

Considering the parameters reveals that conditional convergence is present. Growth rates c.p. decline when regions become richer, indicated by a negative and significant estimate for $\ln y_0$.

Obviously, public spending promote growth. This effect is very robust against modifications. Following the debate of Aschauer (1998), we can support the hypothesis of the relevance of public spending. Evidence of the literature on the effect of public spending on growth are rather mixed. Easterly and Rebelo (1993) find evidence that public spending in transportation and telecommunication support growth applying a cross country study. Hulten (1996), Sanchez-Robles (1998), Milbourne et al. (2003), Calderon and Serven (2004), Canning and Pedroni (2008) and others find also support of the positive effect of public infrastructure. Most of these studies report some special characteristics which limit their results. For example Ford and Poret (1991) find evidence for some but not all countries under focus. Other studies find only evidence for particular infrastructure carriers. Canning and Pedroni (2008) discuss that there is a critical value of public spending - exceeding this value would not generate further growth. Barro (1990) can not find evidence.

To conclude, literature of public spending and its effect on growth seems to reveal that public spending promotes growth to some extend. We can support these findings and give evidence that public nonpersonal spending promote growth of German regions.

Interestingly, the initial value of human capital s_h is only significant as long as no age structure is considered. However, we are going to discuss this point later.

Additional regional characteristics and urbanization measures improve the model. The average age of establishments N_{age} as a measure of the consistency of the regional economy leads to higher growth rates. Denser regions also have better growth perspectives. Since population and infrastructure density are highly correlated, the infrastructure area can be seen as a measure of regional density and associated economic transactions. Thus, more dense regions are better off.

Another urbanization measure, DIV_N gives evidence that urbanization matters. Remember, DIV_N is as N_{age} mean centered by the means of East and West, respectively. Because the linear

Table 3: OLS-Regression of the annual growth rate per capita

dep. Variable	OLS - Estimates			rob.regr.	ML-sp.lag
$g/(n+\delta)$	Model 1	Model 2	Model 3	Model 4	Model 5
$\ln y_0$	-0.3488	-0.4174*	-0.3498***	-0.3321***	-0.3803***
	(0.2357)	(0.2191)	(0.0866)	(0.0774)	(0.0826)
$\ln(n+\delta)$	-0.2587	0.0129			
	(0.1959)	(0.2564)			
$\ln[p(1-u)]$	-0.0537	0.1027			
	(0.2845)	(0.2494)			
$\ln s_g$	0.1857***	0.1425***	0.1490***	0.1218***	0.1851***
	(0.0484)	(0.05)	(0.0473)	(0.0464)	(0.0538)
$\ln s_h$	0.0746**	-0.0092	-0.0045	0.0246	0.0049
	(0.0291)	(0.0446)	(0.0422)	(0.038)	(0.0411)
$\ln infradens$	0.1372**	0.1332**	0.1273**	0.1147**	0.1100**
	(0.0602)	(0.0638)	(0.0573)	(0.0521)	(0.0542)
$No.sepc.ind.$	0.0097	0.0149**	0.0150**	0.0172**	0.0187***
	(0.0078)	(0.0076)	(0.0072)	(0.007)	(0.0071)
N_{age} @	0.0384**	0.0432***	0.0444***	0.0428***	0.0460***
	(0.0176)	(0.0154)	(0.015)	(0.0139)	(0.0143)
DIV_N @	-0.1352	-0.0244	-0.017	0.0728*	0.0206
	(0.0993)	(0.1076)	(0.1083)	(0.0981)	(0.0992)
DIV_N^2 @	-0.716	-0.8274*	-0.8002*	-0.9322**	-0.8335**
	(0.4798)	(0.483)	(0.4533)	(0.4706)	(0.4244)
m_{30-44}		0.2724	0.2279	-0.1128	0.3373
		(0.3767)	(0.3812)	(0.3378)	(0.3742)
m_{45-54}		0.7190***	0.6921***	0.6261***	0.8821***
		(0.2717)	(0.198)	(0.1687)	(0.2113)
m_{55-65}		-0.3937***	-0.3937***	-0.4978***	-0.4606***
		(0.1357)	(0.1317)	(0.1118)	(0.1187)
$Const.$	1.5558	2.8601	2.4471***	1.7605***	3.0221***
	(1.3964)	(1.9221)	(0.5861)	(0.5129)	(0.6908)
ρ					-0.5144**
					(0.2617)
AIC / BIC	-123 / -88	-137 / -92	-141 / -102		-142 / -97

N=180, robust s.e. in (), @ variables are centered with the mean of East and West Germany, respectively. rob.reg - robust regression, sp.lag - spatial lag.
* p<.1; ** p<.05; *** p<.01, N=180, s.e. in ()

term is mostly insignificant the best performing regions are those who have a balanced industry structure. The significant and negative quadratic term punishes deviation of the mean. Thus, in regions where most of the firms are concentrated in a small number of industries or where firms spread widely between industries perform worse compared to mean regions where some industry mix is given. On the other hand but not contradicting, some degree of specialization promotes growth because $No.sepc.ind.$ is significant and robust. For a regional perspective it is recommendable to have a relatively better developed industry compared to other regions. But in order to have a good performance it is necessary to have a healthy industry mix rather than a pure specialization in some industry.

