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The Age Pattern of Human Capital and Regional Productivity

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Abstract:

We explore the impact of the age structure of human capital on average regional productivity by applying a spatial econometric analysis based on an augmented Lucas-type production function. We also apply a new definition of regional human capital focusing on its availability. The estimates provide evidence that there are age specific human capital effects in Germany and that a temporary increase in regional productivity could occur during the demographic transition. Furthermore, it becomes clear that the availability based definition of human capital provides additional insight and so, could enrich future studies on regional human capital.

JEL-Classification: J24, R11

Keywords: Regional Productivity, Human Capital, Demographic Change

1 Introduction

The ageing of the population currently occurring in many industrial countries or regions changes the age and skill pattern of regions. This poses some open questions concerning productivity: what happens to regional productivity of a region facing an ageing population? Is this region likely to experience a decrease in productivity and, thus, a decrease in income? Does the result depend on changes in the age pattern of human capital induced by ageing? These issues are quite important since they have implications for education or labour market policies and economic growth. In particular, policy recommendations, growth perspectives and growth forecasts might depend on such cohort effects of human capital. If there are age dependent effects, an efficient policy should focus on improving human capital of the most productive age cohort. On the other hand, growth perspectives during the demographic transition are less positive for ageing societies if the productivity decreases with age. If, however, there are no age dependent effects, education, lifetime learning, labour market policies or a rise in labour force participation are all substitutes with respect to productivity.

While there is first evidence of age effects on economic growth and the productivity of firms (e. g. Hellerstein et al. 1999), literature focusing on this topic is scarce if it comes to regions or countries. In particular, there is as far as we know yet neither empirical nor theoretical work on the effects of the changing age pattern of human capital on regional productivity or growth. This is quite surprising since human capital shares of the age cohorts differ considerably among regions.

Of course, in theoretical and empirical literature the importance of human capital is well established (e. g. Nelson and Phelps 1966, Lucas 1988, Romer 1990, Grossman and Helpman 1991). In the urban economics literature Jacobs (1969) suggests that there is also a relationship between productivity and human capital. There is also evidence of substantial high productivity gains on the local level induced by human capital expansion (Rauch 1993, see Moretti 2004 for a survey). However, neither the composition of the population nor changes in the age pattern are considered in those studies, except for a few papers. Evidence of an influence of the age distribution of the population on income growth is found for the OECD countries by Lindh and Malmberg (1999), for the U. S. states by Bhatta and Lobo (2002) and from the NUTS2 regions of the European Union by Brunow and Hirte (2006).

On the other hand, ageing also changes the age pattern of human capital and the share of human capital in the population. Whether this is the deep cause behind the influence of the age pattern on growth or productivity is yet not empirically examined. The only exception is the paper of Bhatta and Lobo (2001). By applying a growth accounting approach they calculated that human capital and its age pattern are responsible for about 2/3 of the differences in per capita output between New York and the poorest U.S. states. However, Bhatta and Lobo approximate the age pattern of human capital by the age pattern of the population. Unfortunately, they do not test the validity of this approximation which requires to assume that the skill composition within the labour force is constant across age and regions. This assumption is obviously heroic. For instance, in Germany there is not even an approximate constancy of those shares. Moreover regional differences in the human capital shares of the age cohorts are remarkably high in Germany. The average human capital, i. e. the share of the high-skilled in the German labour market regions is between 1.2 and 6.9 per cent in the age cohort 30-39, between 0.6 and 6 per cent in the age cohort 40-49 and 0.2 and 4.9 in the age cohort 50-65. Their approach is therefore not appropriate[1] These figures make also clear that one has to take explicitly into account the age pattern of human capital when examining human capital effects on productivity.

This lack of studies is surprising since there is clear evidence of age dependent effects of human capital on the level of the individual and the firm. There is a vast literature on the lifetime pattern of individual productivity. This literature is grounded on the Mincer wage equation and examines the private and social rates of return to schooling (see e. g. the survey of Belzil 2007). An inverted u-shaped pattern of individual productivity is well established in this literature. There are also many studies on firm level

[1]Their approach bears some further shortcomings since they do not test for spatial autocorrelation.

productivity establishing that average productivity exhibits also an inverted u-shaped pattern with respect to the average age of the firms employees (e. g. Hellerstein et al. 1999). This literature implies that ageing matters and – eventually – is harmful to productivity and, thus, growth.

Our paper is a first step towards filling this gap in the literature. We examine the effects of the *age pattern of human capital* on the average productivity of regions in an augmented Lucas-type production function (Lucas 1988). To be accurate, we explore whether human capital effects depend on the age composition of human capital. However, we do not focus on growth and, thus, we do not adopt the full endogenous growth model suggested by Lucas (1988). Nonetheless, applying a Lucas-type production function is useful since there are other sources of human capital effects which can be studied using this production function. For instance, human capital mitigates the adoption or imitation of new technologies (Nelson and Phelps 1966) or it facilitates the use of current technologies (Bils and Klenow 2000). Moreover, as far as level effects of human capital are important to economic growth (Romer 1990, Grossman and Helpman 1991, Barro 2001, Benhabib and Spiegel 1994, Krueger and Lindahl 2001), growth perspectives are inherent in our approach. However, we do not study the skill composition of the labour force, as suggested by Acemoglu et al. (2002), but focus entirely on human capital. We are examining all human capital effects and do not distinguish between imperfect substitution effects and externalities (this issue has been discussed in Moretti 2004 or Ciccone and Peri 2006). Further effects such as agglomeration effects and spatial interdependencies are also controlled for in this study.

On account of the accessibility of micro labour market data we choose Germany as our research field. Germany is a very interesting case since it is a country consisting of a mature capitalist economy, West Germany, and a transition economy, East Germany. Insofar the problems we discuss and examine are to some extent also issues relevant to the European integration of transition economies.

