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Age Structure and Regional Income Growth

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Abstract

A spatial econometrics cross-section analysis of the NUTS2 regions of the EU15 is carried out to examine whether the age structure of the regional population or differences in the regional age pattern affect growth of regional per capita income.

We apply two parsimonious models of the age structure and both provide evidence that there is such a link and that spatial autocorrelation occurs. The most significant growth effect is generated by the age groups which are about the age of 30. After correcting for country specific effects, the evidence is slightly weaker.

Keywords: demographics, age structure, regional growth, spatial econometrics
JEL number: J1, R11

1 Introduction

Economic growth of per capita income as well as the age pattern of population are significantly different among countries, among regions and even among regions of the same country. For instance, in the Italian province Liguria (NUTS IT13) only 10.2% of the population was between 0 and 14 years old in the years 1995 to 2000 compared to 23.2% in Northern Ireland (UKN) or 24.2% in the Netherland province Fleyoland (NL23). The age cohort 30-44 encompasses 18.9% of the whole popluation in Voreio Agaio (GR41) but 26% in Berlin (DE3) and 27.2% in Fleyoland (NL23). The share of the age cohort 44-59 was between 13.5 on the Acores (PT2) and 21.3 in Friuli-Venezia Giulia (IT33). Further

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changes in the age patterns are going to occur on account of the population aging process most European countries are facing. This implies changes in the age structure of human capital, the dependency ratio and the age structure of the labor force. One is tempted to infer that this is going to affect regional growth and regional welfare. However, neither economic growth theory nor econometric studies have been really concerned about a correlation between the age strucuture and growth. Sure, there is some evidence that the age pattern affects many economic variables (Sauvy, 1948). For instance, the age pattern of human capital investment was examined by Welch (1979) or Fair and Dominguez (1991). Age dependent labor supply decisions were, e.g., analyzed by Auerbach and Kotlikoff (1987). Other computable general equilibrium (CGE) studies produce effects of the age pattern on taxes, savings, capital accumulation, labor supply, employment and social insurance (e.g. Fehr, 1998 or Hirte, 2001). Nonetheless, effects on income per capita growth are hardly examined. Exceptions are the studies of Lindh and Malmberg (1999) and Bhatta and Lobo (2000). These are the reasons why we examine this issue and present results of an econometric study carried out for 190 EU NUTS2 regions in order to search for evidence of an influence of the age structure of population on regional growth in per capita income.

Our point of departure is a short review of the literature. We then proceed by deriving the theoretical model. This model is based on the approach suggested by Lindh and Malmberg (1999) who implement the age structure in a human capital augmented neoclassical growth model à la Mankiw et. al. (1992).[1] We adjust this model to regional application including the modification implied by spatial dependence. In addition an alternative index of the population structure is applied, based on the uncentered moments of the density of the populations. Moreover, in contrast to the study of Lindh and Malmberg (1999) we focus on regions - the EU15 NUTS 2 regions - and consider spatial dependence.

Then we provide a second approach where we analyze only the deviations of the values of regional variables such as the age structure from their country counterpart. Since the

[1] The papers on convergence and divergence of regions provide us with an approach already prepared to implement an aging structure. They already implement population growth, however without discussing the effects of aging. Nonetheless these papers are fruitful for developing an approach suited for analyzing the effects of aging on differences in the regional performance. This literature differs from the literature on convergence among countries and former literature on convergence among regions by explicitely considering spatial effects (e.g. Islam, 1995, Armstrong 1995, Cheshire and Carbonaro, 1995, Mas et. al, 1995, Fagerberg and Verspagen, 1996, Quah, 1996, Rey and Montouri, 1999, Rodriguez-Pose, 1999, Tondl, 1999, Niebuhr, 2001, Lopez-Bazo et al., 1999, Paci and Pigliaru, 2001, Badinger and Tondl, 2002, Badinger, Müller and Tondl, 2002). The approach employed in almost all of these studies is an augemented Solow-Swan growth model suggested by Mankiw et. al. (1992). In some studies only a neoclassical production function is used (e.g. Tondl and Vuksic, 2003).

regional performance is to a large extent determined by the national performance and national institutions (e.g. Elhorst, 2004 for the discussion of regional labor markets), differencing out country effects allows exploring region specific effects. Using this approach our main question is, whether having an older or younger population than the national average is favorable for regional growth per capita? Of course spatial correlation has to be considered too. This approach also reduces data problems we have in the basic model. The theoretical discussion is followed by the presentation of the regression results. Finally, the results are summarized and an outlook on further tasks is given.

To summarize: we search, first, for evidence of the effects of the regional age structure on regional growth in income per capita and, second, inquire whether deviations of the regional age structure from the country levels are at least partially responsible for differences in regional growth in income per capita.

2 Review and Hypothesis

We expect the following effects: First, the higher the share of children and the higher the share of retirees, i.e. all non-working cohorts, the lower current growth of output per capita. This effect is unambigous and more or less trivial. Second, other effects have to be considered too. With respect to the cohorts of working age the aggregate effects are less clear. Learning, human capital accumulation and savings patterns suggest that all working cohorts raise output per capita. Which group produces the most significantly positive effect is not unambiguously clear. It depends on the strength of these three effects and on the countervailing effects of the employment ratio. Younger working groups accumulate human capital but have a low employment and participation ratio. The middle aged working cohorts have a higher learning effect and a high participation and employment ratio in most countries but their education capital might be partially depreciated. The elder working cohorts have less useful education capital but also a high level of learning capital while their participation and employment ratios decrease when they approach retirement. Though some of these effects are examined in the literature, it is yet not well understood whether these effects add up to an unambiguous age pattern inducing a significant and unambiguous influence of the regional age pattern on the regional growth and economic well-being. There is hardly any literature concerning these issues, except for Lindh and Malmberg (1999) who examine the OECD countries and Bhatta and Lobo (2000) who look into US regions.

Lindh and Malmberg (1999) explore the determinants of productivity growth in the OECD in an human-capital augmented Solow-model over a range of 30 years where they consider five age groups. According to their results, the cohort aged 50-64 promotes growth while the group above 64 depresses growth. The younger working age cohorts do have ambiguous effects on growth. However, following the state of the art in country studies they do not carry out tests for spatial dependence. Since at least on the regional level such spatial interdependencies are likely to exist, one cannot simply deduce similar effects of regional age structures on regional growth. Moreover, even on the country level interdependencies between countries due to capital flows and trade are strong and might induce spatial autocorrelation.

A first study on the regional level has been carried out by Bhatta and Lobo (2000), who examine the influence differences in the human capital and the age structure have on output per capita by carrying out an econometric cross-sectional analysis of US regions for the year 1990. They choose a production function approach where differences in human capital between regions are approximated by differences in the age structure. According to their data analysis, differences in human capital account on average for about 60% of the difference in the gross social product (GSP) per capita between the 17 poorest US-states and New York. About 40% of these differences are explained by differences in the age structure assuming there is an identical educational attainment. As opposed to this they found that the age group 35-44 does not have a significant influence on these differences in the GSP per capita (with only 17 observations). However, since they focus on regions they should have explicitly taken into account spatial dependence between regions. Even on a country-level not testing for spatial autocorrelation might cause a serious problem for the analysis. But on a regional level this is even more essential. In any case there are strong interregional links due to migration or commuting or interregional transfers which has to be taken into account.

3 The Regional Growth Model

3.1 The Regional Model

We follow the suggestion of Lindh and Malmberg (1999) to allow for an experience effect in human capital expressed by the age index M. However, since labor force participation and unemployment are also age specific, our age index also comprises the labor market. Using this index and applying an augmented Solow-Swan growth model (Mankiw et. al., 1992) the aggregate production function of the standard Cobb-Douglas type with constant returns to scale and Hicks-neutral technical progress is

$$Y_{r,l} = AK^{\alpha}(HM)^{\beta}(ML)^{1-\alpha-\beta}, \quad (1)$$

where A is the total factor productivity (TFP), K is the capital stock, H is the stock of human capital, L is the number of employees, and α, β are share parameters of the Cobb-Douglas function.

