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Regional Convergence in Germany. A Geographically Weighted Regression Approach

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Abstract

The convergence of German regions represents a politically explosive question. Different studies examined convergence processes of Germany. We derive equations to estimate the convergence speed on basis of a Solow model, to which human capital is added. The geographically weighted regression permits a detailed analysis of convergence processes, which has not been conducted for Germany so far yet. We estimate a separate speed of convergence for every region, which results from the local coefficients of the regression equations. The application of this procedure to German labour market regions shows that regions move with a different speed towards their steady state level. The half lives are substantially longer in the manufacturing sector than in the service sector. One model even yields tendencies towards divergence of some peripheral regions.

Zusammenfassung

Die Konvergenz von deutschen Regionen stellt eine politisch brisante Fragestellung dar. Verschiedene Studien haben Konvergenzprozesse in Deutschland untersucht. Auf Basis eines um Humankapital erweiterten Solow-Modells werden die empirisch zu untersuchenden Gleichungen entwickelt. Die räumlich-gewichtete Regression erlaubt eine differenzierte Analyse von Konvergenzprozessen, wie sie für Deutschland bisher noch nicht vorgenommen wurde. Wir schätzen für jede Region eine separate Konvergenzgeschwindigkeit, die sich aus den lokalen Koeffizienten der Regressionsgleichungen ergibt. Die Anwendung dieses Verfahrens auf deutsche Arbeitsmarktregionen zeigt, dass sich Regionen mit vollkommen unterschiedlicher Geschwindigkeit auf ihren Steady-State zubewegen. Die Halbwertszeiten sind dabei im produzierenden Gewerbe wesentlich länger als im Dienstleitungssektor. In einem Modell bestehen sogar divergente Tendenzen für einige periphere Regionen.

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1. Introduction

The regional convergence is a politically important question. In the European Community contract the adjustment of the living conditions is explicitly mentioned (s. Lammers 1998, p. 197). The Basic Constitutional Law of the Federal Republic of Germany (Grundgesetz) mentions uniform living conditions (Art. 72 GG). From this the necessity for an economic policy aligned to convergence can be justified. The Planning Committee for Regional Economic Structure, to which important federal ministers are members, has passed a law in 2004 (33. Rahmenplan der Gemeinschaftsaufgabe "Verbesserung der reginalen Wirtschaftsstruktur") about the regional policy. In that law the regional equalization is explicitly mentioned (printed in Eberstein/Karl 1996 cont., D II 2, pp. 7, see also Irmen/Strubelt 1998, p. 2). So many fiscal programmes aim at a reduction of regional differences.

Because of the high political importance, many studies are dealing on the issue of convergence and divergence. On the one hand researchers provide surveys on European level (see for example Neven 1995, Thomas 1995, Engel/Rogers 1996, Thomas 1996, Helliwell 1998, Nitsch 2000, Martin 2001, Niebuhr 2002, Fingleton 2003, Bottazzi/Peri 2003, Arbia/Paelinck 2003, Greunz 2003, López-Bazo/Vayá/Artis 2004 and Eckey/Kosfeld/Türck 2005 a).

On the other hand there are many elaborate analyses of the convergence process in Germany. Smolny (2003) examines, to what extent the bad economic development in East German regions can be explained by a growth model. But he finds no convincing explanation for the low productivity. He assumes that East Germany will not catch up with West Germany soon. The same conclusion is conducted by Ragnitz (2000), who gives several structural reasons for the productivity lag like different sectoral patterns, a low capital intensity of production and a weak market position of firms. Klodt (2000) concludes that the fading out of the catching-up process since the mid-1990s is caused by an inappropriate design of industrial policy, which is concentrated on the subsidy of physical capital.

Kemper (2004) analyses the internal migration in East und West Germany. Before unification there were different ways of migration. While in the GDR had been tendencies towards urbanisation, in West Germany a deconcentration takes place. The 1990s are represented by a convergent development towards a suburbanisation. At the end of the decade there are tendencies towards divergence in the migration patterns.

Other aspects of convergence are the process of specialisation of industries as well as the employment. The paper of Niebuhr (2000) is based on two economic growth equilibriums. First, the development of productivity is explained by the level of production. Second, a regression model analyses the relationship between an indicator of agglomeration and the growth of employment. Both approaches show a convergent development in West Germany's planning regions. Suedekum (2004) doesn't find a trend towards spatial specialisation or concentration. Only in some regions the specialisation is increasing. These areas benefit from it by an above-average employment growth. Suedekum and Blien (2004) supply an accurate analysis of the distribution of employment. The shift share regression of West German administrative districts yields out a negative effect of the regional wages on the employment growths. The employment growths differ, especially suburban regions gain jobs from the core cities. Bayer and Juessen (2004) conduct a time series approach to find out, if the

unemployment rate in the West German Länder will converge. The used data cover the period from 1960 to 2002. Some tests suggest a convergence process and others not.

An important indicator is also labour productivity. Barrel and Velde (2000) provide empirical evidence for a catching-up process of East Germany compared to West Germany. They estimate unbalanced panel models and identify the emergence of West German firms besides exogenous and endogenous technical processes, like the absorption of ideas and the technical progress, as important factors. Kosfeld, Eckey and Dreger (2005) estimate a convergence rate of 7,6 % in German planning regions. Their Solow's growth model predicts an increase of relative labour productivity from 74 % to 88 % in East Germany in comparison to West Germany in the decade from 2000 to 2010.

Researchers often use the GDP per capita to examine convergence processes. Funke and Strulik (2000) develop a two region endogenous growth model to study the regional development of the output. The speed of convergence in unified Germany depends on the expansion of the infrastructure. They introduce several scenarios, which all suggest a quite fast convergence process of both parts of Germany. In the most optimistic scenario East Germany will reach 80 per cent of West Germany's GDP per capita after 20 years. Juessen (2005) finds out using descriptive statistics of the GDP per capita that poor regions are catching up. A nonparametric kernel approach provides evidence for a regional divergence in the long run.

Some researchers use regression models with the income or the GDP per capita as the dependent variable. Bohl (1998) identifies tendencies towards regional divergence, because the null hypothesis of the unit root test for panel data is not rejected. But the result is limited by the fact that there can be found stationarity in some federal states. Kosfeld and Lauridson (2004) estimate an error-correction mechanism to cover tendencies towards convergence in German labour market regions. The adjustment coefficient is not significant, so they conclude: "At the end of the 20s century only weak local adjustment processes (…) towards a global equilibrium can be established" (Kosfeld/Lauridson 2004, p. 720). Funke and Niebuhr (2005 a) use regression models in order to explain the economic growth from West Germany's planning regions. Because the estimations don't fit well, they provide a kernel approach to cluster the regions. They find three convergence clubs, which have different growth equilibriums. Funke and Niebuhr (2005 b) provide insights of the β-convergence in West Germany's planning regions. For the period of 1976 to 1996 a slow rate of convergence is detected. Kosfeld, Eckey and Dreger (2005) study the β-convergence in German functional regions for the period from 1992 to 2000. In an absolute convergence model the speed of convergence amounts to 6,5 %. The convergence rate in a conditional grows model decreases to 4 %.

Beside of the β-convergence Barro und Sala-i-Martin (1991, pp. 112) introduced the σ-convergence. This concept measures the changing in earning differences. If the gap is closing, there is a tendency towards convergence. Only a few papers use the concept of σ-convergence. Bode (1998) analyses this approach by using Markov chain models. He concludes that West German regions are converging since the 1970s. Kosfeld, Eckey and Dreger (2005) find diminishing variances of the income per capita and the labour productivity in German labour regions, so the hypothesis of σ-convergence is confirmed.

A new aspect is the calculation of locally different parameters of β-convergence, because the variation of parameters can lead to inconsistent estimators (Temple 1999, pp. 126). Locally different parameters can be calculated by a geographically weighted

regression, which is developed by Brunsdon, Charlton and Fotheringham (Brunsdon/Fotheringham/Charlton 1998, p. 957). Only one convergence study uses this model. Bivand and Brunstad (2005) estimate a geographically weighted regression of Western Europe. Their coefficients have changing signs. They find a convergence of some regions and a divergence of others.

However a model, which uses different regression coefficients for German regions, is not estimated until now. In addition most models of conditional β-convergence, which use the approach of Mankiw, Romer and Weil (1992), assume the same growth rate of technological progress and rate of depreciation in all regions or neglect the term (see for example Islam 1995, Huang 2005).