Concerning our subject, German unification is of outstanding importance. An adverse employment shock raised the unemployment rate of the New

German Federal States (Länder) to more than 20% in the early 1990s. This caused huge outmigration and a sharp drop in the birth rate. As a consequence, the population in East German regions is nowadays considerably older than in West Germany. Furthermore, before 1990, two totally different education systems were at work in the two Germanies. After unification many formal qualifications acquired in the GDR became worthless. Both the labour market shock and the education shock forced many of the persons who have a high degree of educational attainment to work in jobs demanding only low or at best medium skills. For this reason the share of *educated human capital*, which is used in many studies (e. g. Lucas 1988), is not an appropriate measure for the human capital endowment of a region which is badly performing or subject to strong economic shocks. Therefore we define human capital alternatively according to its *availability*, i. e. we consider human capital which is currently available for jobs demanding high skilled labour.

We find evidence that the age pattern of human capital matters for regional productivity. However, the relative productivity levels of the age cohorts depend on the definition of human capital that is applied. When human capital is traditionally defined an inverted u-shaped pattern of productivity emerges. Then the age cohort 40-49 is the most productive cohort. When human capital is defined according to availability the productivity pattern found in our study contrasts with the traditional finding. Then, the youngest cohort, aged 20-30, is the most productive cohort while age effects of the two eldest cohorts do hardly differ. The second cohort, aged 30-49, in neither case shows any human capital effects. The results are quite robust against modifications. These findings also imply that the average productivity of ageing regions could temporarily increase during the demographic transition. These regions might wrongly believe themselves to be well protected against the adverse effects of ageing. If they do, therefore, not take appropriate measures they are finally worse off. After all regional productivity declines in the medium term if a region is not able to create or attract more young human capital. From this we conclude that an efficient policy should primarily aim at increasing the skill levels of the younger cohorts and providing appropriate jobs for the high skilled.

We proceed as follows. In the next section we develop our model. This is succeeded by a description of the data base, some descriptive statistics, and the presentation and interpretation of the regression results. A summary closes the paper.

2 Basic Model

The regional value-added Y is a function of total factor productivity in a region A, capital K, the total labour force N and the average level of human capital h. The latter is implemented as the Lucas human capital externality h^{γ} (Lucas 1988), where h is a measure of average human capital in a region and γ captures all types of human capital effects. However, in reference to Moretti (2004) and Ciccone and Peri (2006) we actually do not distinguish between imperfect substitutability effects and spillover effects. Instead we decompose human capital effects into two effects: (i) each high-skilled employee provides a basic productivity level which is the same for high-skilled and low-skilled workers, which we call *quantity effects*, and (ii) additional effects of qualification captured in the Lucas human capital term, which we call *quality effects*. The first effect implies that all employees, whether high-skilled or not high-skilled, can be aggregated into regional labour input N (quantity of labour input) and that there is perfect substitutability between different skill levels in this labour input. Both, capital and quantity of labour are encompassed in a basic value added function characterized by constants returns to scale. Nonetheless there might be increasing returns to scale in regional production because of agglomeration effects or human capital effects. We consider these effects by using the regional production

$$Y = A(\cdot)\ K^{a} N^{1-a} h^{\gamma}, \tag{1}$$

which is a slight modification of Lucas (2001) and Ciccone (2002).

The total factor productivity function $A(\cdot)$ includes all types of agglomeration effects except those attached only to human capital (see Eberts and

McMillen 1999 and Rosenthal and Strange 2004). This implies the assumption that agglomeration effects considered below are Hicks neutral with respect to capital, labour and human capital[2]. It encompasses localisation and urbanisation effects (overview in Overman et al. 2003). Since we do not consider time, the usual device of controlling for agglomeration effects is not feasible (Rosenthal and Strange 2004). Instead we approximate these effects by using the following implementations.

The externalities of the Marshall-Arrow-Romer (MAR) type concern *localisation effects*. Usually MAR-externalities are captured in the autoregressive coefficients since, for instance, average firm size or firm number depends on the same figures of the previous period (Combes et al. 2004). We, however, use a much simpler approach. Our indicator for localisation effects is the concentration of an industry at specific locations (other, more sophisticated approaches can be found, e. g. in Wheeler 2007). Of course concentration could also be caused by natural resources or urbanisation effects, but if there are localisation effects they unambiguously favour concentration. Because of our interests in regional performance, we generate a regional specialisation dummy, labelled *Dloc*. This regional dummy is set to unity if at least one of the manufacturing sectors or the industrial services sector is relatively strong localised in the region, where sectoral localisation is defined as

$$q_r^i = \frac{N_r^i}{\sum_r N_r^i}.$$

This is the ratio of employment of industry i in region r relative to employment of the same industry in the whole country. We refer to manufacturing since there is strong evidence of localisation effects occurring particularly in these sectors (Henderson et al. 1995, see also references and evidence e. g. in

[2]Of course, agglomeration effects might affect human capital productivity more than productivity of other factors. However, since we can not reliably test for those differences on account of strong multicollinearities between interactions terms of agglomeration variables with capital intensity, respectively, human capital, we stick to our assumption. Attaching all agglomeration effects only to human capital externalities would provide highly significant results of the age pattern. However, this approach would require to pose the assumption that agglomeration effects do not affect productivity of capital or labour which is against intuition.

van Oort 2007).