Since we focus on regional welfare, we express GDP in per capita terms. Hence we divide (1) by total regional population, B, and obtain

$$y_{r,l} = Ak^{\alpha}h^{\beta}M^{1-\alpha}\frac{L}{B}^{1-\alpha-\beta}. \quad (2)$$

Employment, L, in a region can be decomposed into two components: the labor force participation rate, $p = \left(\frac{N+U}{B}\right)$, where N is the number of employees and U is the number of unemployed individuals. Then we define the employment rate $(1-u) = 1 - \frac{U}{N+U} = \frac{N}{N+U}$, so that (2) can be rewritten as

$$y_{r,l} = Ak^{\alpha}h^{\beta}M^{1-\alpha}\left[p(1-u)\right]^{1-\alpha-\beta}. \quad (3)$$

Now we can specify the interpretation of the age index. Lindh and Malmberg (1999) suggest that the age index encompasses the productivity effects arising by working experience and the negative effects individuals without own working or capital income impose on working individuals. Since unemployment and employment also varies by age, a larger fraction of the unemployed also reduces productivity of that age cohort.

There is a constant fraction of output s_K and s_H that is saved and invested in physical and human capital. We assume both to be equal, $s_K = s_H$. The depreciation rate of both types of capital is assumed to be equal too and is denoted by δ. We further assume that population grows by an exogenously given rate n. Therefore the dynamic equations are

$$\dot{k}_t = s_k f(k_t, h_t) - (n+\delta)k_t = s_k A k_t^{\alpha} h_t^{\beta} M_t^{1-\alpha}\left[p(1-u)\right]^{1-\alpha-\beta} - (n+\delta)k_t \quad (4)$$

$$\dot{h}_t = s_k f(k_t, h_t) - (n+\delta)h_t = s_h A k_t^{\alpha} h_t^{\beta} M_t^{1-\alpha}\left[p(1-u)\right]^{1-\alpha-\beta} - (n+\delta)h_t \quad (5)$$

and the transitional change in output per capita is

$$\dot{y} = \alpha y\hat{k} + \beta y\hat{h}, \quad (6)$$

where a hat indicates growth rates, providing p and u are time invariant. Thus, output per capita growth is

$$\hat{y} = \alpha\hat{k} + \beta\hat{h}. \quad (7)$$

The steady state levels of per capita human capital and capital stock are

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

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

where we assume a constant total factor productivity A.

Accordingly the steady state level of per capita output is

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

Taking the logarithm gives

$$\ln y^* = \frac{1}{1-\alpha-\beta} \ln A + \frac{\alpha}{1-\alpha-\beta} \ln s_k + \frac{\beta}{1-\alpha-\beta} \ln s_h - \frac{\alpha+\beta}{1-\alpha-\beta} \ln (n+\delta) + \frac{1-\alpha}{1-\alpha-\beta} \ln M + \ln p\,(1-u)$$

We linearize this system at the steady state. After some manipulations one obtains

$$\frac{d \ln y}{dt} \approx \frac{d \ln (y/y^*)}{dt} \equiv g = -\lambda \left[\ln (k/k^*) + \beta \ln (h/h^*) \right] = -\lambda \left(\ln y - \ln y^* \right), \tag{11}$$

where $\lambda = (1-\alpha-\beta)(n+\delta)$.

This is the transitional growth rate on the transition path to the steady state (in the neighborhood of the steady state). Taking the logarithm of the steady state output per capita (10), substituting into (11) and rearranging yields the basic equation of the growth model

$$\ln y^* - \ln y = \frac{1}{1-\alpha-\beta} \ln A + \frac{\alpha+\beta}{1-\alpha-\beta} \ln \frac{s}{n+\delta} + \frac{1-\alpha}{1-\alpha-\beta} \ln M + \ln p\,(1-u) - \ln y \tag{12}$$

$$\begin{aligned} d \ln y / dt \equiv g = {} & (n+\delta) \ln A - (1-\alpha-\beta)(n+\delta) \ln y \\ & + (\alpha+\beta)(n+\delta) \ln \frac{s}{n+\delta} + (1-\alpha)(n+\delta) M \\ & + (1-\alpha-\beta)(n+\delta) \ln \left[p\,(1-u) \right] . \end{aligned} \tag{13}$$

In the following we subsume the aggregate depreciation rate $n+\delta$ into the parameters and add an error term. So we get the regression equation

$$g = a_0 + a_1 \ln y + a_2 \ln s + a_3 \ln (n + \delta) + a_4 \ln [p (1 - u)] + a_M \ln M + \varepsilon. \qquad (14)$$

Since one can presume that country performance and country institutions determine regional growth in income per capita to a large part, we adopt an alternative approach where country effects are eliminated by differencing regional variables against their national averages. This model is presented in the subsequent section.

3.2 The deviation model

Differencing against the country average of growth in income per capita gives

$$\begin{aligned} g_r - \bar{g} \equiv d \ln (y/y^*)/dt - d \ln (\bar{y}/\bar{y}^*)/dt = \left(\ln A - \psi \ln \bar{A}\right) \\ - (1 - \alpha - \beta)\left(n + \bar{\delta}\right)(\ln y - \psi \ln \bar{y}) + (1 - \alpha)\left(n + \bar{\delta}\right)\left(\ln M - \psi \ln \bar{M}\right) \\ + (1 - \alpha - \beta)\left(n + \bar{\delta}\right)(\ln [p (1 - u)] - \psi \ln [\bar{p} (1 - \bar{u})]) + \left(\left(n + \bar{\delta}\right)\varepsilon - \left(\bar{n} + \bar{\delta}\right)\bar{\varepsilon}\right), \end{aligned}$$

where $\psi = \left(\bar{n} + \bar{\delta}\right) / \left(n + \bar{\delta}\right)$.

This model resembles a fixed effects approach, where time invariant variables vanish. In our case all variables which are constant within a country are differenced out. We chose the following procedure. Each variable we don't have regional information on is assumed to be constant within a country, e.g. the depreciation rate δ. By using this specification we implicitly assume that economic shocks and business cycles are identical in all regions of a country. Furthermore, we also assume that the parameter of the production function are equal across all regions and nations, that the depreciation and savings rates are equal within one nation and that the aggregate depreciation rates are approximately equal within a country. Eventually, the regression equation becomes

$$\begin{aligned} g_r - \bar{g} \approx d \ln (y/y^*)/dt - d \ln (\bar{y}/\bar{y}^*)/dt = b_0 + b_1 (\ln y - \psi \ln \bar{y}) \\ + b_2 \left(\ln\left(n + \bar{\delta}\right) - \psi \ln (n + \delta)\right) + b_3 (\ln [p (1 - u)] - \psi \ln [\bar{p} (1 - \bar{u})]) \\ + b_M \left(\ln M - \psi \ln \bar{M}\right) + \epsilon. \end{aligned}$$

3.3 Age index

Before we can formulate the regression equation the age index M has to be specified. Following Bloom and Canning (2001) a general regression of growth on all age shares might be

$$g = \alpha + a_X X + \mathbf{a}_Z Z + \varepsilon. \tag{15}$$

X is the vector of the age shares of all age cohorts where the interval of a age group is five years of age, hence $X = [x_1, x_2, ...x_q]$. x_1 is the share of all individuals between the age of 0 and 4 on aggregate population and so on. Z is a vector of all other variables on the right hand side. On account of the strong correlation among these age cohorts it is useful and also possible to reduce the number of variables describing the age structure (Bloom and Canning, 2001). We adopt two approaches a such a reduction in age variables.

The first is the age share representation suggested by Lindh and Malmberg (1999). Here the number of age cohorts is reduced, i.e. the theoretical model and the linearized econometric specifications are

$$M = \Pi_{i=1}^{6} x_i^{\theta_i}$$

which turns into

$$a_M \ln M = a_M \sum_{i=0}^{q} \theta_i \ln x_i = \sum_{i=0}^{q} a_i \ln x_i \tag{16}$$

where $i = 1, ..., 5$ are the five age cohorts (0-14, 15-39, 40-44, 45-59, 60-74), x_i is the population share of age cohort i of that region and θ_i is the aggregate experience and labor market weight of the respective age cohort.