Let us now turn to the age structure. First, from a statistical point of view, regressing shares is complicated because of a high potential of multicollinearity. Fortunately, this problem seems to be a minor one. The variance inflation factors are low considering model 3. I.e., for m_{30-44} it is given by 3.34, m_{45-54} it is 2.49 and for m_{55-65} the value is 2.14. Furthermore, the correlation of the estimated coefficients is rather low[12]. Adding or dropping one of the groups does partially affect the value of the estimated parameter but does not affect the interpretation. Table 5 in the appendix reports further estimates where only one age cohort is considered.
In the presence of multicollinearity the estimated parameters can be higher as they are "in reality". Even more, they have to be larger if standard errors increase to stay significant. The standard errors and the resulting confidence intervals of the coefficients of the age structure are relatively large. Therefore the interpretation of the parameters has to be done with care in its strength. However, except for the sign of the second (insignificant) cohort the signs of the estimates do not change and the parameters are significant. Further robustness checks do not change the basic findings.

The estimated parameters are estimated relatively to the youngest cohort, which is the reference group. The signs suggest that an increase of the second and third cohort increases growth, even if the second cohort is insignificant. On the other hand, the last cohort performs worse. The most growth enhancing age cohort is that of age 45-54. This result is in line with the findings of Lindh and Malmberg (1999) but not with Brunow and Hirte (2006). It indicates an inverse u-shaped pattern of the influence of age. The result is also in line with the theory of human capital which suggests this hump-shaped distribution. A question arises considering the last cohort - why has this

[12] The correlation between coefficients is as follows: $Corr\,(m_{30-44}, m_{45-54}) = 0.0984, Corr\,(m_{30-44}, m_{55-65}) = 0.4082$, $Corr\,(m_{45-54}, m_{55-65}) = -0.3361$.

cohort a negative influence on growth compared with the youngest cohort? One explanation could be that growth occurs on account of innovation. Even if the elder working population has a higher level of experience the young cohort has the newer stock of knowledge. Thus, their knowledge is "up to date" while there might be some obsolescence and depreciation of knowledge considering the oldest age group.

How robust is this pattern of the age cohorts? One concern might be the relatively high growth rates of eastern regions and the higher share of person in the age cohort 45-54, the most growth enhancing group. Introducing interaction effects for the second and third age groups with a East-German dummy yields insignificant results. Considering only the age structure of eastern regions also produces insignificant results. Thus, there seem to be no differences of the effects of the age cohorts on growth rates between the East and the West.

Another concern relates to the point that parameters are estimated relative to the reference group. Thus, we can only compare differences to the reference cohort. To get insights into significant differences between other cohorts we reestimate the model successively choosing every cohort as reference group (see column "alternative" of table 5 for an example). This gives us evidence that there are significant differences in the impact of the different age cohorts on the growth rates of German regions. These significant findings highly support the hypothesis that there is an inverse u-shaped pattern of the influence of the age pattern on regional growth.

So far we found evidence that the age pattern has on average some influence on regional growth. However, the impact of the determinants of growth might also depend on level of the growth rate of an economy. For instance, Acemoglu et al. (2002) suggest that effects near the efficiency frontier differ from those farther away from the efficiency frontier. Moreover, one can presume that there are decreasing returns even with respect to growth. As a consequence, standard regression analyses which only look into average effects might overlook differences in the results arising at different levels of growth.

The approach allowing considering such effects is the quantile regression[13]. To get more insights into variations of the coefficients we apply this technique. Table 4 reports the results of the quantile estimates using different quantils as baseline. Standard errors are estimated using bootstrapping.

To get a better overview of the growth rates relative to $n + \delta$, figure 4 plots the distribution of $g/(n + \delta)$. For example, the white regions belong to those regions with a growth rate less or equal to the 10th percentile. The light grey regions are those with still low growth rates between