The aim of this paper is to estimate a convergence model with locally different parameters of German regions taking into consideration the problems specified above. The paper is organized as follows. First we derive a neoclassical growth model, which augments the Solow-model by human capital. Section 3 outlines the geographically weighted regression. Especially, we show how this approach is estimated and tested. In addition we explain the used data. The estimated models are presented in Section 4. Section 5 concludes the results.

2. The growth model

We use a model that has been suggested by Mankiw, Romer and Weil (1992). They add the human capital, which is stressed in the endogenous-growth theory (s. for example Lucas 1988, Grossmann/Helpman 1989 and as an overview Frenkel/Hemmer 1999, pp. 200), to a Solow model. The production function of type Cob-Douglas in period t is given by:

$$(1) \qquad Y_t = K_t^{\alpha} \cdot H_t^{\beta} \cdot \left(A_t \cdot L_t\right)^{1-\alpha-\beta},$$

where Y is the output, K represents the stock of physical capital, H the stock of human capital, A the level of technology and L the labour (Mankiw/Romer/Weil 1992, p. 416). The production elasticities of physical capital α and human capital β are presumed to be added up smaller than one:

$$(2) \qquad \alpha + \beta < 1.$$

Formula (2) implies decreasing returns to scale. Divide the production function (1) by $A_t \cdot L_t$ yields the equation:

$$(3) \qquad y_t = k_t^{\alpha} \cdot h_t^{\beta},$$

where the lower cases stand for the quantities per effective unit of labour, i. e. $y_t = Y_t / \left(A_t \cdot L_t\right)$, $k_t = K_t / \left(A_t \cdot L_t\right)$ and $h_t = H_t / \left(A_t \cdot L_t\right)$. We presume a closed economy with no public spending. Then the savings take the same value as the gross investments:

$$(4) \qquad I_t = s_k \cdot Y_t.$$

The growth rate of physical capital can be expressed by the net investments, which are defined by the gross investments minus the depreciation:

$$(5) \qquad \dot{K}_t = I_t - \delta \cdot K_t = s_k \cdot Y_t - \delta \cdot K_t,$$

where δ denotes the depreciation rate. The growth of physical capital per effective unit is given by:

$$(6) \qquad \frac{\dot{k}_t}{k_t} = \frac{\partial k_t / \partial t}{k_t} = \frac{\dot{K}_t}{K_t} - \frac{\dot{L}_t}{L_t} - \frac{\dot{A}_t}{A_t}.$$

Substituting equation (5) into formula (6) gives the growth of physical capital per effective labour unit:

$$(7) \qquad \frac{\dot{k}_t}{k_t} = \frac{s_k \cdot Y_t - \delta \cdot K_t}{K_t} - n - g = s_k \cdot \frac{Y_t}{K_t} - \delta - n - g,$$

where n stands for the growth rate of labour L and g for the rate of technological progress A:

$$(8) \qquad L_t = L_0 \cdot e^{nt}$$

and

$$(9) \qquad A_t = A_0 \cdot e^{gt}.$$

If we multiply both sides of (7) with k_t, we get:

$$(10) \qquad \dot{k}_t = s_k \cdot \frac{Y_t}{K_t} \cdot \frac{K_t}{A_t \cdot L_t} - (\delta + n + g) \cdot k_t = s_k \cdot y_t - (\delta + n + g) \cdot k_t.$$

The evolution of the economy for the human capital can be derived in the same way as equation (10):

$$(11) \qquad \dot{h}_t = \frac{\partial h_t}{\partial t} = s_h \cdot y_t - (n + g + \delta) \cdot h_t.$$

The model is based on three assumptions. First, the output can be transformed costless in capital. Second, human and physical capital have the same depreciation rate. Third, there are decreasing returns to scale, which is expressed by formula (2). The decreasing returns to scale imply that there is a steady state level of convergence. The steady state corresponds to a situation, where the changes in physical and human capital are zero:

$$(12) \qquad s_k \cdot y^* - (n + g + \delta) \cdot k^* = 0,$$

$$(13) \qquad s_h \cdot y^* - (n + g + \delta) \cdot h^* = 0.$$

We solve equations (12) und (13) for $s_k \cdot y_t$ and $s_h \cdot y_t$ taking into account formula (3):

$$(14) \qquad s_k \cdot k^{*\alpha} \cdot h^{*\beta} = (n + g + \delta) \cdot k^*,$$

$$(15) \qquad s_h \cdot k^{*\alpha} \cdot h^{*\beta} = (n + g + \delta) \cdot h^*.$$

Taking natural logs of these equations yields (s. Romer 1996, p. 133):

$$(16) \qquad \ln s_k + \alpha \cdot \ln k^* + \beta \cdot \ln h^* = \ln(n + g + \delta) + \ln k^*,$$

$$(17) \qquad \ln s_h + \alpha \cdot \ln k^* + \beta \cdot \ln h^* = \ln(n + g + \delta) + \ln h^*.$$

The values of physical und human capital in the steady state can be calculated on the basis of (16) and (17):

$$(18) \qquad k^* = \left(\frac{s_k^{1-\beta} \cdot s_h^{\beta}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)},$$

$$(19) \qquad h^* = \left(\frac{s_k^{\alpha} \cdot s_h^{1-\alpha}}{n+g+\delta} \right)^{1/(1-\alpha-\beta)} .$$

Thus the steady state levels of physical and human capital depends in a positive way on the proportions of physical and human capital on the income. A higher growth of the labour force n, of the technological change or the depreciation rate lead to lower steady state levels. The steady state of output per effective unit is derived from substituting (18) and (19) in the production function (3) (s. Romer 1996, p. 133):

$$(20) \qquad \ln y^* = \frac{\alpha}{1-\alpha-\beta} \cdot \ln s_k + \frac{\beta}{1-\alpha-\beta} \cdot \ln s_h - \frac{\alpha+\beta}{1-\alpha-\beta} \cdot \ln(n+g+\delta).$$

Using the human capital stock in the steady state, we get the relationship:

$$(21) \qquad y^* = \ln\left(\frac{s_k}{n+g+\delta} \right)^{\frac{\alpha}{1-\alpha}} \cdot h^{\frac{\beta}{1-\alpha}} .$$

Barro and Sala-i-Martin (2004, p. 61) show that approximating equations (18) and (19) around the steady state yields, if one takes a Taylor series extension:

$$(22) \qquad \frac{\dot{y}_t}{y_t} = \lambda \cdot (\ln y^* - \ln y_t),$$

where the convergence rate λ is given by:

$$(23) \qquad \lambda = (n+g+\delta) \cdot (n-\alpha-\beta).$$

The convergence rate λ is a measure, how fast regions attain their long run equilibrium path. From Equation (22) follows:

$$(24) \qquad \ln y_t - \ln y_0 = (1-e^{-\lambda t}) \cdot \ln y^* - (1-e^{-\lambda t}) \cdot \ln y_0 ,$$

which yields after substituting (20):

$$(25) \qquad \ln y_t - \ln y_0 = -(1-e^{-\lambda t}) \cdot \ln y_0 + (1-e^{-\lambda t}) \cdot \frac{\alpha}{1-\alpha-\beta} \ln s_k + (1-e^{-\lambda t}) \cdot \frac{\beta}{1-\alpha-\beta} \ln s_h - (1-e^{-\lambda t}) \cdot \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n+g+\delta) .$$

The growth of the output is positively determined by the proportion of output, which is invested in physical and human capital, and negatively affected by the initial level of output as well as the growth rate of labour force, technological progress and depreciation (Mankiw/Romer/Weil 1992, p. 423). Equation (25) studies conditional convergence. This is a convergence process, where poorer regions grow faster than richer regions and all other variables are hold fixed. Then the regression coefficient for the starting level of output will be significant negative.