As a second approach we choose the polynomial approach suggested by Bloom and Canning (2001). Thereby we assume that there are restrictions on the parameters a_i. Each a_i lies on a polynomial of order p. We use $p = 3$. Then the polynomial is

$$a_i = \zeta_0 + \zeta_1 i + \zeta_2 i^2 + \zeta_3 i^3 + ...\zeta_p i^p, \qquad \forall i = 1, ..., q \tag{17}$$

where the ζ_j are coefficients of the j-th moment of the density function of the population and i is the index of the respective age cohort. Then the age index can be defined as

$$M = \exp^{\sum_{j=0}^{p} \zeta_j m_j} \rightarrow a_M \ln M = \sum_{j=0}^{p} \zeta_j m_j, \tag{18}$$

where m_j is an approximation of the the $j-th$ uncentered moment of the density function

$$m_j = \sum_{i=0}^{n} i^j x_i.$$

Once the ζ_j are estimated one can calculate the a_i according to (17)[2]. Then the coefficient of a specific age cohort i can be computed according to (17) (see Bloom and Canning, 2001).[3]

3.4 Spatial Regression

Eventually, since we focus on regions spatial autocorrelation has to be considered. How to do this in a model of regional convergence has been discussed e.g. by Rey and Montouri (1999) or Niebuhr (2001). Two types of spatial correlation are known: (i) spatial dependence and (ii) spatial heterogeneity. Spatial dependence might be either substantive spatial dependence or nuisance dependence (Anselin and Rey, 1991).

Substantive spatial dependence or spatial lag dependence (Anselin and Rey, 1991) is spatial correlation occurring due to spill-overs or interactions between regions. Some examples are technological spill-overs or regional specialization in tradable goods. In this kind of regional autocorrelation interregional effects are induced by the levels of exogenous or endogenous regression variables of neighboring regions (Anselin et. al. 1998). This can

[2]For instance, for $p = 2$ it follows that

$$\begin{aligned}\sum_{j=1,3} \zeta_j m_j &= \zeta_0 m_0 + \zeta_1 m_1 + \zeta_2 m_2 + \zeta_3 m_3 \\ &= \zeta_0 \sum_{i=0}^{n} (i^0 x_i) + \zeta_1 \sum_{i=0}^{n} (i^1 x_i) + \zeta_2 \sum_{i=0}^{n} (i^2 x_i) + \zeta_3 \sum_{i=0}^{n} (i^3 x_i) \\ &= \sum_{i=0}^{n} \left(\zeta_0 i^0 + \zeta_1 i^1 + \zeta_2 i^2 + \zeta_3 i^3\right) x_i \\ &= \sum_{i=0}^{n} a_i x_i.\end{aligned}$$

Hence,

$$\mu_i = \sum_{j=0}^{p} i^j \zeta_j.$$

On account of

$$a_i = \frac{d \ln y}{d \ln x} \text{ and } \mu_i = \frac{d \ln y}{dx}$$

we finally get

$$a_i = \mu_i \frac{dx}{d \ln x} = \mu_i x_i.$$

[3]The moments approach allows to reduce the number of coefficient to be estimated compared to the age share approach. For instance, if age shares each covering an interval of 5 years of age were considered, 18 coefficients have to be computed. In the moments approach only 3 coefficients are required.

be considered by implementing a spatial lag of the dependent variable. In our case

$$g_r = a_0 + a_1 \ln y + a_2 \ln s + a_3 \ln\left(n + \bar{\delta}\right) + a_4 \ln\left[p\left(1-u\right)\right] + a_M \ln M + \varepsilon + \rho \mathbf{W} g_r + \epsilon, \quad (19)$$

respectively in the case of the difference model:

$$\begin{aligned} g_r - \bar{g} = {} & b_0 + b_1\left(\ln y - \psi \ln \bar{y}\right) + b_2\left[\ln\left(n + \bar{\delta}\right) - \psi \ln\left(\bar{n} + \bar{\delta}\right)\right] \\ & + b_3\left(\ln\left[p\left(1-u\right)\right] - \psi \ln \bar{p}\left(1-\bar{u}\right)\right) + b_M\left(\ln M - \psi \ln \bar{M}\right) + \rho \mathbf{W}\left(g_r - \psi \bar{g}\right) + \epsilon, \end{aligned}$$

where $\mathbf{W}$ is the spatial weights matrix.

Since the endogenous variable depends on its lagged values, a simultaneity problem arises. Therefore OLS is not appropriate. A Maximum Likelihood (ML) or Instrumental Variable (IV) approach should be used for estimation (Anselin, 1988).

Following Rey and Montouri (1999) substantive spatial dependence might also and only occur via the initial level income per capita of neighboring regions. In this case no simultaneity problem occurs since spatial dependence is induced by an exogenous variable. Then we have *spatial regressive* model

$$g_r = a_0 + a_1 \ln y + a_2 \ln s + a_3 \ln\left(n + \bar{\delta}\right) + a_4 \ln\left[p\left(1-u\right)\right] + a_M \ln M + \tau \mathbf{W} y + \epsilon \quad (20)$$

and

$$\begin{aligned} g_r - \bar{g} = {} & b_0 + b_1\left(\ln y - \psi \ln \bar{y}\right) + b_2\left(\ln\left(n + \bar{\delta}\right) + \psi \ln\left(\bar{n} + \bar{\delta}\right)\right) \\ & + b_3\left(\ln\left[p\left(1-u\right)\right] - \psi \ln \bar{p}\left(1-\bar{u}\right)\right) + b_M\left(\ln M - \psi \ln \bar{M}\right) + \tau \mathbf{W}\left(y - \psi \bar{y}\right) + \epsilon. \end{aligned}$$

In contrast *nuisance dependence or spatial error dependence* occurs due to regional shocks which diffuse throughout the entire economic system via spatial dependence of the error term (Rey and Montouri, 1999). Spatial correlation arises on account of a mismatch between the boundaries of the market process under examination and the administrative boundaries used to collect the data (Anselin, 1988, Rey and Montouri, 1999). This is reflected in a autocorrelated error term. If there are growth interdependencies between regions, these effects have explicitly taken into account. Otherwise the residuals would be spatially autocorrelated. One may capture autocorrelation in the error term ε by writing

$$\varepsilon = \lambda \mathbf{W} \varepsilon + \epsilon \quad (21)$$

hence

$$g_r = a_0 + a_1 \ln y + a_2 \ln s + a_3 \ln \left(n + \bar{\delta}\right) + a_4 \ln \left[p \left(1 - u\right)\right] + \alpha_M \ln M + \left(I - \lambda \mathbf{W}^{-1}\right) \epsilon, \quad (22)$$

respectively

$$\begin{aligned} g_r - \bar{g} &= b_0 + b_1 \left(\ln y - \psi \ln \bar{y}\right) + b_2 \left(\ln \left(n + \bar{\delta}\right) - \psi \ln \left(\bar{n} + \bar{\delta}\right)\right) \\ &+ b_3 \left(\ln \left[p \left(1 - u\right)\right] - \psi \ln \bar{p} \left(1 - \bar{u}\right)\right) + b_M \left(\ln M - \psi \ln \bar{M}\right) + \left(I - \lambda \mathbf{W}^{-1}\right) \left(\epsilon - \psi \bar{\epsilon}\right). \end{aligned}$$

Again, OLS is not appropriate due to the autocorrelation of the error term. Following the proposal of Anselin (1988) we use a ML approach for this kind of a spatial AR(1) process.

Both cases of spatial dependence can result in major misspecification of the model (Anselin, 1988). Fortunately, there are some procedures for testing and computing the estimators of such models with explicitly formulated spatial dependence (overviews in: Anselin and Florax, 1995, Anselin and Bera, 1998, Florax et. al. 2003).

The last type of spatial effects is called *spatial heterogeneity*. It occurs if there are differences across sets of regions (regional clusters). We consider spatial heterogeneity by correcting for common country effects. Other sources of regional heterogeneity are left for further research.