Urbanisation effects occur due to proximity of various economic activities. This encompasses diversity of services, intermediates and final products (backward linkages) as well as market size effects (forward linkages) (see Jacobs 1969 and Krugman 1991). In addition, negative agglomeration effects might occur on account of congestion, higher housing prices, higher factor prices or strong competition (e. g. Krugman 1991). The easiest way to approximate these effects is to use population and squared population as variables in the regression. In our case this generates strong endogeneity issues and multicollinearities. Another approach has been suggested by Ciccone (2002). He uses the ratio of employment to the regional area as urbanisation measure. But, again, endogeneity problems arise and instruments are required. However, we do not use these approaches in the following because they perform poorly[3]. Instead we implement another idea. Urbanisation effects are usually caused by a high degree of diversification (Jacobs1969). For this reason, we apply a measure of diversity as proxy for agglomeration. Such an index also allows taking into account spatial heterogeneity. Our index of diversity is the negative Herfindahl-index of a region (e. g. Combes et al. 2004), i. e.

$$Div_r = -\ln\left[\sum_{i=1}^{6}\left(\frac{N_{ri}}{N_r}\right)^2\right],$$

where $i = 1, ..., 6$ are the six manufacturing sectors considered in this index, since there is evidence that manufacturing diversity exerts a positive impact on growth (e. g. Henderson et al. 1995). Therefore, we expect either a significantly positive or an insignificant coefficient.

Total factor productivity is usually assumed to depend on the number of patents. We refrain from doing so because of the following reasons. We are interested in the average productivity of human capital in a region. Since

[3]We tried to follow Ciccone (2002) and approximate agglomeration effects by employment density. Due to endogeneity this implies to instrument employment e. g. by the area per employee as suggested by Ciccone (2002). In addition we tried to instrument employment by the functional type of regions. Neither instrument provided useful results. Futhermore we tried to approximate area by used land area and area used for infrastructure.

the number of patents depends on human capital employed in R&D, and because knowledge transfers or adoption and use of new technologies also depend on human capital, considering human capital effects also encompasses accounting for R&D externalities. This explains why patents correlate with the age pattern of human capital. Actually, both past and current patents correlate with human capital of age cohorts 40-49 and 50-65. As a consequence, considering patents and the age pattern would reduce significance levels on account of strong multicollinearities. This is the main reason why we refrain from using patents as measure for technology. Instead technology is captured by a constant T. Finally, since there are still differences between East and West Germany a dummy variable is introduced, $East$. Collecting terms yields the full specified A function

$$A(\cdot) = T \quad \exp\left[\alpha_D Div + \alpha_L Dloc + \alpha_E East\right].$$

Eventually, we get (note, we omit the indices for the regions)

$$Y = T \ \exp\left[\alpha_D Div + \alpha_L \ Dloc + \alpha_E \ East\right] \ K^a N^{1-a} \, h^\gamma.$$

Division by N yields average regional productivity

$$y = T \ \exp\left[\alpha_D Div + \alpha_L Dloc + \alpha_E \ East\right] \ (k)^\alpha \ h^\gamma,$$

where y denotes gross value-added per employee and k is capital intensity K/N. Since we assume constants returns to scale in K and N, N vanishes in this equation.

Taking logarithm and adding a white noise variable yields the basic econometric equation, our **Model 1**

$$\ln y = \ln T + a_D Div + \alpha_L \ Dloc + \alpha_E \ East + a \ln k + \gamma \ln h + \varepsilon. \qquad (2)$$

Given this basic model we turn now to the issue how to deal with the age pattern of human capital.

3 Age Structure

We assume that the overall human capital coefficient, γ, is fully explained by the contribution of the shares of the age cohorts on regional human capital, i. e.

$$\gamma = \sum_{j=1}^{J} b_j m_j \qquad \text{where } m_j = \frac{h_j}{h} \ \forall j \text{ and } \sum_{j=1}^{J} m_j = 1$$

where m_j is the share of age cohort j on the high-skilled labour force, J is the number of cohorts and b_j is the impact coefficient of age share m_j. Hence, $b_j m_j$ is the part of the human capital effect γ caused by the share of age cohort j on regional human capital. Substituting into (2) yields **Model 2**

$$\begin{aligned} \ln y = \ln T + a_D Div + \alpha_L \ Dloc + \alpha_E \ East \\ + a \ln k + \left(\sum_{j=1}^{J} b_j m_j \right) \ln h + \epsilon. \end{aligned} \tag{3}$$

Since we look at regions we have to control for spatial heterogeneity and test for spatial autocorrelation. Spatial heterogeneity is implemented by a spatial lag of average human capital of the neighbouring region. This yields the spatial regressive **Model 3**

$$\begin{aligned} \ln y = \ln T + a_D Div + \alpha_L \ Dloc + \alpha_E \ East \\ + a \ln k + \gamma \ln h + \ln (\mathbf{W}_N \boldsymbol{h}) + \epsilon. \end{aligned} \tag{4}$$

where $\boldsymbol{W}_N$ is a row standardized binary contiguity weight matrix, respectively, **Model 4** where we take into account the age pattern of human capital

$$\begin{aligned} \ln y = \ln T + a_D Div + \alpha_L \ Dloc + \alpha_E \ East + a \ln k \\ + \left(\sum_{j=1}^{J} b_j m_j \right) \ln h + \ln (\mathbf{W}_N \boldsymbol{h}) + \epsilon. \end{aligned} \tag{5}$$

Since our tests on spatial autocorrelation, described below, are insignificant concerning the spatial lag model, we only present results of the spatial error model (which goes back to Cliff and Ord 1981, Anselin 1988). This is reflected in an autocorrelated error term

$$\varepsilon = \lambda \mathbf{W}_D \varepsilon + \epsilon,$$

where $\mathbf{W}_D$ is a spatial weight matrix based on distance decay[4]. Hence the regression equation (2) becomes **Model 5**, with $\ln h$ instead of the age pattern, and **Model 6**, where the age pattern is considered

$$\begin{aligned} \ln y = \ln T + a_D Div + \alpha_L \; Dloc + \alpha_E \; East + a \ln k \\ + \left(\sum_{j=1}^{J} b_j m_j \right) \ln h + \left(I - \lambda \mathbf{W}^{-1} \right) \epsilon. \end{aligned} \tag{6}$$

Eventually, we also estimate a mixed lag regressive and spatial error model, i. e. **Model 7**, which is Model 5 expanded by the lag regressive term $\ln(\mathbf{W}_D \boldsymbol{h})$, and **Model 8**, which is Model 6 defined in equation (6) plus the lag regressive term.