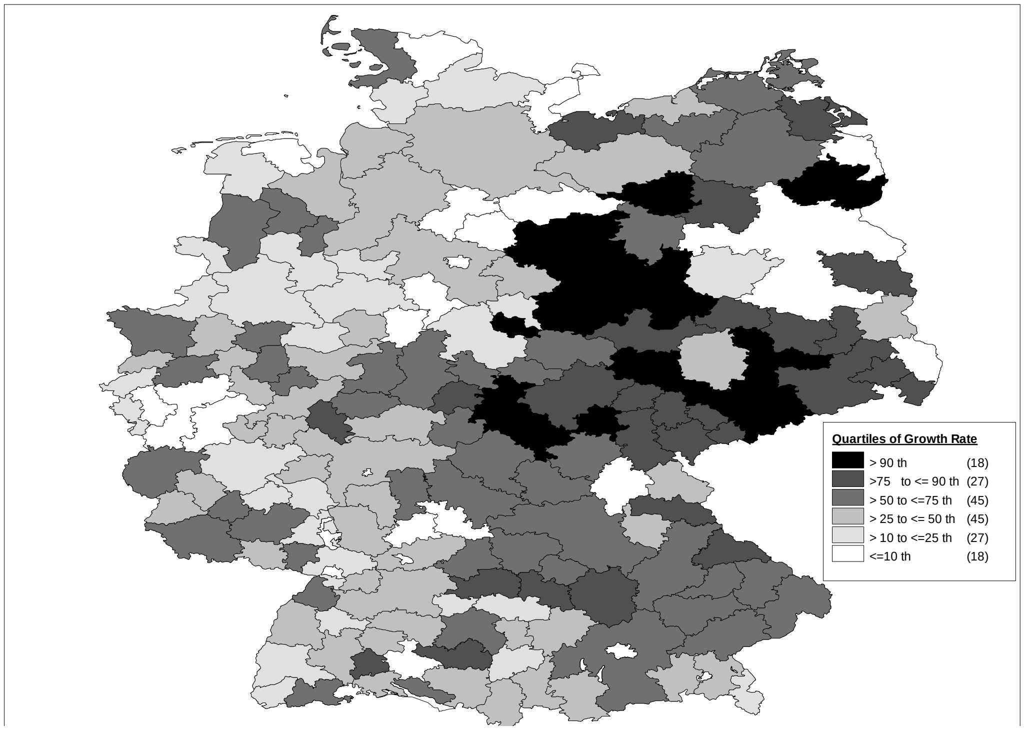
[13] See Koenker and Hallock (2001) or Breuninger and Niebuhr (2008).

Table 4: Quantil Regression and the affect of the age structure on growth

dep. Variable	Quantile of consideration				
$g/(n+\delta)$	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}
$\ln y_0$	-0.5078***	-0.4579***	-0.3894***	-0.2656**	-0.2908**
	(0.186)	(0.135)	(0.147)	(0.1202)	(0.1168)
$\ln s_g$	0.0958	0.0664	0.1129*	0.1530**	0.2114***
	(0.0994)	(0.0675)	(0.0664)	(0.0599)	(0.06)
$\ln s_h$	0.0242	0.036	0.0364	0.0316	-0.0181
	(0.0696)	(0.0574)	(0.06)	(0.0592)	(0.0708)
$\ln infradens$	0.2233	0.0884	0.1185*	0.1202	0.1424
	(0.1552)	(0.0799)	(0.069)	(0.0731)	(0.0901)
$No.sepc.ind.$	-0.0079	0.0029	0.0214***	0.0211*	0.0368***
	(0.0163)	(0.0105)	(0.0078)	(0.0116)	(0.0116)
N_{age}	0.0913**	0.0331	0.0617***	0.03	0.0468**
	(0.0438)	(0.0238)	(0.0231)	(0.0216)	(0.0227)
DIV_N	0.0943	0.0817	0.0583	0.0385	-0.1219
	(0.1901)	(0.1639)	(0.1287)	(0.1716)	(0.2049)
DIV_N^2	-0.4902	-1.1418	-0.8898	-0.9764	-0.0442
	(0.9656)	(0.8018)	(0.616)	(0.7011)	(1.0447)
m_{30-44}	-0.0698	-0.3732	-0.3365	0.393	0.7077
	(0.7411)	(0.4944)	(0.5095)	(0.6371)	(0.7297)
m_{45-54}	0.3812	0.2557	0.6125**	0.6782***	0.9947***
	(0.3603)	(0.2736)	(0.2795)	(0.2534)	(0.2788)
m_{55-65}	-0.4563**	-0.3929**	-0.4188**	-0.5645***	-0.4361*
	(0.2085)	(0.1713)	(0.1636)	(0.1819)	(0.2278)
$Const.$	2.2150**	1.3825*	1.9196***	2.0834**	3.2546***
	(1.0596)	(0.7274)	(0.7029)	(0.8078)	(1.0465)
Pseudo-R^2	0.1917	0.2324	0.3069	0.4057	0.5035

* p<.1; ** p<.05; *** p<.01, N=180, s.e. in ()

the 10th and 25th percentile.



Average anual growth rate of GDP per capita weighted with $n + \delta$ clusterd in percentils

Lets consider first the other variables before we turn again to the age structure. Public spending is relevant for the regions with higher growth rates. Thus, an increase of public spending affects the growth rate more in regions with already high growth rates. Urbanization measures and other control variables do not seem to have an important effect. However, N_{age} and DIV_N is mean centered and therefore harder to interpret in quantile regression. While DIV_N is insignificant, N_{age}, gives now clear pattern. Specialization as some measure of localization externalities tends to matter for higher growth rates.