The conditional convergence model can be also expressed with the human capital in the steady state instead of the invested share in human capital. The relationship follows from formulas (25) and (19):

$$(26) \qquad \ln y_t - \ln y_0 = -(1-e^{-\lambda t}) \cdot \ln y_0 + (1-e^{-\lambda t}) \cdot \frac{\alpha}{1-\alpha} \ln s_k + (1-e^{-\lambda t}) \cdot \frac{\beta}{1-\alpha} \ln h^* - (1-e^{-\lambda t}) \cdot \frac{\alpha}{1-\alpha} \ln(n+g+\delta) .$$

A significant conditional convergence does not necessarily mean that an absolute convergence process takes place. Absolute convergence applies a negative relationship between the initial output and growth of output without using control variables:

$$\ln y_t - \ln y_0 = -(1-e^{-\lambda t}) \cdot \ln y_0 . \tag{27}$$

In empirical analyses are usually used quantities per capita and not per effective unit of labour, because the level of technology A is unknown. The equations (26) and (27) are given in units per capital as follows (s. Hemmer/Lorenz 2004, p. 49; Temple 1999, p. 122):

$$\ln\left(\frac{Y_t}{L_t}\right) - \ln\left(\frac{Y_0}{L_0}\right) = -(1-e^{-\lambda t}) \cdot \ln\left(\frac{Y_0}{L_0}\right) + (1-e^{-\lambda t}) \cdot \ln A_0 + gt . \tag{28}$$

and

$$\begin{aligned} \ln\left(\frac{Y_t}{L_t}\right) - \ln\left(\frac{Y_0}{L_0}\right) = {} & -(1-e^{-\lambda t}) \cdot \ln\left(\frac{Y_0}{L_0}\right) + (1-e^{-\lambda t}) \cdot \frac{\alpha}{1-\alpha} \ln s_k \\ & + (1-e^{-\lambda t}) \cdot \frac{\beta}{1-\alpha} \ln\left(\frac{H}{L}\right)^* - (1-e^{-\lambda t}) \cdot \frac{\alpha}{1-\alpha} \ln(n+g+\delta) \\ & + (1-e^{-\lambda t}) \cdot \ln A_0 + gt . \end{aligned} \tag{29}$$

Note that the restriction of model (26) of absolut equal coefficients for $\ln s_k$ and $\ln(n+g+\delta)$ leads to the equation:

$$\begin{aligned} \ln\left(\frac{Y_t}{L_t}\right) - \ln\left(\frac{Y_0}{L_0}\right) = {} & -(1-e^{-\lambda t}) \cdot \ln\left(\frac{Y_0}{L_0}\right) + (1-e^{-\lambda t}) \cdot \frac{\alpha}{1-\alpha} \left[\ln s_k - \ln(n+g+\delta)\right] \\ & + (1-e^{-\lambda t}) \cdot \frac{\beta}{1-\alpha} \ln\left(\frac{H}{L}\right)^* + (1-e^{-\lambda t}) \cdot \ln A_0 + gt . \end{aligned} \tag{30}$$

However, the investments in human capital are difficult to measure, because the forgone labour earnings can hardly be numeralized. Mankiw, Romer and Weil (1992) use the percentage of working-age-population that attends secondary school. They assume that their input based indicator is proportional to the investments. So the estimators will not be biased. This input based indicator is criticised by Dinopoulus and Thompson (1999 pp. 141-142). They argue that the indicator from Mankiw, Romer and Weil (1992) will underestimate human capital in poor countries and overestimate it in rich countries.

Dinopoulus and Thompson (1999) point out further reasons for the inadequateness of this indicator. First, human capital involves tertiary education and training on the job too. Second, the attendance at school does not necessarily imply, that human capital is rising. There are differences in the ability of learning. In addition some educated skills are difficult to use in praxis. However, because the human capital stock in the steady state is unknown and there are not available data for the investments in human capital, the human capital stock should be used instead (Hemmer/Lorenz 2004, p. 158).

Note that in the conditional convergence model of Mankiw, Romer and Weil (1992, p. 411) gt is a constant, because the period t is fixed [s. formula (30)]. Mankiw, Romer and Weil argue that the differences in the technological level i. e. climatic and institutional circumstances can be measured by a constant α and a country-specific error term ε:

$$\ln A_0 = \alpha + \varepsilon . \tag{31}$$

Their assumption of noncorrelation between this error term and the independent variables seem not to be convincing (Islam 1995, p.1134). So we measure gt and A_0 by locally specific constants. However, there is empirical evidence for threshold values of regional convergence or regional different parameters of β-convergence (s. for example Bivand/Brunstad 2005, Funke/Niebuhr 2005 a, Juessen 2005, Huang 2005). Thus we allow also regional different values for all other parameters to prevent inconsistent estimators (Temple 1999, p. 126). In addition we do not use the not convincing assumption of the same growth rate of technological progress and rate of depreciation in all regions (s. Temple 1999, p. 122, Kosfeld/Eckey/Dreger 2005). All regression coefficients, especially the rate of convergence, are estimated separately for all regions. This model of conditional convergence is given by:

$$(32) \qquad \ln\left(\frac{Y_t}{L_t}\right)_i - \ln\left(\frac{Y_0}{L_0}\right)_i = -(1-e^{-\lambda_i t})\cdot\ln\left(\frac{Y_0}{L_0}\right)_i + (1-e^{-\lambda_i t})\cdot\frac{\alpha_i}{1-\alpha_i}\left[\ln s_{ki} - \ln(n_i + g_i + \delta_i)\right] + (1-e^{-\lambda_i t})\cdot\frac{\beta_i}{1-\alpha_i}\ln\left(\frac{H}{L}\right)_i + (1-e^{-\lambda_i t})\cdot\ln A_{0_i} + g_i t\,.$$

The analogical model of absolute convergence can be expressed as follows:

$$(33) \qquad \ln\left(\frac{Y_t}{L_t}\right)_i - \ln\left(\frac{Y_0}{L_0}\right)_i = -(1-e^{-\lambda_i t})\cdot\ln\left(\frac{Y_0}{L_0}\right)_i + (1-e^{-\lambda_i t})\cdot\ln A_{0_i} + g_i t\,.$$

3. Regression model and data sources

3.1 Geographically weighted regression

The influence between a dependent variable Y and some independent variables X_k differs often across the regions (spatial nonstationarity). Therefore our regression models consist of locally different parameters [s. formulas (32) and (33)]. We use a geographically weighted regression (GWR), which has been developed by Brunsdon, Charlton and Fotheringham in the past ten years (Brunsdon/Fotheringham/Charlton 1998, p. 957).

The global regression model without taking into consideration a spatial dependence is written by the form

$$(34) \qquad y_i = \beta_0 + \sum_{k=1}^{m}\beta_k \cdot x_{ki} + u_i\,,$$

where y_i, i = 1, 2, …, n, are the observation of the dependent variable Y, β_k (k = 0, 1, 2, …, m) represent the regression coefficients, x_{ki} is the *i*th value of X_k and u_i are the error terms. In matrix notation (34) is given by

$$(35) \qquad \mathbf{y} = \beta_0 + \sum_{k=1}^{m}\beta_k \cdot \mathbf{x}_k + \mathbf{u}$$

with $\mathbf{y}$ as vector of the dependent variable, $\mathbf{x}_k$ as vector of the *k*th independent variable and $\mathbf{u}$ as vector of the error term. In geographically weighted regression the global regression coefficients in (34) are replaced by local parameters:

$$(36) \qquad y_i = \beta_{0i} + \sum_{k=1}^{m} \beta_{ki} \cdot x_{ki} + u_i$$

where β_{ki} (k = 0, 1, 2, …, m) is the regression coefficient, which expresses the influence of x_{ki} on y_i. If the β_{ki} are constant for all i = 1, 2, 3, …, n, the global model of equation (34) or (35) respectively holds (Brunsdon/Fotheringham/Charlton 1996, pp. 282; Fotheringham/Charlton/Brunsdon 1997, pp. 62). In model (33) the dependent variable y_i is $\ln(Y_t/L_t)_i - \ln(Y_0/L_0)_i$ and **X** assembles the independent variables in a $n \times 2$-matrix. It contains a column of 1s to estimate the influence of $\ln A_{0_i} + g_i t$ on Y. In the second column stand the values of $\ln(Y_0/L_0)_i$. The conditional convergence model (32) differs only regarding **X** from model (33). The matrix **X** contains two further columns, first $\left[\ln s_{k_i} - \ln(n_i + g_i + \delta_i)\right]$, second $\ln(H/L)_i$.

Thus the global model is a special case of the GWR-function. For every region are estimated separate parameters. Here is the advantage over the spatial-error- and the spatial-lag-model (s. Anselin 1988). A spatial dependence in the error term can be caused by a missing spatial varying relationship (Brunsdon/Fotheringham/Charlton 1999, pp. 497).