4 Hypotheses

According to evidence provided in the literature we state the following *hypotheses*: average productivity depends to a large part on the human capital stock, while there are constants returns to scale with respect to capital and labour; there are increasing returns to scale because of effects induced by average human capital (Lucas 1988) and due to agglomeration effects. Concerning the latter, evidence provided in the literature suggests that diversity raises productivity (e. g. van Oort 2007, Henderson et al. 1995), while the evidence of specialisation gains is mixed (e. g. van Oort 2007). The wage level in the East is about 70-75 per cent of wages in the West. For this reason one can expect that the East dummy is negative and very large (see also Eckey et

[4]The construction of the matrices is described in Brunow and Hirte (2006). After evaluating the results of Lagrange multiplier tests we decided to use a weight matrix which moderately discounts distance. However, we also carried out estimates using a binary contiguity weight matrix and two other weight matrices, where distance is discounted weaker and stronger.

al. 2007). Though the use of the definition of labour market regions implies that most of spatial autocorrelation, e. g. commuting, is integrated within those large regions, on account of evidence provided elsewhere we expect that there is spatial autocorrelation (see Brunow and Hirte 2006). Next we turn to the empirical part. There we, first, discuss data and, second, the results of the regressions.

5 Data

Regional data of gross-added value (GVA), regional employment, types of region are taken from the "INKAR" data base of the Federal Office of Regional Planning and Construction (BBR, Bundesamt für Raumordnung und Bauwesen) and the "Genesis Regional" database provided by the Federal Statistical Office ("Genesis Regional"). The regional capital stock has been calculated by Eckey et al. (2007). The data on human capital and the age pattern of human capital in 2000 are from the "IABS", i.e. the labour force sample of the Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung). The IABS is a two per cent sample of the full labour force statistics, collected for administrating and carrying out labour market policy, unemployment insurance and public education programs for unemployed persons. This sample is representative on the NUTS 3 regional level ("Kreise") as well as on the sectoral level (16 sectors).

The IABS provides data on individual education levels as well as the region and the sector where a person works. We use these data to calculate the share of the high-skilled persons on the labour force as well as the age pattern of the high-skilled[5]. In that we distinguish four age cohorts - cohort 1, younger than 30 years old, cohort 2, aged 30-39 years, cohort 3, aged 40-49, and cohort 3, which encompasses all employees older than 50.[6]

We apply two definitions of "high-skilled" on account of the following

[5] We correct for some problems in the Data base. For instance there are individuals who are reported as high-skilled in a period but as non-high-skilled in a subsequent period.

[6] We also distinguished more skill levels - but only the high-skilled proved to be significant.

problems: Because the former communistic system pushed education, educational attainment of the elder labour force in East Germany is on average higher than in West Germany. Moreover, many of the former Eastern field of studies did not have an equivalent counterpart in the Western university system, which replaced the Eastern system after unification. Some of the disciplines focused on the former socialist system and, therefore, were useless after German unification, e. g. studies of (communistic) law or economics. In addition, the collapse of the East German economy lead to high and long term unemployment in all skill groups. As a result, many high skilled individuals were not able to find a job adequate to their skill levels.

The first definition of human capital we use is that of *"educated" human capital*. This the usual ("old") one: the educated human capital share is the labour force share of the persons with university degree or equivalent education. This definition focuses on educational attainment. On account of the reasons given above, this traditional definition could be a poor approximation to available human capital. Therefore we propose and use the definition of *available human capital* alternatively, named later on the "new" definition. This encompasses all persons working in typical high-skilled jobs[7]. In addition we add all high-skilled unemployed persons who did previously work in a high-skilled job or did not work before entering unemployment and who where only unemployed for less than one year. Accordingly, all short-term unemployed are included in our definition of the labour force, while the long-term unemployed individuals are not member of the labour force. As a consequence, highly-educated employees are not encompassed in regional human capital if they work in jobs requiring lower qualifications. On the other hand, originally "less qualified" persons are added to regional human capital if they work on a job usually requiring a university or equivalent degree. These are persons who accumulated knowledge mainly by experience[8].

[7]We are indebted to Anne Otto for suggesting to link data on high-skilled jobs with data on educational attainment.

[8]These two concepts of human capital are close to the definitions of actual and required education in the overeducation literature, which has been launched by Duncan and Hoffmann (1981) and recently surveyed by Groot et al. (2007). However, we also include skills acquired by experience and unemployed human capital.

	Mean	Std. Dev.	Min	Max
common variables				
gross value added	3.9962	0.1706	3.6028	4.6061
capital per capita	4.1053	0.1999	3.5755	4.9086
old definition				
human capital: h	0.085	0.0313	0.0325	0.1923
m_1: age 20-29	0.1251	0.0484	0.0172	0.2679
m_2: age 30-39	0.362	0.0737	0.1589	0.561
m_3: age 40-49	0.29	0.0455	0.1591	0.4299
m_4: age 50-65	0.2229	0.0839	0.0541	0.4463
$\boldsymbol{W}_N h$	-2.4451	0.2024	-3.0792	-1.94
Div	1.4132	0.1581	0.4562	1.5975
new definition				
human capital: h	0.0904	0.026	0.048	0.1792
m_1: age 20-29	0.1867	0.0596	0.0323	0.3571
m_2: age 30-39	0.3162	0.054	0.172	0.4742
m_3: age 40-49	0.2581	0.0448	0.1421	0.3939
m_4: age 50-65	0.239	0.0673	0.125	0.4516
$\boldsymbol{W}_D h$	-2.3844	0.1398	-2.8284	-2.0558
Div	1.4133	0.1587	0.4432	1.5974

"old definition" human capital defined by educational attainment (university education or equivalent education); h share of human capital in the labour force; m_i share of age cohort i on human capital; W_N spatial weight matrix based on distance decay; $W_N h$ spatially lagged human capital; Div diversification index; "new definition" human capital defined by availability; W_D binary contiguity weight matrix; $W_D h$ spatially lagged human capital.