3.5 The weights of the distance matrix

All kinds of spatial dependence require the use of a spatial weight matrix $\mathbf{W}$. In the literature there is no unambiguous way to model this spatial weights or distance matrix. The simplest approach is to adopt a binary matrix consisting of elements (0,1). In this case $w_{ij} = 1$ if i and j are neighbors, and $w_{ij} = 0$ otherwise. The diagonal elements of the weights matrix are set to zero.

One can also use different measures of the elements of $\mathbf{W}$. For instance the inverse distance or the inverse of the quadratic distance might be candidates. We, however, implement a distance decay function as suggested by Bröcker (1989). An element of the weights matrix $\mathbf{W}$ is then given as

$$w_{ij} = \exp\left(-d_{ij}\phi\right), \quad (23)$$

where d_{ij} is the distance between region i and j and ϕ is a distance decay parameter. This distance decay parameter depends on the average distance between all neighbors and a normalized distance decay parameter, γ, which is normalized to lie between 0 and 1 and describes the influence of the distance on regional dependence. The lower γ the slower is the reduction of interregional interdependencies with distance. We also row-standardize the resulting distance matrix $\mathbf{W}$, which means that all elements of a row are divided by the sum of the row so that they add up to unity. The link between γ and ϕ is

$$\gamma = 1 - \exp^{-\phi D_{\min}}, \tag{24}$$

where $D_{\min}$ is the average distance of all regions to their respective neighbors (see Niebuhr, 2001). In our case $D_{\min}$ is 114 km and γ is chosen to be 0.5, so that $\phi = 1/225$[4].

4 Empirical Specification

4.1 Data

Most of the data come from the EUROSTAT Regio Database. These are the regional real GDP, regional population structures, the aggregate regional labor force and unemployment rates. All these data are collected for the EU15 on the NUTS 2 level. In addition, we approximate the savings rate by the investment to GDP ratio. This is given by the Penn World Tables (Heston et. al. 2002). Migration and commuting are implicitly handled by considering spatial autocorrelation.

Our data suffer from missing values in the following way:

- because auf missing time series data we study the time period from 1995 to 2000,
- growth rates are computed just by $\frac{x_{2000}-x_{1995}}{x_{1995}}$ because it is not possible to compute growth rates using the geometric mean.
- Another problem arises from missing values within the age structure, especially in the case of the oldest groups. We simply assume that no people live in the particular region over -for example- 80 years if it is indicated as missing value. Therefore we drop the age cohort 75+.

The distance matrix is computed as the average as-the-crow-flies distance of cities of one region to all cities of another region. All available cities of the GISCO database were used to compute distances. Moreover we take the terrestrial bending of the earth into account.

[4] We carried out some kind of sensitivity analysis. For all γ between zero and one, the value of the Moran-I-statistic provided evidence for the existence of spatial dependence. For this reason, we preferred $\gamma = 0,5$ instead of a extreme value of γ.

In total there are 197 regions. Because of different NUTS2-structures between 1995 and 2000 (there was a change in 1997/1998), we aggregate some NUTS2-regions in Sweden (SE03/SE04) and UK (UKK3 and UKK4). Furthermore, we are forced to use NUTS1-level for a couple of UK-regions because of missing data (UKL, UKM, UKI) and drop Ireland due to missing values. In the difference model Denmark is dropped too.

On account of the lack of time series data, we use only one period - the years 1995 to 2000. For this reason we only adopt a pure cross-sectional analysis, though a panel data approach would be preferable (e.g. Lindh and Malmberg, 1999, or Badinger, Müller and Tondl 2002). In the latter case, provided a longer time horizon is available, the influence of the business cycle on the results would be strongly reduced and the long term trend could be expected to dominate the outcomes. This, at least, is implicitly assumed in almost all studies on regional convergence. The above derived model does not include any cyclical effects. So these effects, if there are any, appear in the white noise variable ε. Carrying out some tests for autocorrelation allow to evaluate whether cyclical effects are important. However, in our case, such a test is not feasible. Moreover, it is quite certain that economic shocks or business cycle effects appear in the data and might also be responsible for differences in regional per capita growth. We are also not able to isolate this effect in the cross-sectional study.

4.2 Data Analysis

We can get a first impression of the existence of spatial interdependence by computing the regional Moran-I-Statistics. Figure 1 shows the GDP growth per capita, z, on the x-axis and its spatial lag on the y-axis. The four different quadrants of the Moran scatterplot provide four types of spatial dependence between a region and all other regions. The first quadrant shows the regions growing faster than the average with stronger spatial dependence to other faster growing regions. The second quadrant shows faster growing regions with stronger spatial dependence to slower growing regions. The third quadrant shows a stronger spatial correlation between slower growing regions and the fourth quadrant displays slower growing regions which have a stronger correlation with faster growing regions.

The Moran scatterplot of the GDP growth per capita shows that there is a strong dependence between equally good or equally bad performing regions (see figure 2)[5]. Since strong growing regions have a strong spatial dependence on other strong growing regions

[5]The numbers in figures 1 and 2 represent the NUTS2 regions. g is the regional GDP per capita growth rate, Dg is the relative regional GDP per capita growth rate und Wg or WDg the respective spatially laged GDP growth rate.

(quadrant I) while slow growing regions have a strong spatial dependence on other slow growing regions (quadrant III), one can deduce that there is positive spatial correlation between regions.

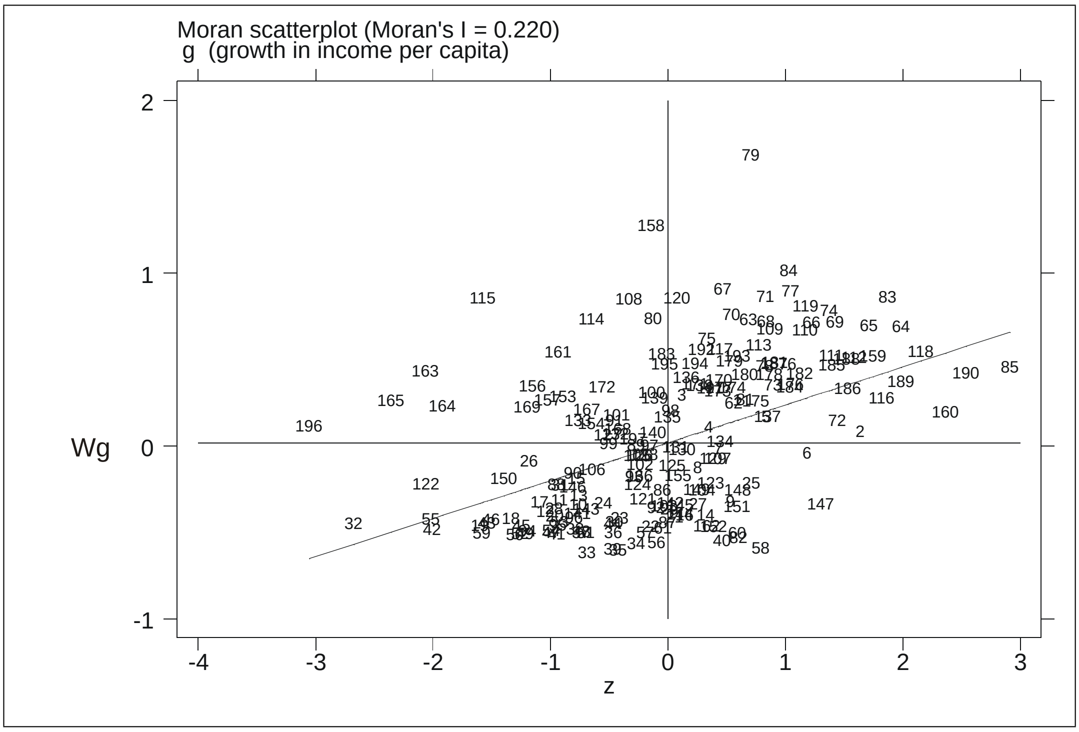

Figure 1: Moran scatterplot - regional model

In the difference model, where all variables are demeaned by the respective country effects, spatial dependence is expected to be much weaker. While there might be dependence between countries, spatial correlation between regions of different countries are less likely to occur after eliminating country effects. For these reasons we use another weights matrix in the difference approach. To consider only interregional correlations within a country, we use a binary contiguity matrix where unity denotes neighboring regions and zero non-neighboring regions as well as distance within a region. The corresponding Moran scatterplot shows a much weaker dependence between equally good performing regions (see figure 2). This scatterplot makes clear that country effects are extremely strong and that spatial links across regions even within countries are low after eliminating country effects.