How can the GWR-parameters be estimated, because there are more unknowns in (36) than degrees of freedom? In the calibration observations are weighted in accordance with its proximity to region i. As the distance between two regions becomes smaller, the weight will be greater. We use the Euclidean distance between to regions d_{ij} to calculate the weights (Gaussian weighting function):

$$(37) \qquad w_{ij} = e^{-0,5\cdot(d_{ij}/\text{bandwidth})^2}.$$

The bandwidth indicates the extent to which the distances are weighted. With a greater bandwidth the smoothing increases. Then regions i and j get a smaller (greater) weight w_{ij}, if they are far from (close to) each other. The bandwidth is computed by cross-validation or minimising the Akaike information criterion (Fotheringham/Brunsdon/Charlton 2000, pp. 56; Fotheringham/Charlton/ Brunsdon 1998, p. 1910).

The regression coefficients are estimated by weighted least squares (WLS). The values of the independent variables from regions, which are nearer to region i, have a greater influence, because they are multiplied with the weight matrix for region i $\mathbf{W}_i$:

$$(38) \qquad \hat{\boldsymbol{\beta}}_i = (\mathbf{X}' \cdot \mathbf{W}_i \cdot \mathbf{X})^{-1} \cdot \mathbf{X}' \cdot \mathbf{W}_i \cdot \mathbf{y}.$$

$\hat{\boldsymbol{\beta}}_i$ is the GWR-estimator for the *i*th region:

$$(39) \qquad \hat{\boldsymbol{\beta}}_i = \begin{pmatrix} \hat{\beta}_{i0} & \hat{\beta}_{i1} & \dots & \hat{\beta}_{im} \end{pmatrix}'$$

and $\mathbf{W}_i$ a n by n diagonal matrix, which is denoted by the weights w_{ij}, j = 1, 2, …, n:

$$(40) \qquad \mathbf{W}_i = \begin{bmatrix} w_{i1} & \dots & 0 & 0 \\ 0 & w_{i2} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & w_{in} \end{bmatrix}.$$

However, one should test, if the GWR-model is appropriate. The global test of nonstationarity compares a regression of **y** on **X** with sum of squared residuals to a geographically weighted regression. The extra complexity of varying regression coefficients is worthwhile only, if the GWR-model supplies a smaller residual sum of

squares in comparison to the OLS-estimation. The sum of squared residuals from the OLS-model can be expressed as:

(41) $\hat{\mathbf{u}}_0' \cdot \hat{\mathbf{u}}_0 = \mathbf{y}' \cdot \mathbf{R}_0 \cdot \mathbf{y}$

with

(42) $\mathbf{R}_0 = \left(\mathbf{I} - \mathbf{S}_0\right)' \cdot \left(\mathbf{I} - \mathbf{S}_0\right)$

and

(43) $\mathbf{S}_0 = \mathbf{X} \cdot \left(\mathbf{X}' \cdot \mathbf{X}\right)^{-1} \cdot \mathbf{X}'$.

$\mathbf{S}_0$ is called OLS-smoothing operator, because it transfers or "smoothes" the observed values $\mathbf{y}$ to the expected values $\hat{\mathbf{y}}$:

(44) $\hat{\mathbf{y}} = \mathbf{S}_0 \cdot \mathbf{y}$.

The *i*th row of the GWR-smoothing operator $\mathbf{S}_1$ is given by

(45) $\mathbf{r}_i = \left(\mathbf{X}' \cdot \mathbf{W}_i \cdot \mathbf{X}\right)^{-1} \cdot \mathbf{X}' \cdot \mathbf{W}_i \cdot \mathbf{y}$.

Letting $\mathbf{R}_1$ be a quadratic matrix computed with the GWR-smoothing operator:

(46) $\mathbf{R}_1 = \left(\mathbf{I} - \mathbf{S}_1\right)' \cdot \left(\mathbf{I} - \mathbf{S}_1\right)$,

the GWR-residuals may be written using the quadratic form of this matrix

(47) $\hat{\mathbf{u}}_1' \cdot \hat{\mathbf{u}}_1 = \mathbf{y}' \cdot \mathbf{R}_1 \cdot \mathbf{y}$.

If we assume **y** has a normal distribution, the ratio

(48) $F = \dfrac{\left(\hat{\mathbf{u}}_0' \cdot \hat{\mathbf{u}}_0 - \hat{\mathbf{u}}_1' \cdot \hat{\mathbf{u}}_1\right)/v}{\left(\hat{\mathbf{u}}_1' \cdot \hat{\mathbf{u}}_1\right)/w}$,

where v denotes the trace of $\mathbf{R}_1 - \mathbf{R}_0$ and w the trace of $\mathbf{R}_1$, is approximative F-distributed (Brunsdon/Fotheringham/Charlton 1999, pp. 501). If the null hypothesis of stationarity is rejected, the GWR-model is appropriate.

Beside the nonstationarity of all regression coefficients one can check, if one parameter is nonstationary. The test is based on a Monte Carlo simulation (for details see Fotheringham/Brunsdon/Charlton 2000, pp. 56). If the null hypothesis of stationarity is rejected for some but not all parameters, a mixed GWR-model could be appropriate (Fotheringham/Brunsdon/Charlton 2000, pp. 65; Mei/He/Fang 2004). If the global test of nonstationarity suggests using a geographically weighted regression model and the Monte Carlo simulation is not significant for all coefficients, one should also calculate a GWR-approach.

3.2 Sources of data

We estimate an absolute and a conditional convergence model for Germany [s. formulas (32) and (33)]. As spatial units we do not use the administrative units (Kreise). A regression analysis with administrative units can provoke spatial autocorrelation (Keilbach 2000, pp. 120 and Döring 2005, p. 100), which is strengthened by suburbanization tendencies (Kühn 2001, Kaltenbrunner 2003, Motzkus 2001, pp. 196 and Schönert 2003). This spatial autocorrelation would cause an inefficiency of the geographically weighted regression.

Instead our analysis is based on labour market regions, which Eckey defined by commuter flows (Eckey/Horn/Klemmer 1990; Eckey 2001). This demarcation worked satisfactorily in different studies (s. for example Kosfeld/Lauridsen 2004, Kos-

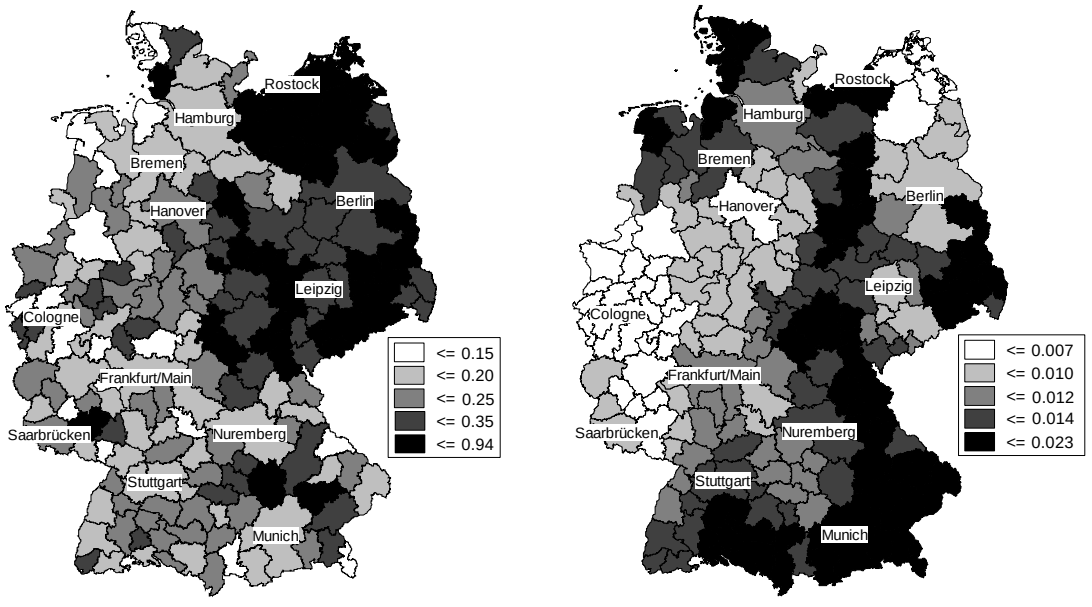
feld/Eckey/Dreger 2005, Eckey/Kosfeld/Türck 2005 and Eckey/Kosfeld 2005). The official data on the basis of administrative units (Kreise) can be aggregated to labour market regions.