Table 1: Descriptive Statistics

Table 1 displays descriptive statistics of the most important variables. There is a huge regional variation in GVA, the capital stock per capita and the diversity index. The most concentrated region is Wolfsburg (automobile industry) but there are also regions with high diversity like Munich.

The other figures in Table 1 concern human capital of different age cohorts. These are based on different definitions of human capital. The share of the youngest cohort is considerably higher under the new definition compared to the old definition. On the other hand, the next two elder cohorts are smaller given the new definition of human capital.

There are different reasons for this outcome. Since members of the youngest age cohort just have entered the labour force there is a relatively low share of long-term unemployed persons in this group. In contrast, this share is much higher in the other working groups. In addition parenthood breaks and restructuring of firms forces more high-skilled persons to work in less skills requiring jobs. Moreover, the eldest two groups in the East experienced an adverse labour market shock after German unification, pushing many highly educated persons either into long-term unemployment or into less human capital intensive jobs. Both implies depreciation of skills formerly acquired by education. On the other hand, since work experience is higher in these age cohorts, human capital includes more individuals without high educational achievement. These effects are taken into account in the definition of available human capital ("new"). By and large we expect that the adverse effects dominate and that the elder groups have a lower share in human capital. Table 1 shows that this is indeed true for both middle aged working cohorts. But, surprisingly, the human capital share of the eldest working cohort, which has the highest long-term unemployment rate, increases from a percentage of 22 to 23 per cent when we switch from formal to available human capital. These figures imply that there have to be strong countervailing effects others than only work experience. Labour shortage could be one of these reasons. Particularly, in the 1960s a huge excess in labour demand in the West provided opportunities for persons whithout education or with a low degree of educational achievement to enter high-skilled jobs or leading positions. Similarily, the IT boom facilitated to move into high-skilled job without having achieved high educational attainment.

In the following we present our results of the pure human capital approach. In this model human capital effects are enriched by considering agglomeration effects. Thereafter we switch to the age pattern models.

6 Regressions and Results

Table 2 and Table 3 display the results of the regressions. Model 1, equation (2), is the augmented human capital approach where human capital is not decomposed and where spatial heterogeneity is absent. Model 3, equation (4), refers to the same model expanded by a spatially lagged covariate (spatial regressive model). Following the procedure of model selection as suggested by Florax et al. (2003), we start with an OLS estimation and apply the Moran-I-test and the Lagrange Multiplier tests for spatial error, LM_{err}, or spatial lag, LM_{lag}, dependence (Anselin and Florax 1995) as well as the corresponding robust LM tests . If the tests suggest that there is spatial dependence, the approach with the higher robust LM test value should be preferred. The test results are given in the lower part of Table 2 and Table 3 together with the Aikake Information Criterium, AIC. Since the AIC does not unambiguously favour the spatial regressive model, since the spatial regressive coefficient is insignificant and since the tests on spatial autocorrelation indicate that the spatial error model should be used, we only present estimates of the basic OLS and the spatial error model.

The results of the OLS estimates with robust standard errors are presented on the left hand side of Table 2 The last two columns of Table 2 display the results of the spatial error model where we neglect spatial heterogeneity (Model 5, see equation (6)). The AIC, the insignificance of the lag regressive variables, as well as the spatial error tests all imply that the spatial error model, i. e. Model 5, should be preferred in both human capital definitions.

We also test for constant returns to scale with respect to capital and labour. In each case the zero hypothesis of constant returns to scale could not be rejected. The estimates on the elasticity of the capital intensity which lie in the range of 0.326 to 0.347, are in line with empirical evidence in the literature. Even 10 years after unification – note our data are from 2000 – there is a clear difference between East and West Germany. The East dummy suggests that East Germany reaches only about 78 per cent of West Germany's productivity. This effect is robust against all modifications we implemented.

Both measures of agglomeration effects are highly positive significant in all models. Hence, the higher regional diversification in manufacturing, Div, the more productive is the region. In the literature there is mixed evidence of the sign of diversity. It seems to depend on the definition of the diversity index, particularly, whether it only refers to manufacturing diversity or overall diversity (see the discussion in van Oort 2007, Combes et al. 2004). However, these studies examine employment growth. Nonetheless, since we use a manufacturing based diversity index our findings are in line with these results (e. g. Henderson 1995). In all models where we refer to available human capital the coefficient of the diversity index is slightly higher. This is caused by the job-based definition of human capital, which implicitly depends on the industrial pattern of the regions. In any case, there is clear evidence of a significant influence of manufacturing diversity. However, because this variable also captures differences in the regional industrial structure, we are reluctant to interpret this as strong evidence in favour of the Jacobs hypothesis.

The second regional variable, which is the dummy $Dloc$, is also significant in all estimates. This gives evidence of positive specialisation effects in the following sense: a region in which at least one sector is clustered above national average is more productive due to specialisation gains or localisation externalities. These positive externalities are stronger in the spatial error model, where interregional links are taken into account. Though literature provides mixed results, positive localisation effects are also found in other studies (e. g. Henderson 2003).