Independent of the percentile under consideration, the last age cohort affects the growth rate significant and with negative sign. To get information on the variation of this effect we performed a test on an equal coefficient. The zero hypothesis cannot be rejected. Hence, there is evidence that there is no difference in the effect of the age cohort concerning growth clubs. Considering the age cohort of $45 - 54$, one can see that it is significant only for higher growth rates. The effect is positive and highly significant. This indicates that higher growth rates can be achieved when the share of this group, remember which is the most growth promoting group, increases. Thus, a higher share of this group does not necessarily imply an increase in the growth rate. It depends on the level of the growth rate already achieved. Hence, increasing this cohort, e. g. by raising the participation rate, is not in each case a useful policy option concerning growth. It does not lead to higher growth in regions where the growth rate is already low. Looking to the second cohort, all parameters are insignificant again. Interaction terms of East Germany are always negative albeit insignificant.

The findings of the quantile regression which pass the same robustness checks as the other regressions confirm the results of the OLS and the spatial models. But it add additional insights to the other estimates.

To review the intermediate results concerning the age structure. We find evidence that the age structure promotes growth. Especially the cohort aged 45-54 is the most growth stimulating group. The second cohort seems to improve growth compared to the first group, however, the results are not significant. The estimated parameters are not driven by the relatively high shares of the elder working population in eastern regions because the results differ considerably between eastern regions. We can support the hypothesis of an inverse u-shaped pattern of the influence of the age on growth. However, since the age pattern matters, we draw the conclusion that in addition to school qualification and skills, learning by doing and experience exerts influence on average growth rates.

One variable was left out so far - the stock of human capital s_h. The parameter significant in the basic estimates is insignificant when the age structure is added to the regressions. This implies that the age structure captures all effects of differences in the stock of employed regional human capital. The correlation between s_h and the age structure is moderately high, especially for the middle-aged cohorts. Furthermore, the relatively strong negative correlation of the youngest cohort with s_h is expected because an university degree is usually awarded not before an age of 25. To account for a possible presence of multicollinearity s_h was excluded from the regressions. This does not change the picture described above.

If the age structure represents effects of human capital, such as experience and the possibility of adopting new knowledge, it is a measure of the stock of human capital. Unfortunately, the data base of the establishment history panel does not allow to construct an age structure based on experience and qualification as suggested by Brunow and Hirte (forthcoming). In their work the age structure of human capital was considered. Based on a regression of a production function they find evidence that a "job-based" definition of human capital highly improves the model. This implementation should be done in future research to understand in more detail the forces at work and regional perspectives on growth possibilities.

However, the results so far indicate that the age structure matters for growth. Especially the cohort of 45-54 is the best performing cohort. If experience explains this tendency, further training during the working live would rise the individual and aggregate stock of human capital which in turn permits growth perspectives in future. However, the results of the quartile regression sounds a not of caution to this deduction. In this estimate a significant coefficient of this age cohort was only found for faster growing regions. Hence, further training for this cohorts might have ambiguous effects on growth, positive effects in faster growing regions while no effect in slower growing regions.

5 Conclusion

This paper analyses the effect of the age structure of employees on growth in Germany for 1996-2005. An augmented Mankiw, Romer, Weil model (1992) was applied. In addition to the approach of Brunow and Hirte (2006) which considers the age structure, public spending was implemented as suggested by Crihfield and Panggabean (1995a, b). In order to control for externalities urbanization and location measures were considered as well. Spatial autocorrelation was accounted for. To get deeper insights into effectiveness quantile regression was applied as well. The main findings are as follows. We can support findings of the literature and conclude for conditional convergence for unified Germany. Increasing public spending affects growth positively but not in slower growing regions. Public investment seems to affect only regions with higher growth rates. To capture the effect of Jacobs externalities (Jacobs 1969) a diversity measure of firms over industries was constructed. We find evidence that a balanced industrial structure promotes growth whereas a tendency to a uniform distribution or extreme concentration of firms over industries reduces growth perspectives. However, it is advantageous at least for faster growing regions to be specialized in some industry.

Concerning the age structure of employees we find evidence that it follows an inverse u-shaped pattern. The most growth promoting age cohort is aged 45-54. The effect of this cohort is stronger the higher the actual growth rate. This result can be explained by the theory of human capital. If experience matters and learning-by-doing occurs during work live and exceed depreciation, individual and the aggregate stock of human capital exceed the stock of educational attainment (school or university). In this case additional aggregate knowledge promotes growth. Obviously, an increase in the share of employees of age 55 and older reduces growth independent of the level of the growth rate. Thus, obsolescence and depreciation of knowledge seems to matter. Furthermore it is argued that the age structure explains to some extent the stock of human capital measured by the share of employees with university degree. If experience matters for the stock of human capital then the age structure already includes human capital information. So far we can not go beyond these findings. This is left for future research.