We use the official data to estimate the convergence models, which cover the period between 1995 and 2002 (Statistische Ämter des Bundes und der Länder 2003 and 2004). We focus on the labour productivity (Y/L), which is measured by gross value added per employee, and the gross value added per capita (Y/N). The conditional model contains additional variables. The investment rate in physical capital s_k is given by gross investments in physical capital divided by gross value (s. Fig. 1 a). Human capital covers the labour force with a degree of an upper school providing vocational education (tertiary education), a university of applied sciences or a university. We use the initial values to prevent an endogeneity bias (s. Temple 1999, pp. 128). The growth of labour force n is given by the official statistics. The depreciation rate can be computed using the gross investments and the physical capital stock.[1]

In many studies a constant rate of technological progress is used for all regions (see for example Islam 1995, p. 1139 and Kosfeld/Eckey/Dreger 2005, pp. 198). We estimate g with a panel GWR-approach of the production function:

(49) $$Y = f(\text{dummy West / Ost}, \text{dummy for g}, L, K, H).$$

Fig. 1: Investment rate and technological progress



a) investment rate in physical capital b) rate of technological progress g

The dummy variable for estimating g is 1, if the values of 2002 are used. The regression coefficient belonging to this dummy yields the growth rate over the whole period. Fig. 1 b provides a visual impression of the spatial structure. The rate of technological progress is high in some regions around Munich and Stuttgart as well as in East

[1] The regional capital stock is not denoted by the official statistics. We use therefore an estimation, which is described in the appendix.

Germany and low in the industrially shaped Ruhr district and Saarland.[2] The average growth rate for Germany corresponds with the estimation of Grömling (2004).[3]

Table 1: Descriptive statistics

Variable	Mean	Standard deviation	Minimum	Maximum
Gross value (Y) 1995	9391.956	14922.431	950.000	88829.000
Gross value (Y) 2002	10882.694	17479.038	1039.000	108565.000
Population (N) 1995	453763	590980	88940	4383669
Population (N) 2002	458235	601503	82609	4417028
Labour force (L) 1995	207.506	284.761	36.100	1936.900
Labour force (L) 2002	214.839	298.759	30.700	1894.600
Human capital (H) 1995	15.436	28.777	1.100	222.400
Physical capital (K) 1995	48910.661	72357.732	4303.300	452136.500
Physical capital (K) 2002	57657.334	82425.905	6262.300	503232.500
Investment rate in physical capital (s_k)	0.268	0.131	0.080	0.937
Growth rate of labour force (n)	0.002	0.010	-0.034	0.026
Growth rate of technological progress (g)	0.012	0.005	-0.002	0.025
Rate of depreciation (δ)	0.023	0.002	0.020	0.027

4. Empirical evidence on convergence

4.1 Absolute convergence

At first we estimate an absolute convergence model of the neoclassical growth theory. On the one hand the annual labour productivity is used, which is measured by gross value added per employee. The average growth of labour productivity is explained by the initial labour productivity level. The GWR-equilibrium of this model can be expressed as [s. formulas (33) and (36)]:

$$(50) \qquad \frac{\ln y_{i,2002} - \ln y_{i,1995}}{7} = \beta_{0i} + \beta_{1i} \cdot \ln y_{i,1995} + u_i .$$

The results of the calculations are listed in Table 2. The coefficient of determination R^2 (global OLS-estimation of the equilibrium

$$(51) \qquad \frac{\ln y_{i,2002} - \ln y_{i,1995}}{7} = \beta_0 + \beta_1 \cdot \ln y_{i,1995} + u_i),$$

[2] In addition we estimated the rate of technological progress with the Solow residual (Barro/Sala-i-Martin 2004, pp. 434). The regional results of this approach, which is usually used (see for example Grömling 2001 and Grömling 2004), do not convey a big deal, because the coefficient g is negative in about 10 % of the regions.

[3] Our estimation averages out 1.1 %.

yields a value of 33.7 %. This proportion of explained variation is significant. The regression coefficients have the expected sign. We obtain a level of technology in the base period 1995, which is expressed by the intercept, of 0.137. The negative coefficient of the initial labour productivity level confirms a convergence of German regions. Regions, which have a low labour productivity, grow faster than regions with a high labour productivity. The parameter β_1 is linked to the speed of convergence λ by the following relationship (s. Barro/Sala-i-Martin 2004, p. 462):

$$\beta_1 = -(1 - e^{-\lambda}). \tag{52}$$

The speed of convergence in the global OLS-model,

$$\lambda = \ln(1 - \beta_1) = \ln[1 - (-0.032)] = \ln(1.032) = 0.031[\hat{=} 3.1\,\%], \tag{53}$$

shows a quite fast decline in regional disparities. A 3.1 % convergence rate implies about a:

$$t = \frac{-\ln(1/2)}{\lambda} = \frac{-\ln(1/2)}{0{,}031} = 22 \tag{54}$$

year half life of the convergence process.

Table 2: Absolute convergence of the labour productivity

Coefficient	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Global OLS
β_{0i} or β_0	0.042	0.079	0.110	0.147	0.183	0.137**
β_{1i} or β_1	-0.046	-0.035	-0.025	-0.017	-0.007	-0.032**
R_i^2 or R^2	0.158	0.278	0.333	0.407	0.521	0.337**
Bandwidth = 1.419; Global test of nonstationarity: F = 7.646**						

Notes: R^2: coefficient of determination; R_i^2: local coefficient of determination; F: empirical F-value; **: significant at the 1 % level; *: significant at the 5 % level; (*): significant at the 10 % level

Because the null hypothesis of the global test of nonstationarity [s. formula (48)] is rejected, we estimate a GWR-model, too.[4] The regression coefficients vary remarkable, but the signs are all the same. Thus the results can be interpreted well. The intercept is always positive and it shows the different extent of using technology. The slope has a negative sign, so German labour regions are converging concerning the labour productivity. The convergence speed covers the range between 0.7 % and 4.5 %.

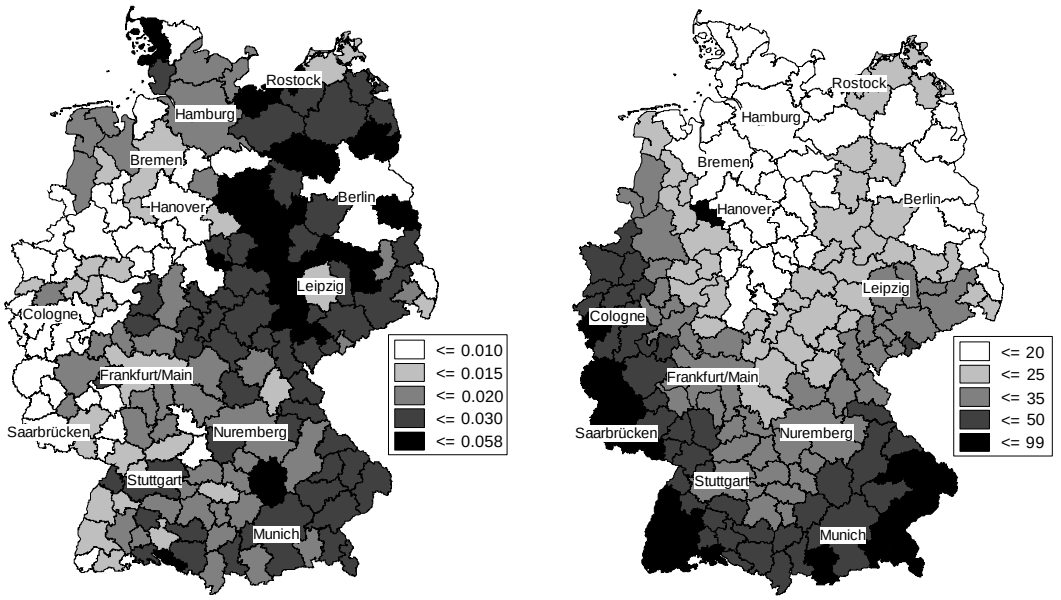
Fig. 2 a shows the distribution of the average labour productivity growth in the period from 1995 to 2002 and the half life across German labour regions. Especially regions in the former GDR and in Bavaria have comparably high growth rates. The values increase from the west to the east. The subsidies in the former GDR favoured investments in capital intensive branches (Quehenberger 2000, pp. 122-123). This process caused a labour-saving technological progress and a high growth in labour productivity.