In all estimates average human capital, $\ln h$, improves productivity implying that there are human capital effects. The human capital elasticities lie in the range between 0.09 and 0.116 depending on the definition of human capital. Since the new definition focuses on actually required skills, it is more

Estimates: average productivity - average human capital						
	OLS estimates		OLS: sp regressive		ML spatial error	
	Model 1		Model 3		Model 5	
	old	new	old	new	old	new
$\ln k$	0.346***	0.345***	0.347***	0.347***	0.326***	0.331***
	(0.035)	(0.036)	(0.034)	(0.035)	(0.032)	(0.033)
East	-0.259***	-0.248***	-0.250***	-0.243***	-0.265***	-0.252***
	(0.018)	(0.017)	(0.020)	(0.018)	(0.025)	(0.023)
Div	0.062*	0.060*	0.059*	0.059*	0.072**	0.073**
	(0.034)	(0.035)	(0.033)	(0.035)	(0.034)	(0.035)
Dloc	0.069**	0.074***	0.068**	0.074***	0.089***	0.089***
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
$\ln h$	0.094***	0.116***	0.100***	0.118***	0.093***	0.113***
	(0.025)	(0.029)	(0.026)	(0.029)	(0.023)	(0.027)
$\ln \mathbf{W}_N\mathbf{h}$			-0.040	-0.033		
			(0.038)	(0.045)		
$\ln T$	2.782***	2.830***	2.699***	2.750***	2.850***	2.864***
	(0.161)	(0.170)	(0.185)	(0.206)	(0.152)	(0.162)
λ					0.753***	0.698***
					(0.161)	(0.182)
AIC	-385.5	-386.4	-384.7	-384.9	-395.6	-393.1
ll	198.7	199.2	199.3	199.5	205.8	204.5
Moran I	7.6***	6.5***	7.5***	6.5***		
sp error						
LM	28.7***	20.4***	26.6***	20.6***		
rob LM	27.3***	18.4***	25.7***	18.7***		
sp lag						
LM	2.3	2.2	1.9	2.1		
rob LM	0.8	0.3	0.9	0.3		

* $p < .1$; ** $p < .05$; *** $p < .01$, $N = 172$, robust s.e. in parentheses

“sp” spatial; “Model 1” OLS without spatial dependence; “Model 3” OLS with spatially lagged human capital (spatial regressive); “Model 5” ML with spatial error dependence; $\ln k$ logarithm of capital intensity; *East* Dummy for East Germany; *Div* diversity index; *Dloc* location index, indicating specialisation; $\ln h$ logarithm of average human capital; $\ln W_N h$ spatially lagged human capital; $\ln T$ the constant; λ coefficient of the spatial error component; “sp error" spatial error; “LM” spatial LM tests; “rob LM” robust spatial LM test; “sp lag” spatial lag

Table 2: Results of regressions without an age pattern

sensitive to changes in average human capital. The results fit well to findings of Eckey et al. (2007) on Germany, but are on the bottom of estimates in the growth literature, where the upper limit is about 0.3.[9] However, since most authors do not control for agglomeration effects, the elasticity is presumably overestimated in many studies.

The spatial error coefficient λ proves to be significant in both spatial error estimates. This confirms the results of the spatial tests. Hence, there is spatial autocorrelation occurring, however, not via human capital or productivity levels but on account of other not examined reasons, for instance, infrastructure[10]. Differences between the spatial error and the OLS estimates are moderate, except for agglomeration effects. The gains from specialisation and urbanisation effects are considerably higher in the spatial error model while capital intensity effects are lower. Human capital effects are higher concerning available human capital compared to formal human capital. This is a consequence of the focus on the use of human capital in the first definition.

Having found evidence of the significance of human capital for regional productivity, we now switch to the effects of the age pattern of human capital. The results of the estimates are displayed in Table 3.

The results of the tests for spatial autocorrelation printed in the lower part of Table 3 show that spatial error dependence cannot be rejected in the age pattern models. This is also true for the spatial regressive model. As a consequence, the spatial error is, again, our preferred approach. This is also reflected in the AIC which is smaller for all spatial error estimates compared to the corresponding OLS estimates. The coefficient of the spatial error dependence, λ, is also significant in the spatial error estimates.

So, we can concentrate on the spatial error estimates, given in columns 7-8 of Table 3. The difference to the approach discussed above is that we now consider the age pattern of human capital. Nonetheless, the coefficients of capital intensity, $\ln k$ and specialisation, $Dloc$, do not change. Diversification, Div, and the East dummy coefficients are slightly lower given the

[9] If we carry out a regression for West Germany only, the elasticity is slightly higher.

[10] We also controlled for a spatial regressive diversity index in the spatial error model which, however, is also insignificant (Model 7).

old definition. This implies that the decomposition of human capital effects induces effects which differ between East and West. Some intuitions for these differences are given above.

Most of the age coefficients are significant in all models. They also differ among the age groups, thus, providing evidence that the age pattern of human capital matters. This is confirmed by the tests on the influence of the age pattern.

The main difference between the estimates can be found by looking on the coefficients of the age cohorts. When looking at educational attainment, "old", the human capital endowment of a region exerts lower effects on productivity. In the spatial error model, our favoured model, there is almost a humped-shaped pattern of human capital effects with respect to age. The age cohort 40-49 is the most productive followed by age cohort 50-65, age cohort 20-29 and cohort 30-39. This evidence is in accordance with our study on the effects of the age pattern of the population in the EU regions (see Brunow and Hirte 2006). In contrast, if we switch to the job-based definition of human capital, denoted "new", an u-shaped pattern of human capital productivity appears. In this case the youngest cohort contributes more to human capital effects than the eldest and the 40-49 cohort, while there are no significant effects of age cohort 30-39.

The average impact of an age cohort i on the coefficient of human capital is given by $b_i m_i$, which is displayed in column 4 of Table 4. The fifth column shows the relative contribution of an age cohort to the human capital effects, γ, given in per cent. The figures are remarkably different if we compare both definitions of human capital. With respect to educated human capital, "old", the age cohort 40-49 accounts for about 36 per cent of γ, while age cohort 20-29 accounts only for 12.5 per cent. Concerning available human capital 37 per cent of the human capital effects are caused by cohort 20-29, 31 per cent by cohort 40-49 and 32 per cent by cohort 50-65.