6 Literature

1. Abreu, M, H.L.F. de Groot, R.J.G.M. Florax (2005): A Meta-Analysis of Beta-Convergence, *Journal of Economic Surveys*, 19, 389-420

2. Acemoglu, D., Aghion, P., Zilibotti, F. (2002), Distance to Frontier, Selection, and Economic Growth, *NBER Working Paper* No. 9066.

3. Acs, Z. J., D. B. Audretsch, P. Braunerhjelm and B. Carlsson (2006): Growth and Entrepreneurship: An Empirial Assessment. CEPR Discussion Paper No. 5409.

4. Anselin, L., F.J.G.M. Florax (1995): Small sample properties of tests for spatial dependence in regression models: some further results. Erschienen in: Anselin, L., F.J.G.M. (ed.): *New Directions in Spatial Econometrics*, Springer, Berlin, 21-74.

5. Anselin, L., R. Moreno (2003): Properties of tests for spatial error components, *Regional Science and Urban Economics*, 33, 595-618.

6. Arrow, K.J. (1962): The economic implications of learning by doing, *Review of Economic Studies*, 29, 153-173.

7. Aschauer, D.A. (1989): Is public expenditure productive?, *Journal of Monetary Economics 23*, 177-200.

8. Baldwin, R., P. Martin, G. Ottaviano (2001): Global income divergence, trade and industrialization: the geography of growth take-off, *Journal of Economic Growth*, 6, 5-37.

9. Barrell, R., D.W. te Velde (2000): Catching-up of East German Labour Productivity in the 1990s, *German Economic Review*, 1, 271-297.

10. Barro, R. (1990): Government Spending in a Simple Model of Endogenous Growth, *The Journal of Political Economy*, 98, 103-125.

11. Becker, G.S. (1964): Human Capital: A Theoretical and Empirical Analysis, with special reference to education, New York: National Bureau of Economic Research, Columbia University Press.

12. Berk, R.A. (1990): A primer on robust regression, in: J. Fox, J.S. Long: *Modern Methods of Data Analysis*, Newbury Park, Sage, 292-324.

13. Bohl, M.T. (1998): Konvergenz westdeutscher Regionen? Neue empirische Ergebnisse auf der Basis von Panel-Einheitswurzeltests, *Konjunkturpolitik*, 44, 82-99.

14. Breuninger, M., A.Niebuhr (2008): Agglomeration, Spatial Interaction and Convergence in the EU, *Schmollers Jahrbuch*, 128, 329-349.

15. Brunow, S., G. Hirte (2006): Age structure and regional economic growth, *Jahrbuch für Regionalwissenschaft* 26, 3-23.

16. Brunow, S., G. Hirte (forthcoming):

17. Calderon, C., L. Serven (2004): The Effects of Infrastruture Development on Growth and Income Distribution, *World Bank Policy Research Working Paper* No. 3400.

18. Canning, D., P. Pedroni (2008): Infrastructure, Long-run Economic Growth and Causality Tests for Cointegrated Panels, *The Manchester School*, 76, 504-527.

19. Combes, P.-P., T. Magnac, J.-M. Robin (2004): The dynamics of local employment in France, *Journal of Urban Economics* 56, 217-243.

20. Crihfield, J.B., M.P.H. Panggabean (1995a): Is public infrastructure productive? A metropolean perspective using new capital stock estimates, *Regional Science and Urban Economics* 25, 607-630.

21. Crihfield, J.B., M.P.H. Panggabean (1995b): Growth and Convergence in U.S. Cities, *Journal of Urban Economics*, 38, 138-165.

22. Easterly, W., S. Rebelo (1993): Fiscal policy and economic growth: An empirical investigation, *Journal of Monetary Economics*, 32, 417-458.

23. Eckey, H-F. (2001), Der wirtschaftliche Entwicklungsstand in den Regionen des Vereinigten Deutschlands, *Volkswirtschaftliche Diskussionspapiere* Nr. 20/01, Universität Kassel, Fachbereich Wirtschaftswissenschaften, Kassel.

24. Florax, R.J.G.M., H. Folmer, S.J. Rey (2003): Specification searches in spatial econometrics: the relevance of Hendry's methodology, *Regional Science and Urban Economics*, 33, 557-579.

25. Ford, R., P. Poret (1991): Infrastructure and Private-Sector Productivity, *Economic Studies*, 17.

26. Fritsch, M., P. Mueller (2004): Effects of New Business Formation on Regional Development over Time, *Regional Studies*, 38(8), 961-975.

27. Funke and Strulik (2000): Regional Growth in West Germany: Convergence or Divergence?, *Economic Modelling*, 16, 489-502.

28. Glaeser, E.L., H. D. Kallal, J.A. Scheinkman, A. Shleifer (1992): Growth in Cities, *Journal of Political Economy* 100 (6), 1126-1152.