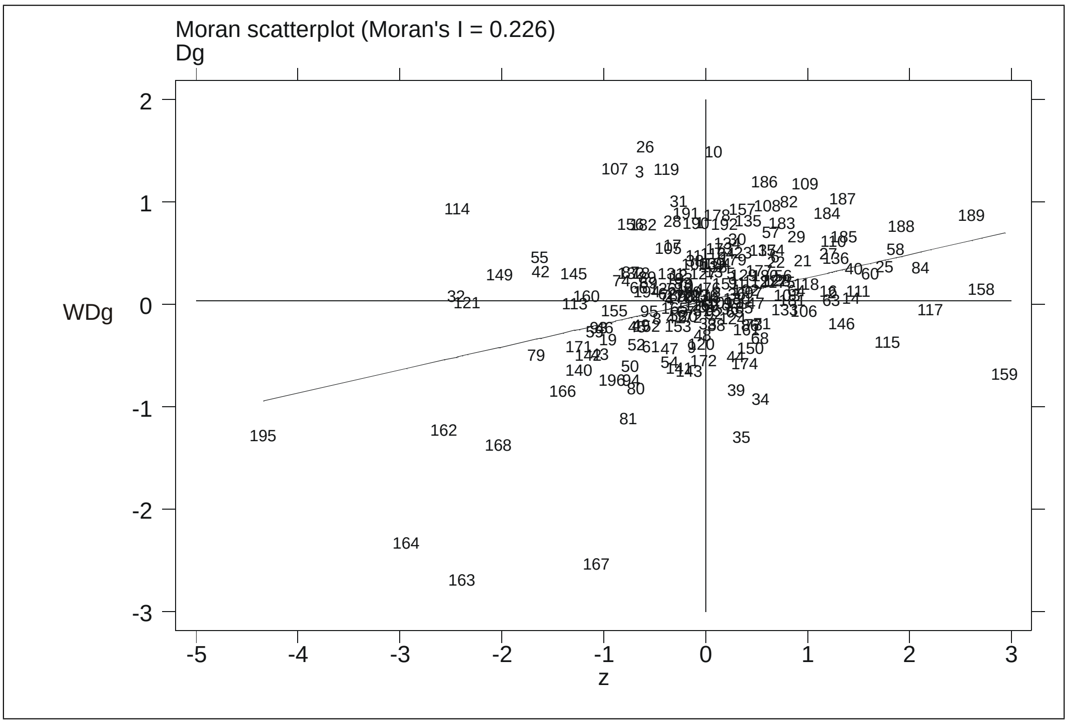

Figure 2: Moran scatterplott in the difference model.

4.3 Regression and Results

4.3.1 Hypothesis

Due to the hypothesis of convergence or according to the law of the regression to the mean (Dalton's fallacy) a high level of initial GDP per capita, $\ln y$, should induce lower growth, while a low level should induce higher growth. The effects of a higher saving or investment rate $\ln s$ are not unambiguously clear. While more investment raises growth in the future it currently reduces consumption and thus current growth. However, here, in the pure production model, savings should increase growth. The labor force variables should also foster growth – the more individuals work the higher growth per capita.

With respect to the shares of the age group one should in general expect the youngest age cohorts and the elderly to have a negative influence on growth per capita. The elderly and the children depend on the support of other age cohorts. Even part of the working cohorts are dependent on other working individuals, for instance, since they study, are rising children, or are unemployed. Changes in these variables affect the steady state and, thus, the transitional growth rate. So, even variables which are relatively constant in the short-term, might affect transitional growth.

We can devide the different age effects considered in our approach in two categories: the *productivity effects* and *labor force effects*. Productivity effects encompass two aspects:

human capital and learning effects. The first aspect is expected to be higher for younger working cohorts, while the latter increases with working experience. On aggregate productivity effects are expected to follow a hump-shaped curve with a peak at about the age of 45 (Kotlikoff and Gokhale, 1992).

Labor force effects depend on the employment rate which is is the lower the higher the share of children, the higher the share of eduction, the higher the share of retirees, the higher the age dependent unemployment rate and the lower the age dependent labor force participation rate. On aggregate it might also be hump-shaped with a sharp decrease between 52 and 60 (for Germany, see Hirte, 2001).

As a consequence we expect that overall age effects also have a hump-shaped curvature with a strong increase in the second half of the 20th years of age, a slight increase until it peaks at about 44-45 and a huge decrease after 52. Accordingly, the cohort 45-59 is expected to be on average less important for the economic welfare growth of the regions than the cohort 30-44. This hypothesis is not in accordance with the evidence found by Lindh and Malmberg (1999) for the OECD countries, where only the cohort 45-59 has a significantly positive effect on national growth. If cohorts are defined in intervals of five years of age the cohorts 35-39 and 40-45 are expected to have the most positive influence on the growth of regional per capita income. However, the low employment rate of the elder working cohorts is a relatively new phenomenon, which might have a minor effect in the time series analyzed in their paper.

4.3.2 Remarks

Following the procedure of model selection as suggested by Florax et. al. (2003), we start with an OLS estimation (*OLS*, *stage 1*), i.e. equation (14), and use the results of this estimation to carry out the Moran-I-test[6] and the Lagrange Multiplier tests for spatial error, LM_{err}, or spatial lag, LM_{lag}, dependence[7] (*stage 2*). The Moran's I Statistic accurately indicates spatial dependence. However, it does not discriminate between the spatial error and the spatial lag model. For this reason, the Lagrange Multiplier tests, and LM_{lag} (Anselin and Florax, 1995, Anselin et. al. 1996), are applied since they give precise information about the true kind of spatial dependence (Anselin and Rey, 1991, or Anselin and Bera, 1998, Burridge 1980, Anselin, 1988, Florax et. al. 2003)[8]. If the tests

[6] This test depends on the assumption of normally distributed error terms. A more general test is the KR-test suggested by Kelejian and Robinson (1992).

[7] A more profound discussion of diverse tests and their applications can be found in Florax and deGraaff (2004).

[8] One should however note that the LM tests might be misleading if there is misspecification of the model or if there is heteroskedasticity of the error term. To test for heteroskedasticity a spatially adjusted Breusch-Pagan test is advocated (Anselin, 1988) or a KR test (Kelejian and Robinsonm 2004).

suggest that there is spatial dependence the next stages of the model selection procedure depend on the results of the LM multiplier tests. If the LM error test, LM_{err}, is significant but not the LM lag test, LM_{lag}, the spatial error model is the appropriate model (*stage 3*) and vice versa (*stage 4*). If both tests are significant one could use both approaches but the approach with the higher robust LM test value should be preferred (*stage 5*). Besides the test for spatial dependence we are testing for the significance of the age structure by carrying out a F-test over the zero hypotheses of no effect of the age structure variables.

If the LM tests indicate the existence of spatial dependence we first compute the *spatial error* and the *spatial lag* model, both estimated by using a ML procedure. In another approach spatial dependence is implemented only via a spatial lag of the initial levels of the regional GDP per capita (*regressive*). This regressive model can be estimated by OLS. The last spatial dependence model we consider is a combination of the two types of spatial lag, i.e. the spatial AR(1) and the regressive model, the so called *lag regressive* model. If the coefficient of the regressive spatial dependence is significant and the LM tests indicate that there is spatial dependence despite the regressive model, the spatial lag regressive or spatial error regressive model are the preferred model, depending on the levels of the robust LM tests.