However, these figures represent the effects of a whole age cohort including its size. In contrast, during demographic transitions the size of the age cohorts differ and change. For this reason it is much more instructive with respect to political implications to see how productivity responds to a move-

Estimates: average productivity - age approach						
	OLS		OLS: sp regr		ML sp error	
	Model 2		Model 4		Model 6	
	old	new	old	new	old	new
$\ln k$	0.341***	0.349***	0.342***	0.351***	0.326***	0.338***
	(0.035)	(0.036)	(0.035)	(0.036)	(0.032)	(0.033)
$East$	–0.246***	–0.236***	–0.242***	–0.234***	–0.250***	–0.250***
	(0.035)	(0.030)	(0.035)	(0.030)	(0.037)	(0.034)
Div	0.061*	0.069*	0.058*	0.069**	0.070**	0.086**
	(0.035)	(0.035)	(0.034)	(0.035)	(0.035)	(0.035)
$Dloc$	0.070***	0.072***	0.069***	0.071***	0.089***	0.084***
	(0.027)	(0.026)	(0.026)	(0.026)	(0.027)	(0.026)
$m_1 \ln h$	0.111*	0.184***	0.115*	0.198***	0.094*	0.197***
	(0.061)	(0.054)	(0.062)	(0.058)	(0.055)	(0.053)
$m_2 \ln h$	0.048	0.031	0.057	0.035	0.069**	0.049
	(0.033)	(0.047)	(0.037)	(0.048)	(0.034)	(0.044)
$m_3 \ln h$	0.155***	0.153***	0.159***	0.154***	0.115***	0.120***
	(0.045)	(0.049)	(0.045)	(0.049)	(0.04)	(0.046)
$m_4 \ln h$	0.083*	0.129***	0.084*	0.129***	0.105**	0.133***
	(0.050)	(0.049)	(0.050)	(0.049)	(0.047)	(0.046)
$\ln \boldsymbol{W}_N \boldsymbol{h}$			–0.035	–0.047		
			(0.039)	(0.047)		
$\ln T$	2.802***	2.795***	2.733***	2.684***	2.848***	2.820***
	(0.164)	(0.172)	(0.189)	(0.21)	(0.153)	(0.159)
λ					0.737***	0.703***
					(0.180)	(0.181)
AIC	–383	–385.6	–381.9	–384.6	–390.3	–392.1
ll	200.5	201.8	200.9	202.3	206.2	207.1
Moran I	6.3***	6.3***	6.3***	6.5***		
sp error						
LM	17.9***	18.5***	16.9***	19.5***		
rob LM	16.0***	17.2***	15.3***	18.5***		
sp lag						
LM	2.1	1.7	1.8	1.6		
rob LM	0.2	0.3	0.4	0.5		

* $p < .1$; ** $p < .05$; *** $p < .01$, $N = 172$, robust s.e. in parentheses

"sp" spatial; "Model 2" basic OLS model; "sp regr" spatial regressive; "Model 4" OLS with spatially lagged human capital; "Model 6" ML with spatial error dependence; $\ln k$ logarithm of capital intensity; $East$ Dummy for East Germany; Div diversity index; $Dloc$ location index; $m_i \ln h$ interaction term of age share i and human capital; m_1 share of cohort 20-29; m_2 share of cohort 30-39; m_3 share of cohort 40-49; m_4 share of cohort 50-65; $\ln W_N h$ spatially lagged human capital; $\ln T$ the constant; λ coefficient of the spatial error component; "LM" spatial LM test; "rob LM" robust spatial LM test.

Table 3: Results when controlling for the age pattern

Age cohort's contribution (average)					
old h	b_i	m_i	$b_i m_i$	share of γ	transition effect
20-29	0.0935	0.1251	0.0117	0.1253	-0.0030
30-39	0.0692	0.362	0.0251	0.2682	0.0161
40-49	0.1147	0.29	0.0332	0.3562	-0.0028
50-65	0.1048	0.2229	0.0234	0.2502	
HC-effect			0.0933		
new h					
20-28	0.1973	0.1867	0.0368	0.3700	-0.0142
30-39	insign.	0.3162			
40-49	0.1196	0.2581	0.0309	0.3100	0.0035
50-65	0.1333	0.239	0.0319	0.3200	
HC-effect		1	0.0996		

"old" human capital based on educational attainment (university degree or equivalent); b_i age cohort coefficient; m_i share of cohort i on average human capital; $b_i m_i$ contribution of age cohort i to the human capital effect γ; "share γ" contribution of age cohort i to the human capital effect in per cent; "transition effect" change in average productivity of an average region as response to a shift of one per cent of the members of age cohort i to age cohort $i+1$; "HC-effekt" sum of the contribution of all age cohorts, which equals the human capital effect γ; "new" is the human capital based on availability.

Table 4: Elasticities with respect to the age cohorts

ment of individuals from one age cohort to the next cohort. For instance, we can think about carrying out the following experiment: one per cent of the human capital share of a cohort leaves this cohort and enters the next elder cohort, ceteris paribus. The change in the human capital effects induced, c. p. by this movement is approximately given by the difference in the human capital effects of both age cohorts[11]. These transition effects are given in the last column of Table 4. Accordingly we can conclude: a one per cent reduction in the human capital share of age cohort 1 which ages into age cohort 2 will decrease productivity by 0.3 per cent in the old case. Since the coefficient of age cohort 30-39 is insignificant we can not calculate a corresponding figure for the new definition. However, we can compute the effects of a transition from the youngest cohort to cohort 40-49. In this case productivity will decrease by 1.4 per cent[12]. Concerning formal human capital, productivity increases when individuals grow from age cohort 30-39 into age cohort 40-49. Unfortunately, we cannot calculate the corresponding figure for the new definition, because of the insignificance of the coefficient. Moreover, a shift from age cohort 40-49 to age cohort 50-65 will decrease productivity by 0.28 percentage points given the old definition, but increases productivity by 0.35 percentage points under the new definition.

This experiment illustrates our results that the age composition of human capital affects regional productivity. A very young region in terms of available human capital is more productive than an old region, while a young region with respect to formal human capital is less productive than an old region. This result warns us that increasing the level of average educational attainment is not sufficient for improving regional productivity. It is also important to attract the jobs which require these qualifications.