The half life of the convergence process varies in German labour regions (s. Fig. 2 b). Its value increases from the north to the south. Regions in south Bavaria and Baden-

[4] In addition the nonstationarity of the two regression coefficients is checked by Monte Carlo simulation (the p-values are smaller than 0.01). These tests confirm the result of the global test of nonstationarity.

Württemberg as well as in Saarland need more than fifty years to achieve half of the rise in labour productivity to their steady-state, while this value lies in Northern Germany at less than 20 years.

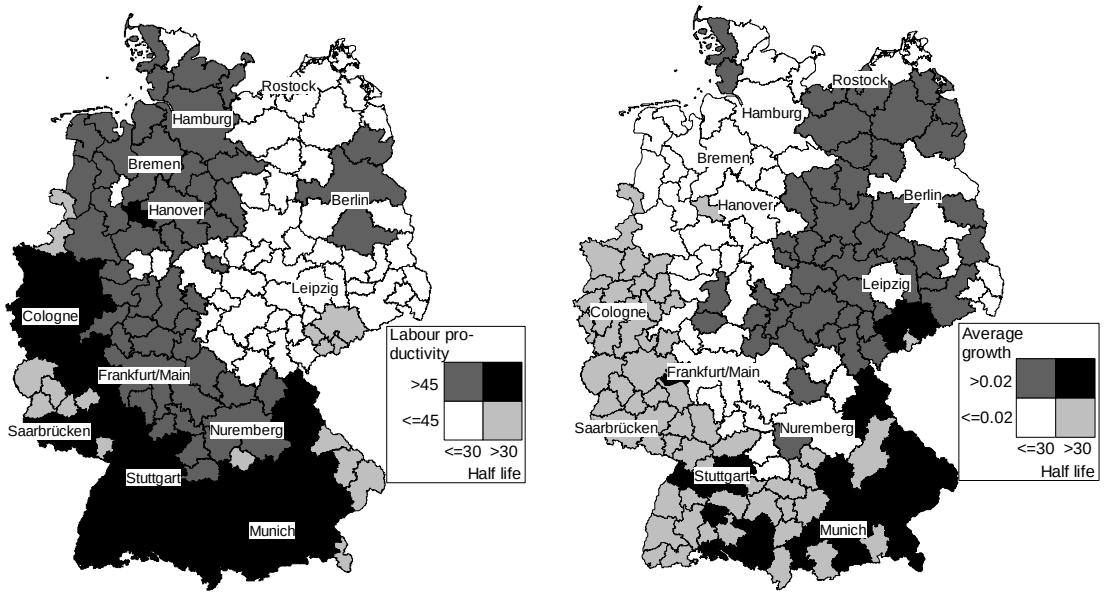
Fig. 2: Average growth of labour productivity and half life of the convergence process



a) Labour productivity growth b) Half life

Figs. 3 a and 3 b provide a visual impression of the spatial structure of the half life in combination with the labour productivity and the labour productivity growth. The regions in the former GDR have a low labour productivity and a short half life. Their steady-state of the labour productivity will probably not reach the value from most regions in West Germany, because their relative high growth in the mid 1990s is declining. Some regions in the south of Bavaria and near Stuttgart have a high final labour productivitiy, an above average growth of this variable and a long half life. They will be the most prosperous regions of Germany on a long-term basis.

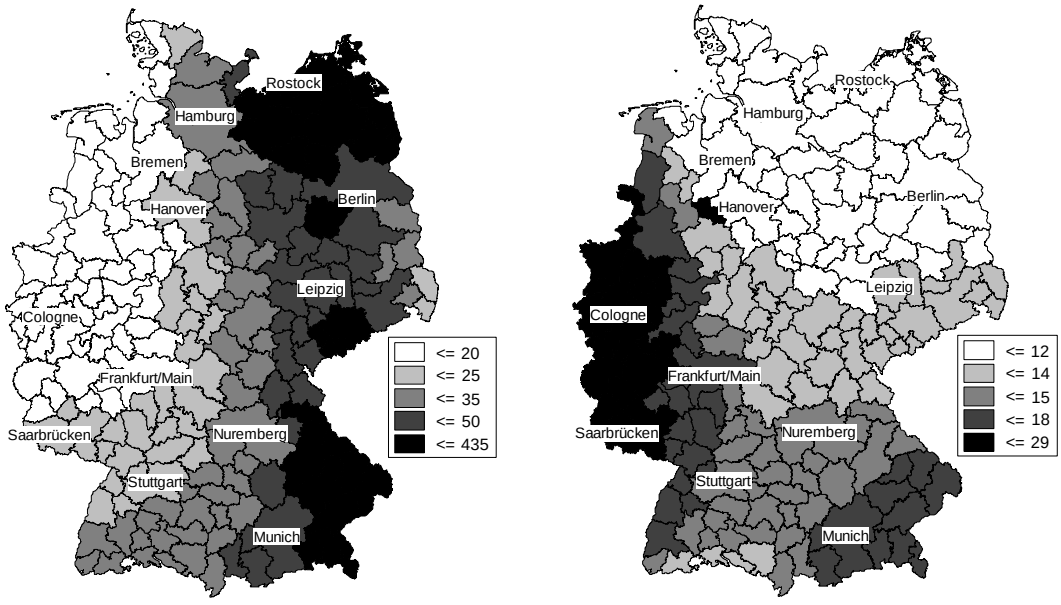
Fig. 3: Half life of the convergence process



a) Half life and labour productivity 2002 b) Half life and labour productivity growth

In addition we estimate an absolute convergence model of the labour productivity using the manufacturing and the service sector. The estimation results are reported in the appendix. The half life of the manufacturing sector exceeds the corresponding value of the service sector (s. Fig. 2). Note that the spatial pattern of both sectors is different, too. Many regions, which have a long half life in one sector, will converge quite fast in the other sector. On an aggregated level this difference will compensate each other.

Fig. 4: Half life of the convergence process (different sectors)



a) Manufacturing sector b) Service sector

Beside the labour productivity the gross value added (GVA) per capita is an often used indicator to measure absolute convergence. In equation (50) y now stands for this variable. The results of the calculations are shown in Table 3. The global OLS-estimation yields a R-square of only 0.088. Thus the fit of the model is not particularly good. However, the F-test indicates a significant proportion of explained variance. Both regression coefficients have the expected sign. The speed of convergence is with a value of 1.2 % much slower than in the absolute convergence model with the labour productivity. This result corresponds to studies of Spanish (Tortosa-Ausina et al. 2005) and German (Kosfeld/Eckey/Dreger 2005) regions.

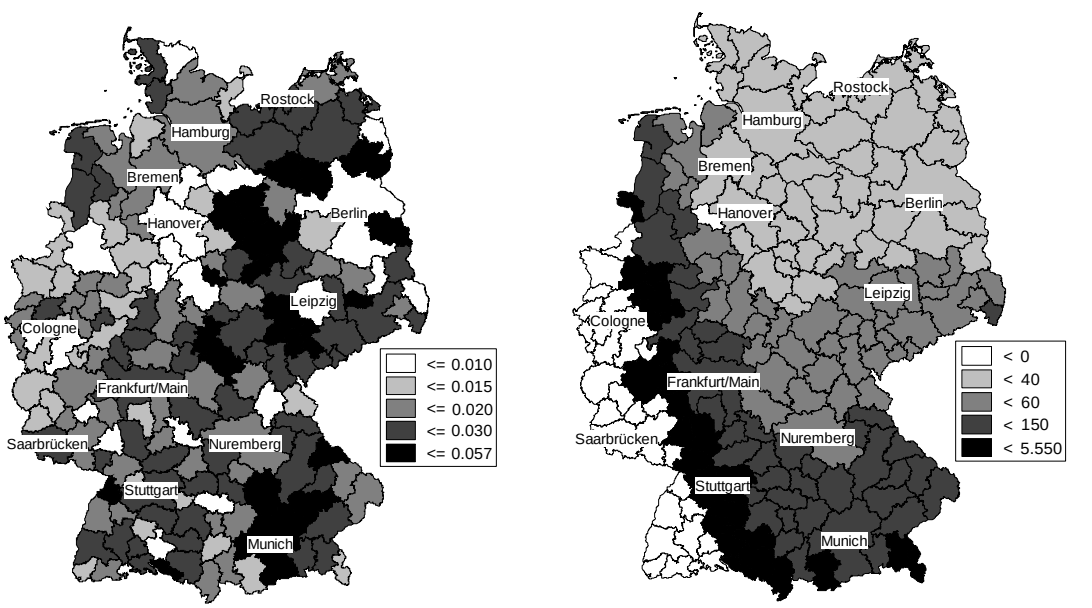
Table 3: Absolute convergence of the gross value added per capita

Coefficient	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Global OLS
β_{0i} or β_0	0.000	0.028	0.050	0.069	0.092	0.054**
β_{1i} or β_1	-0.026	-0.017	-0.011	-0.004	0.006	-0.012**
R_i^2 or R^2	0.052	0.127	0.179	0.224	0.283	0.088**
Bandwidth = 1.640; Global test of nonstationarity: F = 4.680**						

Notes: R^2 : coefficient of determination; R_i^2 : local coefficient of determination; F: empirical F-value; **: significant at the 1 % level; *: significant at the 5 % level; $^{(*)}$: significant at the 10 % level

In addition to the global OLS-model a GWR-approach is calculated, because a global nonstationarity is proved (s. last row in Table 3).[5] The intercept exceeds zero in all regions, but there is a changing sign of the slope. This result is also reported in the analysis of Biwang and Brunstad (2005, p. 19), who use EU-regions. The regions, which have a positive slope, do not reach their steady-state, but they diverge.