Furthermore we compare two age structure indices - the polynomial or moments based index and the age share index. In the latter case each age cohort cover 15 years of age. The former approach allows to derive the effects of age groups with smaller age intervals but suffers from a higher degree of multicollinearity. By using three moments we are able to calculate the effects of cohorts composed of five years of age. Using also five year intervals for the age groups in the age share approach would require to consider 18 age structure variables in the estimates with a high degree of multicollinearity. So, the moments model is extremely useful since one can reduce the number of variables describing the age structure much more than in the age share approach.

Since one can expect that national regulations and national economic conditions determine the regional economic performance to a large degree, we account for country effects by eliminating all country specific effects. This is achieved by additionally applying a model where we consider only the difference between regional values and the mean values of their respective country, i.e. the regional means of all regions of a country. This model is called the *difference model*[9]. All spatial models in the regional approach are estimated

[9] Country effects in the basic model are considered in the saving/investment variable $\ln s$, which differs only between countries. This does not allow searching for country specific effects. For this reason some regressions of a country dummy approach are carried out. Unfortunately, the coefficient of a country dummy also entails some of the spatial effects attached to the country. Thus, we refrain from discussing the dummy approach and focus on the difference model to discuss country specific effects.

by assuming that the normalized distance decay parameter γ equals 0.5. However in the case of the difference model cross-border correlations are excluded and only neighbors have a non-zero value in the weight matrix.

We start with the *regional model* where all variables are aggregate regional variables. Thereafter we present the results of the *difference model* [10]. For both approaches the results of adopting the moments index, see equation (18), and the age share index are presented, see equation 2. In each case the different OLS and spatial approaches are given, if necessary.

4.3.3 The regional model

Moments of the population density Table 1 displays the results of the regressions of the regional model where the age structure is approximated by three moments of the density of regional and national populations[11]. Column 2 gives the results of the basic OLS regression. The first result to be emphasized is that adding the age structure to the regression improves the fit of the model compared to the basic neoclassical growth approach. The adjusted R^2 is 14.33 in the age structure adjusted model but only 6.87 the in the basic neoclassical approach.

The zero hypothesis of a zero spatial lag is rejected by all three spatial dependence tests, the Moran-I-statistic test, the LM error, LM_{err}, and the LM lag, LM_{lag}, test. Since all tests reject the zero hypothesis of no spatial dependence, the OLS model is not appropriate. So spatial dependence is expected to be present in the data. For this reason the next task is to compare the results of the robust LM tests. These tests have more power for the model selection, while the standard LM error and LM lag tests are sufficient to test for spatial dependence. The robust spatial error Lagrange multiplier in the OLS regression is 2.53, the robust spatial lag Lagrange multiplier is 12.3. Consequently, the spatial lag model should be selected (see Anselin and Rey, 1991).

Despite this model selection, we also provide the results of the spatial error model in column three (22) and of the regressive model, (20), which has not yet been tested for, in column five. The Moran-I-test and both LM tests carried out in the regression model show that the regressive model does not eliminate spatial autocorrelation and, in addition, the coefficient of the regressive dependence variable is insignificant. Therefore, the spatial regressive model is not appropriate. Nonetheless we provide the results of the spatial lag regressive model which refers to equation (19) in the last column. If a regressive spatial

[10] We used Stata 8 for performing the regressions.

[11] We also carried out regressions with two and four moments. But the results where less appealing. Since population is not normally distributed and not symmetric distributed, using only two moments is not appropriate. On the other hand multicollinearity increases when adopting four moments.

g					
	OLS	spatial error	spatial lag	regressive	lag regressive
const	-1.48***	-0.52	-1.01**	-1.18**	-1.04**
	(0.44)	(0.61)	(0.42)	(0.52)	(0.13)
$\ln y_0$	-0.003***	-0.003**	-0.003**	-0.003**	-0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\ln(n+\delta)$	0.01	-0.01	0.004	0.01	0.005
	(0.01)	(0.01)	(0.01)	(0.11)	(0.01)
m_1	1.10***	0.30	0.54*	0.86**	0.56
	(0.31)	(0.48)	(0.31)	(0.38)	(0.35)
m_2	-0.16***	-0.01	-0.06	-0.12*	-0.06
	(0.06)	(0.09)	(0.06)	(0.07)	(0.06)
m_3	0.006**	-0.001	0.001	0.004	0.001
	(0.03)	(0.004)	(0.002)	(0.003)	(0.003)
$\ln p(1-u)$	0.02	0.02	0.003	0.02	0.003
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
$\ln s$	-0.25***	-0.13	-0.14**	-0.23***	-0.14**
	(0.06)	(0.10)	(0.06)	(0.06)	(0.06)
$W \ln y_0$				-0.003	0.0003
				(0.003)	(0.003)
Wg			0.62***		0.62***
			(0.13)		(0.13)
$W\varepsilon$		0.70***			
		(0.138)			
Moran I	5.6***			5.7***	
LM_{err}	15.6***			15.0***	
LM_{lag}	25.5***			23.5***	
F	5.7***			33.0***	
F age	6.6***	12.3***	14.0***	5.0***	14.0***
R^2	0.1739			0.1796	
adj. R^2	0.1433			0.1447	

g is the GDP growth rate per capita, $\ln y_0$ the logarithm of the initial output per capita level, $\ln(n+\delta)$ is aggregate depreciation, the four moments are m_0, which is subsumed in the constant, the *mean*, m_1 and the uncentered *variance*, m_2, and the uncentered *skewness*, m_3, $\ln p(1-u)$ is the logarithm of the participation rate times the employment rate and $\ln s$ is the logarithm of the saving rate. F_{age} gives the result of the F-test of the zero hypothesis of no aggregate effect of the age structure variables.

Table 1: Regression results – regional model, moments approach

dependence were present a spatial lag should be added to the regression, because the robust spatial lag Lagrange Multiplier has a higher result, 15.872, than the robust spatial error Lagrange multiplier, 7.427.

Looking at the age structure, the evidence is unambiguous. The zero hypothesis of no effect of the age structure is rejected on account of the F test on the aggregate influence of the age structure variables, *F age*, in all regressions. This is evidence of an influence of the age structure on GDP per capita growth. In contrast evidence for an effect of specific moments is weak. Despite the significant influence of the age pattern no model provides a significant influence of each age structure variable[12]. The spatial lag, as the most preferred model, and the spatial regressive model provide significance of the first moment, m_1. The coefficient of the second moment, m_2, is only significant in the spatial regressive and the OLS model and the coefficient of the third moment is insignificant in all but the OLS models.

An increase in the participation rate, p, does not significantly affect the GDP growth per capita, while a higher saving rate, s, reduces growth. This effect is not in accordance with theory. The reason might be that on account of the short time series we consider higher saving is likely to reduce growth via reduced consumption while the effects of investment on growth are likely to occur only in future periods. Additionally, other country effects are also subsumed in the investment share and might overcompensate the positive investment effect. Nonetheless this indicates problems in the model specification. For instance it might be appropriate to consider the demand side too.

Age Shares Following the suggestion of Lindh and Malmberg (1999) we also carried out regressions where the age index is the product of the age shares of total population. We tried different definitions of the age cohorts. Due to a high degree of correlation we finally decided to use intervals of 15 years of age each. The results are presented in table 2. In order to overcome the problem of perfect linearity we dropped the age cohort 0-14. As a consequence, the coefficients of the other age shares are relative to the unknown coefficient of that age cohort.

In all estimates the F-test, *F age*, rejects the zero hypothesis of no effect of the age structure and, thus, provides evidence for a significant influence of the age structure on regional income per capita growth. Furthermore, according to results of the Moran-I and LM tests in the basic OLS regression spatial correlation between regions is likely to exist. As the robust LM lag test provides a higher value than the robust LM error test, 19.6 against 7.0, the spatial error specification is likely to be the better model. While these

[12] We presume that this is caused by the high degree of collinearity between age shares or the moments.

results are in favor of the spatial lag model it is not yet clear whether the spatial lag or the lag regressive model should be preferred. However, the coefficient of the regressive spatial dependence is insignifcant in the corresponding lag regressive regression (see column 5 of table 2). Even if the regressive model were appropriate it does not sufficiently correct for spatial dependence, as the LM error as well as the LM lag tests show. Both tests reject the zero hypothesis of no spatial dependence in the regressive model. Since in the regressive model the robust LM lag value is higher than the LM error value, 23.9 compared to 13.1, the spatial lag model would be the preferred modification of the regressive approach. The results of this spatial lag regressive model are displayed in the last column.