29. Goodall, C. (1983): M-estimators of location: An outline of the theory, in D.C. Hoaglin, F. Mosteller, J.W. Tukey: *Understanding Robust and Exploratory Data Analysis*, New York, Wiley.

30. Henderson V., A. Kuncoro, M. Turner (1995): Industrial Development in Cities, *Journal of Political Economy*, 103 (5) 1067-1090.

31. Henderson V. (2003): Marshall's scale economies, *Journal of Urban Economics*, 53, 1-28.

32. Herz, B., W. Röger (1995): Economic growth and convergence in Germany , *Review of World Economics*, 131 (1), 132-143.

33. Hulten, C.R. (1996): Infrastructure Capital and Economic Growth: How Well You Use It May Be More Important Than How Much You Have, *NBER Working Paper Series*, w5847.

34. Jacobs, J. (1969): *The Economy of Cities,* Random House, New York.

35. Kosfeld, R., H.-F. Eckey, C. Dreger (2005): Regional convergence in Unified Germany: A Spatial Econometric Perspective, in: Dreger, C., H. Galler (eds.): Advances in macroeconometric modeling, Papers and Proceedings of the 3rd IWH Workshop in Macroeconometrics, Nomos, Baden-Baden, S. 189-214.

36. Koenker, R., K. Hallock (2001): Quantile Regression: An Introduction, *Journal of Economic Perspectives*, 15, 143–156.

37. Lindh, T., B. Malmberg (1999): Age structure effects and growth in the OECD, 1950-1990, *Journal of Population Economics* 12, 431-449.

38. Mankiw, N.G., D. Romer, D. N. Weil (1992): A Contribution to the Empirics of Economic Growth, *The Quarterly Journal of Economics*, 407-437.

39. Marshall, A. (1920): *Principles of Economics*, London.

40. Martin, P., T. Mayer, F. Mayneris (2008): Spatial concentration and firm-level productivity in France, *CERP Discussion Paper* No. DP6858.

41. Martin, P., G. Ottaviano (1999): Growing locations: industry location in a model of endogenous growth, *European Economic Review*, 43, 281-302.

42. Milbourne, R., G. Otto, G. Voss (2003): Public investment and economic growth, *Applied Economics*, 35, 527-540.

43. Mincer, J. (1974): Schooling, Experience and Earnings, New York: Natuional Bureau of Economic Research.

44. Niebuhr, A. (2001): Convergence and the Effects of Spatial Interaction, *Jahrbuch für Regionalwissenschaft*, 21, 113-133.

45. Romer, P. (1986): Increasing returns and long-run growth, *Journal of Political Economy*, 94, 1002-1037.

46. Romer, P. (1990). Endogenous Technological Change, *Journal of Political Economy*, 98, 71–102.

47. Rosenthal, S.S., W.C. Strange (2004): Evidence on the Nature and Sources of Agglomeration Economies, in Henderson and Thisse: *Handbook of Regional and Urban Economics* 4, Ch. 49.

48. Rousseeuw, P.J., A.M. Leroy (2003): *Robust Regression and Outlier Detection*, New York, Wiley.

49. Sanches-Robles, B. (1998): Infrastructure Investment and Growth: Some Empirical Evidence, *Contemporary Economic Policy*, 16, 98-108.

50. Schalk, H.J., G. Untied (1996): Technologie im neoklassischen Wachstumsmodell: Effekte auf Wachstum und Konvergenz, Empirische Befunde für die Arbeitsmarktregionen der Bundesrepublik Deutschland 1978-1989, *Jahrbücher für Nationalökonomie und Statistik*, 215, 562-583.

51. Schultz, T.W. (1962): Reflections on Investment in Man, in Journal of Political Economy 70 (5), 1-8.

52. Seitz, H. (1995): Konvergenz: Theoretische Aspekte und empirische Befunde für Westdeutschland, *Konjunkturpolitik*, 41, 25-49.

53. Skirbekk V. (2004) Age and Individual Productivity: A Literature Survey, in: Feichtinger G. (ed.) Vienna Yearbook of Population Research, Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