Fig. 5: Average growth of GVA per capita and half life of the convergence process



a) Growth of GVA per capita b) Half life

[5] Monte Carlo simulations provide evidence for nonstationarity of both coefficients, too.

The diverging regions have a negative convergence speed. They are located at the Western border (s. Fig. 5 b). These regions are surrounded by districts, which are converging slowly. The comparison with Fig. 2 b shows that the diverging regions have in the other model partly the highest half life value. But there are simularities between the two models. The half life of the convergence process increases from southwest to northeast.

4.2 Conditional convergence

The conditional model differs from the model of the absolute convergence by the fact that control variables are included. We use a model, which was conducted by Mankiw, Romer and Weil (1992). They added the human capital, which is stressed in the endogenous-growth theory (s. for example Lucas 1988, Grossmann/Helpman 1989 and as an overview Frenkel/Hemmer 1999, pp. 200), to a Solow model.

The equation of the labour productivity growth model with locally different regression coefficients is given by [s. formulas (32) and (36)]:

$$(55) \qquad \frac{\ln y_{i,2002} - \ln y_{i,1995}}{7} = \beta_{0i} + \beta_{1i} \cdot \ln y_{i,1995} + \beta_{2i} \cdot \ln\left[\ln s_{k_i} - \ln(n_i + g_i + \delta_i)\right]. + \beta_{3i} \cdot \ln h_i + u_i,$$

where $y_{i,2002}$ represents the labour productivity 2002 in region i and $y_{i,1995}$ the same quantity in 1995 and all other variables are denoted as before. The global test of nonstationarity suggests using a geographically weighted regression model.[6]

The influence of the control variables is quite small. In the global OLS-estimation the coefficient of human capital is not significant at the 10 % level. In the GWR a significance test of the local parameters is not computed, but the coefficients lie all in the proximity of zero. The regression coefficient of the investment rate and the growth rate of labour force and technological progress as well as the rate of depreciation rate is significant at the 5 % level. So the local coefficients of determination are only slightly higher than in the model of the absolute convergence, although we use substantially more variables.

Table 4: Conditional convergence of the labour productivity

Coefficient	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Global OLS
β_{0i} or β_0	0.061	0.095	0.110	0.117	0.140	0.110**
β_{1i} or β_1	-0.035	-0.029	-0.027	-0.022	-0.013	-0.026**
β_{2i} or β_2	0.002	0.003	0.003	0.004	0.004	0.003*
β_{3i} or β_3	-0.001	0.000	0.000	0.001	0.001	0.000
R_i^2 or R^2	0.231	0.400	0.444	0.488	0.532	0.360**
Bandwidth = 2.429; Global test of nonstationarity: F = 6.090**						

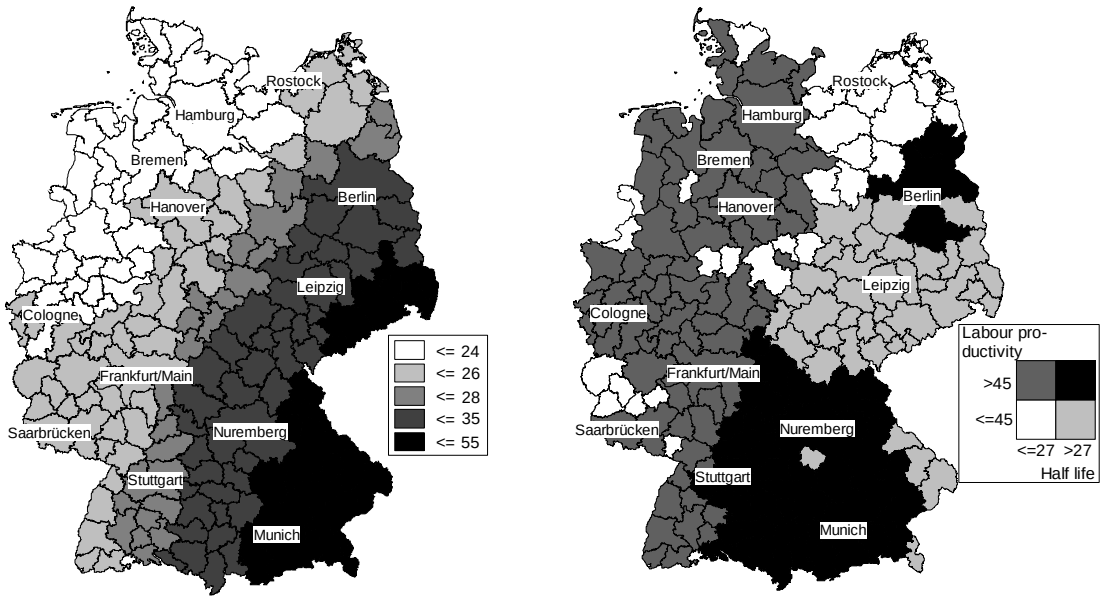
Notes: R^2 : coefficient of determination; R_i^2 : local coefficient of determination; F: empirical F-value; **: significant at the 1 % level; *: significant at the 5 % level; (*): significant at the 10 % level

[6] The Monte Carlo simulation does not reject the null hypothesis of stationarity for all regression coefficients in both conditional convergence models. However, the local determination coefficients are higher in the GWR-model, so this model is more appropriate.

The GWR-parameters of the initial labour productivity lie in the range between -0.035 and -0.013. The negative signs confirm the result of the absolute convergence model with the labour productivity as dependent variable that all regions are converging. The parameters indicate a speed of convergence, which disperse less than the coefficients in the model of absolute convergence.

Fig. 6 a shows the spatial structure of half life, which is calculated using the speed of convergence. The half life increases from northeast to southwest. Some regions at the east border of Saxony and Bavaria will need more than 35 years to achieve half of the rise in labour productivity to their steady-state value. Fig. 6 b gives a visual impression of the half life in combination with the labour productivity in 2002. The white shaped regions have a small labour productivity and a short half life. They are located peripherally in the Harz, in the north of the former GDR and between Cologne and Saarbrücken. In contrast to the models of absolute convergence many regions of East Germany exhibit an above average half life. Most regions in Bavaria and in Baden-Württemberg have above average values of labour productivity and half life.

Fig. 6: Half life of the convergence process (conditional model of labour productivity)



a) Half life b) Half life and labour productivity 2002

In addition we estimate the model of conditional convergence of the gross value added per capita. The global coefficient of determination is significant but quite small. Only 10 % of the variance of the gross value added per capita is explained by the three independent variables. The influence of the control variables is again small. The regression coefficient of human capital yields no significant influence.