In some of the models different age cohorts have a significant effect on the GDP growth per capita. The age cohorts 15-29 and 45-59 significantly foster growth in all but the spatial error model. The age cohort 30-44 significantly promotes GDP growth per capita in all specifications. In contrast we don't find any significant effects of the age share of cohort 60-74.

Age Groups Figure 3 shows the effects of each age group on growth per capita resulting from the estimate of the moments of the density function and the spatial lag estimates of the age share model (*age share - spatial lag*).

The coefficients of the moments approach are computed as semi-elasticities without considering a_0. The constant, i.e. the effect of the youngest group could not be estimated, since a_0 was subsumed to the constant of the regression equation in the moments model. Similarly, the youngest cohort was omitted in the age cohort model. Hence, all effects are considered as relative to the effects of the first age group. The corresponding elasticities of the age shares on GDP per capita growth are presented in figure 3. Similarly the effects of the two most preferred regressions in the age share approach are also displayed in figure 3 as *Share - lag* and *Share - lag regr.* for the spatial lag and the lag regressive model.

Generally, the effects are as expected. Starting with a small effect the influence of the age cohorts is growing until it reaches a peak at about 30-34 in the moments model and 30-44 in the age share specifications. Thereafter the effect decreases. Since the coefficients of the eldest age cohort is insignificant in all age share estimates, the influence of this group is less clear. At any rate is much lower than the effects of the working cohorts. Compared to the youngest cohort aged 0-4 the eldest groups is slightly more productive in most regressions of the moments approach. The only exception is the favored spatial lag approach. Here the cohort 70-74 is just as unproductive as the youngest cohort.

The main difference to the results of the country study of Lindh and Malmberg (1999) is that we found evidence that on the regional level the cohorts with the strongest positive

g					
	OLS	spatial error	spatial lag	regressive	lag regressive
const	1.32***	0.94*	0.99***	1.24***	0.98***
	(0.34)	(0.48)	(0.13)	(0.35)	(0.33)
$\ln y_0$	-0. 004***	-0.003***	-0.003***	-0.004***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\ln(n+\delta)$	0.01	-0.01	0.002	0.003	0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$\ln s1529$	0.40***	0.13	0.25***	0.33**	0.24**
	(0.09)	(0.14)	(0.09)	(0.11)	(0.10)
$\ln s3044$	0.25**	0.29**	0.29***	0.27**	0.30***
	(0.12)	(0.13)	(0.11)	(0.12)	(0.11)
$\ln s4559$	0.21**	0.13	0.19**	0.20**	0.19**
	(0.10)	(0.10)	(0.09)	(0.10)	(0.09)
$\ln s6074$	-0.02	-0.08	-0.04	-0.04	-0.05
	(0.05)	(0.06)	(0.04)	(0.05)	(0.05)
$\ln p(1-u)$	0.01	0.02	-0.002	0.01	-0.003
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
$\ln s$	-0.22***	-0.14	-0.14**	-0.21***	-0.14**
	(0.07)	(0.10)	(0.06)	(0.07)	(0.06)
$W \ln y$				-0.003	-0.000
				(0.003)	(0.003)
Wg			0.62***		0.62***
			(0.13)		(0.13)
$W\varepsilon$		0.72***			
		(0.13)			
Moran I	8.6***			5.4***	
LM_{err}	42.7***			12.1***	
LM_{lag}	63.6***			22.9***	
F	5.7***			5.0***	
F_{age}	6.2***	16.1**	18.9**	4.7***	18.9****
R^2	0.1944			0.1997	
adj. R^2	0.1602			0.1612	

g is the GDP growth rate per capita, $\ln y_0$ the logarithm of the initial output per capita level, $\ln(n+\delta)$ is aggregate depreciation, the four age cohorts are computed by their shares, $s1529$, $s3044$, $s4559$, $s6074$. $\ln p(1-u)$ is the logarithm of the participation rate times the employment rate and $\ln s$ is the logarithm of the saving rate. F_{age} gives the result of the F-test of the zero hypothesis of no aggregate effect of the age structure variables.

Table 2: Regression results – regional model, age share approach

effect on regional per capita income growth are considerably younger and lie either at the age 25-29 or at the age 30-34 in the moments approach or at the age 30-44. The only exception is the regressive model of the moments approach which, as discussed above, is not the preferred model.

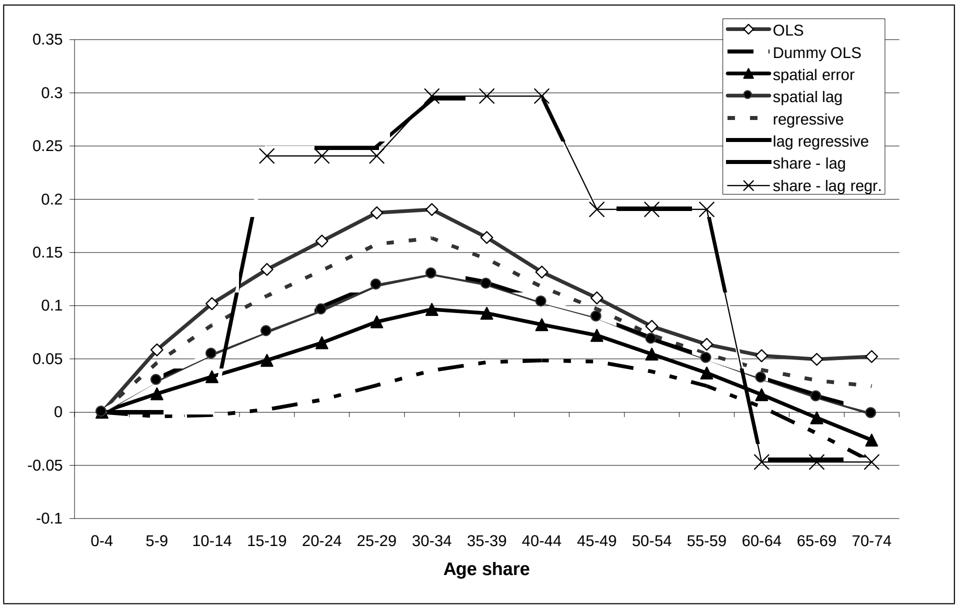

Figure 3: Age share elasticities of income per capita growth

4.3.4 Difference Model

Tables 3 and 4 display the results for the regressions carried out after eliminating country effects through demeaning regional variables within each country. In this regressions we search for evidence of whether a deviation of the age structure of regions from their country age structure affects the relative performance of the regions. To consider that country effects and, thus, spatial correlations between countries are eliminated, we use another weights matrix. The distance matrix is a binary contiguity matrix, where neighbors within a country have the coefficient 1 while all other field of the matrix are set to zero. By normalizing the distance matrix transforms into the weights matrix[13].

Our hypothesis is that a region with a higher share of the more productive age groups, i.e. the groups between 30 and 50, perform better than other regions.

[13] As an alternative we also considered a distance matrix similar to the matrix in the basic regional model. In that matrix spatial interdepence is restricted to occur within the borders of a country and all coefficients of the weights matrix between countries are set to zero. However, in this case, no spatial interdepence is present in the regressions. Nonetheless, the coefficients of the moments and age share are almost equal to the coefficients in the binary weights matrix approach. Only spatial effects do not occur, so that the OLS approach is the preferred regression.

Moments approach The results of the moments index approach support our hypotheses of a significant influence of the different age cohorts (see table 3). The moments coefficient as well as the *F age* test significantly reject the zero hypotheses of no effect of the age structure. However, this specification does hardly explain any deviations in per capita growth. The adjusted R^2 is only 0.5.