7 Appendix

Table 5: Robustness checks and detection of multicollinearity

dep. Variable	Model 3				
$g/(n+\delta)$	all groups	group 2	group 3	group 4	alternative
$\ln y_0$	-0.3498***	-0.4243***	-0.4725***	-0.4479***	-0.3283***
	(0.0866)	(0.1033)	(0.0725)	(0.0832)	(0.0899)
$\ln s_g$	0.1490***	0.1705***	0.1909***	0.1357***	0.1511***
	(0.0473)	(0.0449)	(0.0474)	(0.0494)	(0.0473)
$\ln s_H$	-0.0045	0.0699**	0.0433	0.0962***	-0.0149
	(0.0422)	(0.03)	(0.0385)	(0.025)	(0.0439)
$\ln infradens$	0.1273**	0.1270**	0.1527***	0.1143*	0.1290**
	(0.0573)	(0.0607)	(0.0561)	(0.0598)	(0.0565)
$No.spec.Ind.$	0.0150**	0.0103	0.0137*	0.0124	0.0142*
	(0.0072)	(0.0081)	(0.0078)	(0.0078)	(0.0073)
N_{age}	0.0444***	0.0430**	0.0416**	0.0460***	0.0444***
	(0.015)	(0.0179)	(0.019)	(0.0158)	(0.0152)
DIV_N	-0.017	-0.1561	-0.1566	-0.0859	-0.0193
	(0.1083)	(0.0995)	(0.1033)	(0.102)	(0.1077)
DIV_N^2	-0.8002*	-0.7409	-0.8241*	-0.8106*	-0.7955*
	(0.4533)	(0.4738)	(0.4528)	(0.4596)	(0.4478)
m_{18-29}		Reference group			-0.2437
					(0.2595)
m_{30-44}	0.2279	0.4998			
	(0.3812)	(0.4082)			
m_{45-54}	0.6921***		0.3700*		0.5260**
	(0.198)		(0.1942)		(0.2556)
m_{55-65}	-0.3937***			-0.2757**	-0.4453***
	(0.1317)			(0.1366)	(0.1205)
$Const.$	2.4471***	2.9588***	3.3047***	1.9524***	1.4595
	(0.5861)	(0.3242)	(0.4197)	(0.6224)	(1.0806)
	Variance-Inflation-Factors				
m_{18-29}					6.58
m_{30-44}	3.34	2.15			
m_{45-54}	2.49		2.03		3.89
m_{55-65}	2.15			1.32	1.60

* p<.1; ** p<.05; *** p<.01, N=180, robust s.e. in ()

Table 6: Correlation Table of the Regression Variables

	$\frac{g}{n+\delta}$	$\ln y_0$	$\ln(n+\delta)$	$\ln[p(1-u)]$	$\ln s_g$	$\ln s_h$	$\ln infradens$	$No.of$ $spec.ind$	N_{age}	DIV_N
$\frac{g}{n+\delta}$	1.000									
$\ln y_0$	-0.581	1.000								
$\ln(n+\delta)$	-0.554	0.774	1.000							
$\ln[p(1-u)]$	-0.488	0.886	0.722	1.000						
$\ln s_g$	0.407	-0.433	-0.265	-0.176	1.000					
$\ln s_h$	0.278	-0.240	-0.398	-0.244	-0.024	1.000				
$\ln infradens$	-0.298	0.544	0.410	0.341	-0.629	-0.093	1.000			
$No.spec.ind$	0.209	-0.221	-0.219	-0.147	0.269	-0.079	-0.198	1.000		
N_{age}	0.110	0.115	0.031	0.225	0.165	-0.106	0.053	-0.070	1.000	
DIV_N	-0.032	0.139	0.178	0.241	0.193	0.055	0.113	0.065	0.252	1.000
$\ln m_{18-29}$	-0.437	0.527	0.728	0.550	-0.056	-0.762	0.251	-0.052	0.112	0.026
$\ln m_{30-44}$	0.499	-0.629	-0.651	-0.619	0.219	0.486	-0.277	0.177	-0.110	-0.090
$\ln m_{45-54}$	0.303	-0.281	-0.538	-0.326	-0.061	0.680	-0.147	-0.119	-0.091	-0.076
$\ln m_{55-65}$	-0.374	0.368	0.236	0.337	-0.291	0.011	0.220	-0.094	0.092	0.253

N=180

Here we derive the growth equation. Given the output in per capita terms of equation (1), and the dynamic equations for the capital stock of private, public and human capital

$$\dot{k} = s_k y - (n+\delta) k \tag{3}$$

$$\dot{h} = s_h y - (n+\delta) h \tag{4}$$

$$\dot{g} = s_g y - (n+\delta) g \tag{5}$$

and the assumption that a change in the stock is zero in long run. This allows to derive k^* and h^* as

$$k^* = \frac{s_k y}{n+\delta}, \quad h^* = \frac{s_h y}{n+\delta} \tag{6}$$

and from $\dot{g} = 0$ follows

$$y = \frac{(n+\delta) g^*}{s_g} \tag{7}$$

Substitution of (6) in (1), rearranging and inserting (7) yields a solution of g^*,

$$\begin{aligned} y &= A k^\alpha g^\beta h^\gamma M^{1-\alpha-\beta} \left[p(1-u)\right]^{1-\alpha-\beta-\gamma} \\ g^* &= A^{1/(1-\alpha-\beta-\gamma)} \left(\frac{1}{n+\delta}\right)^{1/(1-\alpha-\beta-\gamma)} s_k^{\frac{\alpha}{1-\alpha-\beta-\gamma}} s_h^{\frac{\gamma}{1-\alpha-\beta-\gamma}} s_g^{\frac{1-\alpha-\gamma}{1-\alpha-\beta-\gamma}} M^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}} \left[p(1-u)\right]. \end{aligned}$$