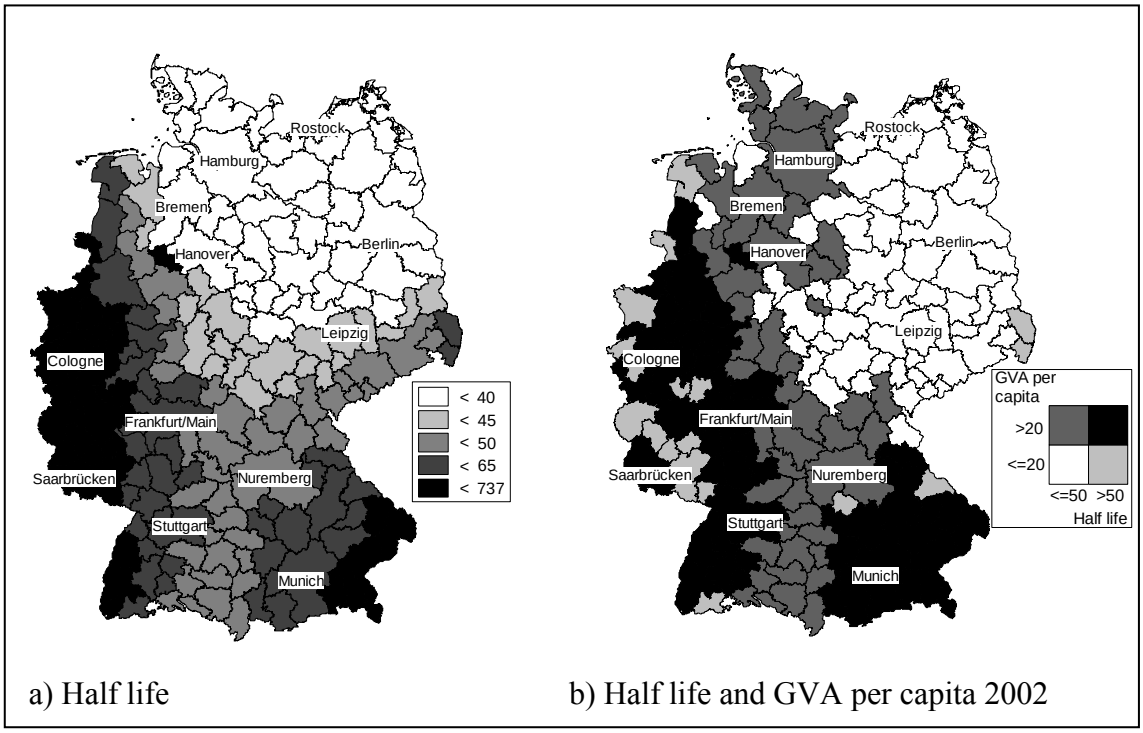
Table 5: Conditional convergence of the gross value added per capita

Coefficient	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Global OLS
β_{0i} or β_0	0.020	0.051	0.059	0.068	0.097	0.061**
β_{1i} or β_1	-0.026	-0.017	-0.014	-0.012	-0.001	-0.015**
β_{2i} or β_2	-0.003	-0.001	0.000	0.000	0.001	-0.001
β_{3i} or β_3	-0.000	0.001	0.001	0.002	0.003	$0.001^{(*)}$
R_i^2 or R^2	0.134	0.212	0.247	0.270	0.290	0.102**
Bandwidth = 2.117; Global test of nonstationarity: F = 4.082**						

Notes: R^2 : coefficient of determination; R_i^2 : local coefficient of determination; F: empirical F-value; **: significant at the 1 % level; *: significant at the 5 % level; $^{(*)}$: significant at the 10 % level

In contrast to the absolute convergence model (s. Table 3) all local regression coefficient of the initial gross value added per capita have a negative sign and indicate a convergence. A short half life characterizes the regions in the northern parts of Germany. The diverging regions in the absolute convergence model (s Fig. 5 b) have the highest half life value (s. Fig. 7 a). The comparison between Fig. 6 and Fig. 7 shows that in the first mentioned model most regions in East Germany have a half life above average, while it is pronounced below average in the other model.

Fig. 7: Half life of the convergence process (conditional model of gross value added per capita)



a) Half life b) Half life and GVA per capita 2002

5. Discussion and conclusion

The assumption of stationarity cannot be founded theoretically for most research questions. The behaviour and attitudes of people as well as the infrastructure vary across

regions. That will cause locally different parameters, which is neglected by a global approach. In addition a global estimation may lead to a bias and provoke autocorrelation. To that extent the geographically weighted regression represents an important extension of spatial econometrics.

The geographically weighted regression procedure is applied to a convergence model of German labour market regions. The estimation yields different speeds of convergence of the regions. In particular it showed up that Bavarian regions have a long and north German districts a short half life. The approach provides evidence that the south German regions with a high labour productivity and a small unemployment rate will be the most prosperous regions in Germany. On the basis of the economic development in the long-run there will be a gap between north and south Germany. One model even shows divergence tendencies of some peripheral regions.

The substantially varying coefficients show that a global convergence model, which was estimated by many researchers (see for example Kosfeld/Lauridson 2004, Funke/Niebuhr 2005 a, Funke/Niebuhr 2005 b, Kosfeld/Eckey/Dreger 2005), might be inproved by a geographically weighted regression approach. Our paper represents the first step of a local analysis of convergence processes in Germany.

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Appendix

a) Estimation of the capital stock

Mostly the physical capital stock is estimated with the "perpetual inventory accounting"-method (s. for example Rovolis/Spence 2002, pp. 67 and Eckey/Kosfeld/Stock 2000, pp. 41-49). This very complex procedure has the disadvantage that the initial capital stock must be specified and the same depreciation rate is used for all regions. Thus we estimate the capital stock with a similar approach to the shift analysis. For checking purposes we calibrate our estimation with the official data. Our estimated capital stock was already used in different studies (Eckey/Kosfeld/Türck 2005 b; Eckey/Türck 2005).

We have calculated the physical capital stock on the basis of the gross fixed capital (equipment and other plants) to replacement prices. As usual in a shift analysis (Schätzl 2000, pp. 77, Tengler 1989, pp. 110) we distinguish between the structural and the location component. The structural factor indicates, whether due to the industrial structure of a region an above or below average capital stock can be expected, thus capital-intensive industries are over- or underrepresented. The location factor expresses that we expect a high capital stock in regions with high investments in the last ten years. Data of the investments and the industry structure are taken from the official statistics. By weighting the German capital stock with the regional structure and location factors we get a first estimation, which is adjusted of west and east differences (the official statistics shows that the capital intensity in West Germany is around 5,1 % higher).

An evaluation of the estimation is possible for the three city states Berlin, Bremen and Hamburg. The own estimations deviate from the results of the official statistics between 1.4 % and 9 %. Therefore in the last step a correction on regional level is calibrated. The estimated regional capital stocks are weighted in such a way that their sum for the federal states corresponds to the results of the official statistics.

b) Additional tables

Table 6: Descriptive statistics (manufacturing sector)

Variable	Mean	Standard deviation	Minimum	Maximum
Gross value (Y) 1995	3013.078	4185.903	206	26273
Gross value (Y) 2002	3135.233	4343.802	130	32868
Labour force (L) 1995	67.561	79.751	10.1	503.2
Labour force (L) 2002	59.806	70.540	5.4	481.2

Table 7: Descriptive statistics (service sector)

Variable	Mean	Standard deviation	Minimum	Maximum
Gross value (Y) 1995	6258.128	10843.541	579	67089
Gross value (Y) 2002	7625.417	13363.431	712	85730
Labour force (L) 1995	120.637	183.525	18.1	1353.8
Labour force (L) 2002	149.818	228.226	20.1	1516.8

Table 8: Absolute convergence of the labour productivity (manufacturing sector)

Coefficient	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Global OLS
β_{0i} or β_0	0.037	0.089	0.123	0.156	0.325	0.118**
β_{1i} or β_1	-0.080	-0.036	-0.014	-0.017	-0.002	-0.026**
R_i^2 or R^2	0.025	0.278	0.206	0.277	0.471	0.221**
Bandwidth = 1.567; Global test of nonstationarity: F = 4.346**						

Notes: R^2 : coefficient of determination; R_i^2 : local coefficient of determination; F: empirical F-value; **: significant at the 1 % level; *: significant at the 5 % level; (*): significant at the 10 % level

Table 9: Absolute convergence of the labour productivity (service sector)

Coefficient	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Global OLS
β_{0i} or β_0	0.088	0.173	0.193	0.225	0.278	0.217**
β_{1i} or β_1	-0.073	-0.060	-0.051	-0.046	-0.025	-0.057**
R_i^2 or R^2	0.164	0.337	0.560	0.725	0.815	0.654**
Bandwidth = 1.521; Global test of nonstationarity: F = 4.999**						

Notes: R^2 : coefficient of determination; R_i^2 : local coefficient of determination; F: empirical F-value; **: significant at the 1 % level; *: significant at the 5 % level; (*): significant at the 10 % level

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