Since the Moran, LM error and LM lag test all are highly significant, spatial dependence is likely to exist. Again, the robust LM lag statistic is higher (LM_{lag} 0.2 and LM_{err} 0.0), so that the spatial lag model should be preferred.

In this model hardly any variable matters significantly. Only the deviation in initial per capita income, $D \ln y_0$, are negatively weakly significant in the spatial error and the regressive model and the constant is significant in the regressive model. For all these reasons this approach seems not to be appropriate.

Age share approach In contrast to these results, the age share approach provides much better results. First, the adjusted R^2 of the OLS approach indicates that about 7.4 percent of the deviation of the regional performance from the average performance of a country are explained by this approach. Moreover, as displayed in table 4, the age structure matters in all estimates, i.e. *F age* is significant. There is also evidence for spatial correlation. Since initial per capita incomes of the neighboring regions have a weakly significant influence on relative regional growth in income per capita, the regressive model is preferred to the basic approach. However, as the spatial tests show, even in this approach spatial correlation is not entirely elimnated by the regressive variable. For this reason and since the LM_{lag} statistic provides a higher value than the LM_{err} statistic, 6.2 versus 2.3, the regressive model is augmented a spatial lag. The results of this approach, our best model, are presented in the last column.

The difference in the initial level of GDP per capita is significantly negative in this estimate while the coefficient of the age variables for the age cohort 45-59 is significantly positive and the coefficient of the age cohort 60-74 is significantly negative compared to the age cohort 0-14. However, younger cohorts as well as the labor force participation don't impose a significant effect on income per capita growth. Thus a relative higher share of the elder working cohort promotes income per capita growth while a relative higher share of the eldest cohort lowers income per capita growth. The last effect is intuitively clear since a higher share of the elderly increases the financial burden imposed on the working cohorts. The positive effect of a relative large share of the eldest working cohort is surprising, since higher shares of the younger working cohorts don't have a clear effect on the relative performance of a region. This is in contrast to the findings in the regional

g					
	OLS	spatial error	spatial lag	regressive	lag regressive
const	-0.001	-0.01	-0.006	-0.006**	-0.004
	(0.005)	(0.01)	(0.004)	(0.005)	(0.43)
$D\ln y_0$	-0.04	-0.04*	-0.04	-0.05*	-0.04*
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
$D\ln(n+\delta)$	-0.01	-0.02	-0.01	-0.01	-0.01
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)
Dm_1	0.03	-0.13	-0.04	0.05	-0.02
	(0.14)	(0.14)	(0.14)	(0.15)	(0.14)
Dm_2	0.002	0.03	0.02	-0.002	0.01
	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)
Dm_3	-0.0005	-0.003	-0.001	-0.0003	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
$D\ln p(1-u)$	0.06	0.03	0.04	0.06	0.04
	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)
$WD\ln y_0$				0.04	0.04
				(0.04)	(0.04)
WDg			0.34***		0.35***
			(0.08)		(0.08)
$W\varepsilon$		0.39***			
		(0.08)			
Moran I	4.4***			4.4***	
LM_{err}	16.1***			16.2***	
LM_{lag}	16.3***			16.6***	
F	1.2			1.2	
F_{age}	1.4	4.9	3.6	1.6	4.1
R^2	0.0359			0.0410	
adj. R^2	0.0053			0.0053	

Dg, $D\ln y_0$, $D(n+\delta)$, Dm_1, Dm_2, Dm_3 and $D\ln p(1-u)$ are the deviations of the regional variables from their respective country mean.

Table 3: Regression results - difference model, moments approach

approach where all working cohorts significantly foster growth of per capita income. From this one would expect that a relatively higher share of the younger cohorts, which are the most productive in the regional model, would be even better. This is however not the evidence we found in the difference model. What are the reasons for this outcome?

These results found in the difference approach are in accordance with the evidence found by Lindh and Malmberg (1999) for the OECD countries. They stated that the learning effect raises productivity until it peaks at about the age of 50. Therefore, the age cohort 45-59 is the most productive. If these reasons where true in our regional approach, they should also be true in the regional model. However, in the regional model the aggregate age effects of productivity and labor force participation where the strongest for the youngest working cohorts. This could be explained by a decreasing labor force participation rate near retirement which reduces the positive productivity effects of the elder working cohort. In addition, empirical evidence found a peak of the producitivity at about 45 not 50 (see Gokhale and Kotlikoff, 1992). These are reasons for a relatively strong influence of the eldest working cohort. But to get more insight into the reasons for the insignificance of the relative share of younger working cohorts, one has to look into productivity and labor market conditions in more detail. This will be left for further research.

5 Conclusions

Population aging and migration changes the age structure of regions and might cause differences in regional wealth across countries as well as within countries. We examined the consequences of these developments by carrying out an econometric analysis for the EU15 NUTS2 regions. The human capital and age structure augmented growth models of Mankiw et. al. (1992) and of Lindh and Malmberg (1999) have been modified and applied to the issue whether the age pattern of a region affects regional GDP per capita growth.

Our main results are:

- First, adding an age structure to the basic neoclassical growth model considerably improves the fit of the model.
- Second, the evidence we found is in favor of a strong effect of the population structure on the regional growth of the real GDP per capita. All working cohorts significantly improve growth. But in contrast to the results of the OECD study of Lindh and

g					
	OLS	spatial error	spatial lag	regressive	lag regressive
const	-0.004	-0.005	-0.003	0.0004	0.001
	(0.05)	(0.006)	(0.004)	(0.005)	(0.005)
$D\ln y_0$	-0.03	-0.03**	-0.03	-0.05**	-0.05**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$D\ln(n+\delta)$	-0.02	-0.02	-0.02	-0.02	-0.02
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)
$D\ln s1529$	0.01	-0.001	0.006	0.03	0.02
	(0.05)	(0.04)	(0.04)	(0.05)	(0.04)
$D\ln s3044$	-0.03	0.02	-0.01	-0.04	-0.02
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
$D\ln s4559$	0.20***	0.17***	0.17***	0.21***	0.18***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
$D\ln s6074$	-0.13***	-0.13***	-0.12***	-0.14***	-0.13***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
$D\ln p(1-u)$	-0.001	-0.005	-0.01	-0.01	-0.02
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
WDy_0				0.06*	0.06*
				(0.04)	(0.03)
WDg			0.30***		0.30***
			(0.08)		(0.08)
$W\varepsilon$		0.31***			
		(0.09)			
Moran I	3.3***			3.1***	
LM_{err}	8.6***			7.3***	
LM_{lag}	11.1***			11.2***	
F	3.2***			3.2***	
F_{age}	4.9***	12.7**	14.8***	5.5**	17.1**
R^2	0.1077			0.1211	
adj. R^2	0.0554			0.0835	

Dg, $D\ln y_0$, $D(n+\delta)$, $D\ln s1529$, $D\ln 3044$, $D\ln 4559$, $D\ln 6074$ and $D\ln p(1-u)$ are the deviations of the regional variables from their respective country mean.

Table 4: Regression results – difference model, age share approach

Malmberg (1999) the strongest positive effects on growth are exerted by the working cohorts younger than 45.

- In addition, there is evidence, that a deviation of the regional age structure from the age structure of the respective country is one of the sources for a relative better or worse performance of the region. We found evidence that a region with a relatively higher share of the eldest working cohort, 45-59, and a relatively lower share of the eldest cohort aged 60-74 perform relatively better than the average of its respective country. But a higher share of the younger working cohorts don't have a significant effect.

Of course, this study is a first step and some further methodological issues should be explored in the future. For instance, a longer time series should be constructed. This would be more in line with the theoretical model used here. Another caveat is our assumption of an exogenously given total factor productivity A. In the regression it is equivalent to the constant. This specification is hardly up to date, since endogenous growth models suggest how to implement an endogenous A. Cheshire and Carbonaro (1995), Badinger, Müller and Tondl (2002) and recently Vayá et. al. (2004) suggest how to implement technological progress and spillover in technology and growth. However, we tried some specifications, e.g. number of patents, but without noticeable changes to our results. Nonetheless, we are going to implement human capital in further research.

6 Literature

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