Doing the same for the other variables, we find k^* and h^*

$$h^* = A^{1/(1-\alpha-\beta-\gamma)} s_k^{\frac{\alpha}{1-\alpha-\beta-\gamma}} s_g^{\frac{\beta}{1-\alpha-\beta-\gamma}} s_h^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}} \left(\frac{1}{n+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}} M^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}} \left[p(1-u)\right], \tag{8}$$

$$k^* = A^{1/(1-\alpha-\beta-\gamma)} \left(\frac{1}{n+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}} s_k^{\frac{1-\beta-\gamma}{1-\alpha-\beta-\gamma}} s_g^{\frac{\beta}{1-\alpha-\beta-\gamma}} s_h^{\frac{\gamma}{1-\alpha-\beta-\gamma}} M^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}} \left[p(1-u)\right]. \tag{9}$$

Putting g^*, h^* and k^* in (1) we find the steady state values of the production function in per capita terms

$$y^* = A^{\frac{1}{1-\alpha-\beta-\gamma}} \left(\frac{1}{n+\delta}\right)^{\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}} M^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}} \left(s_k^\alpha s_g^\beta s_h^\gamma\right)^{\frac{1}{1-\alpha-\beta-\gamma}} \left[p(1-u)\right]. \tag{10}$$

In the next step we linearise the dynamic equations (3), (4) and (5) in the area of the steady state.

$$\begin{aligned} \frac{d\ln\left(\frac{\dot{k}}{k}\right)}{dt} &\simeq (\alpha-1)(n+\delta)\ln\left(\frac{k}{k^*}\right) + \beta(n+\delta)\ln\left(\frac{g}{g^*}\right) + \gamma(n+\delta)\ln\left(\frac{h}{h^*}\right) \\ \frac{d\ln\left(\frac{\dot{g}}{g}\right)}{dt} &\simeq \alpha(n+\delta)\ln\left(\frac{k}{k^*}\right) + (\beta-1)(n+\delta)\ln\left(\frac{g}{g^*}\right) + \gamma(n+\delta)\ln\left(\frac{h}{h^*}\right) \\ \frac{d\ln\left(\frac{\dot{h}}{h}\right)}{dt} &\simeq \alpha(n+\delta)\ln\left(\frac{k}{k^*}\right) + \beta(n+\delta)\ln\left(\frac{g}{g^*}\right) + (\gamma-1)(n+\delta)\ln\left(\frac{h}{h^*}\right) \end{aligned}$$

Furthermore we can derive the growth rate of y closed to the steady state,

$$\begin{aligned}\frac{\dot{y}}{y} &= \alpha\frac{dk}{k}+\beta\frac{dg}{g}+\gamma\frac{dh}{h} \quad \text{which can be written as} \\ \frac{d\ln\frac{y}{y^*}}{dt} &= \alpha\frac{d\ln\left(\frac{\dot{k}}{k}\right)}{dt}+\beta\frac{d\ln\left(\frac{\dot{g}}{g}\right)}{dt}+\gamma\frac{d\ln\left(\frac{\dot{h}}{h}\right)}{dt}..\end{aligned}$$

Inserting the linearized set of equations we derive

$$\frac{d\ln\frac{y}{y^*}}{dt}=-\left(1-\alpha-\beta-\gamma\right)\left(n+\delta\right)\left[\alpha\ln\left(\frac{k}{k^*}\right)+\beta\ln\left(\frac{g}{g^*}\right)+\gamma\ln\left(\frac{h}{h^*}\right)\right]$$

With $\ln\left(y/y^*\right)\simeq\frac{\dot{y}}{y}=\alpha\frac{dk}{k}+\beta\frac{dg}{g}+\gamma\frac{dh}{h}$, it follows

$$g\equiv\frac{d\ln\frac{y}{y^*}}{dt}=\left(1-\alpha-\beta-\gamma\right)\left(n+\delta\right)\left[-\ln y+\ln y^*\right].$$

Substitution of (10) yields the regression equation

$$\begin{aligned}\frac{g}{n+\delta} &= \ln A-\left(1-\alpha-\beta-\gamma\right)\ln y-\left(\alpha+\beta+\gamma\right)\ln\left(n+\delta\right)+\left(1-\alpha-\beta\right)\ln M \\ &\quad +\alpha\ln s_k+\beta\ln s_g+\gamma\ln s_{educ}+\left(1-\alpha-\beta-\gamma\right)\ln\left[p\left(1-u\right)\right].\end{aligned}$$

To achieve a regression equation based on s_H, we rearrange (8) to s_h and substitute into (10). The regression equation contains the same variables but the underlying parameters change.

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