[11] We totally differentiate $\ln y$ given constant k, Div and all dummies as well as spatial dependence while assuming that there is no change in m_3 and m_4 and $dm_2 = dm_1$. Then we can ask what happens if people move from one age cohort to the next without changing overall human capital ($d \ln h = 0$).

$$\frac{d \ln y}{d \ln m_i} = (b_i - b_{i+1})\, m_i \ln h$$

[12] Given the old definition, a corresponding shift from cohort one to cohort three will increase productivity by 0.26 per cent.

Hence, this experiment implies that population ageing is likely to affect regional productivity even during the demographic transition period. However, the effects depend on who is ageing. At a first glance demographic ageing is linked to ageing of educated human capital, provided education is not improved sufficiently to compensate for this effect. However, even an ageing of educated human capital could be accompanied by a slower or faster ageing of available human capital or even by a raise of available human capital. What happens depends among others on the response of labour demand.

Until now we did not discuss endogeneity problems. Since we focus on human capital, which is very mobile, endogeneity is an issue. Even if we consider per capita terms, migration is not neutral. The reason is that high-skilled persons are relatively more mobile than others. This is present in the data base. On the other hand daily commuting is not a problem in our approach since we consider labour market regions which are defined in such a way that daily commuting occurs within the regions (see Eckey et al. 2007). In addition, particularly in Germany mobility is a matter concerning the younger age cohorts but hardly the age cohorts 40-49 and 50-65. Usually one is supposed to instrument human capital. However, we are not able to use past human capital as instrument. Because of German unification our data allow at best to use human capital in 1995. Since we focus on age cohorts, using past human capital means using currently elder cohorts as instruments for the currently young cohorts. Unfortunately these natural candidates for instruments are already in use and are not available anymore.

To examine endogeneity, we are planning to extend our analysis to a panel approach where migration or firm location is explicitly considered. For the time being this issue remains unsolved. However, we carried out a kind of robustness check. We reduced the model by omitting the variables which are candidates for endogeneity, i. e. the age shares of the two younger age cohorts, $m_1 \ln h$ and $m_2 \ln h$. This gives us a reduced model which could be estimated without producing endogeneity problems. Omitting $m_2 \ln h$ does not change any result, while omitting $m_1 \ln h$ changes the exact numbers but not the quality of the results such as significance levels, sign and size[13].

Finally, we did look into differences between West and East Germany. Unfortunately, multicollinearities in the East did not allow to produced robust results when comparing East and West Germany in more detail by considering interaction terms of human capital.and the region[14]. However, these estimates give rise to expect strong differences in the human capital productivity and the diversity externality between East and West Germany. The latter corresponds to evidence of low spillover effects in East Germany already found by Eckey et al. (2007).

7 Summary and Conclusions

While literature provides evidence of an impact of the age pattern of population on country or regional growth, there is to our knowledge no research on the effects of the age pattern of human capital despite the literature on social returns of education. On the other hand, many studies on individual productivity found evidence of a hump-shaped productivity curve over the life cycle of individuals. There is also evidence that social returns of education are of similar size than private returns to education. In addition, the literature provides evidence that the productivity of firms depends on the average age of its employees. From this we hypothesised that the age pattern of human capital also matters with respect to average regional productivity. To examine this issue we presented the results of spatial cross section regressions for the German labour market regions. We started by augmenting a Lucas type production function with agglomeration effects and the age pattern of human capital. To be more precise, we decompose the human capital effects into age cohort effects.

In addition to the use of the traditional definition of human capital we

[13]Results of the reduced spatial error estimation (results of the full model in parentheses): $\ln k$ 0.34 (0.34). $m_3 \ln h$ 0.09 (0.12), $m_4 \ln h$ 0.12 (0.13), *East* -0.19 (-0.25), *Div* 0.07 (0.09), *Dloc* 0.11 (0.08), λ 0.66 (0.70), $\ln T$ 2.68 (2.82).

[14]We carried out estimates for West Germany only, each providing higher levels of age dependent productivity. However, such a regression neglects the high degree of spatial autocorrelation between East and West German regions and, thus, produces biased results.

suggest and implement a new definition. While the old definition only looks at educational attainment we focus on available human capital in the new definition. In doing so we are reasoning that regional human capital potential encompasses only those individuals available on the labour market for being used in jobs requiring high skills.

Our estimates provide evidence of human capital effects and of an impact of the age pattern of human capital on productivity. While the traditional definition leads to the results that there is a hump-shaped productivity pattern of human capital with respect to age, using the new definition delivers evidence of a u-shaped pattern of productivity concerning the age composition of available human capital. The results also suggest that the demographic transition affects productivity. It either induces gains or losses during the transition period. But in the end, productivity will decrease on account of the high human capital effects.

Policy recommendations can be drawn as follows: more education, more life-long learning as well as immigration of high-human capital are required to work against the reduction in human capital caused by ageing. The use of the new definition which is based on availability of human capital makes clear that only raising the number of graduated persons is not enough. Education has also to be oriented to later use and experience as well as life-long learning are also important. Moreover, an increase in vertical mobility, for instance by carrying out programs for integration of individuals after maternity leave, might also affect available human capital. Looking only at the traditional way of defining human capital does not allow to deduce such recommendations.

The new definition of human capital also emphasises the importance of labour demand, which is neglected when using the traditional definition. Applying this new definition is, in particular, useful for studies on countries or regions where unemployment is high, experience is important, or a demographic transition is occurring. In addition all transition countries should be examined by using this new definition.

Of course, our estimates provide only first evidence. Further studies are necessary to corroborate our findings. This requires carrying out panel analyses, studies for other countries or multi-country analyses and so on. In addition endogeneity issues have to be taken into account, for instance, by implementing a migration equation or labour demand. We will look into some of these issues in future work.

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