

Eckey, Hans-Friedrich; Döring, Thomas; Türck, Matthias

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Convergence of Regions  
from 23 EU Member States

von

Hans-Friedrich Eckey  
Thomas Döring  
Matthias Türck

Nr. 86/06

**Volkswirtschaftliche Diskussionsbeiträge**

## Convergence of Regions from 23 EU Member States\*

Hans-Friedrich-Eckey<sup>†</sup>, Thomas Döring<sup>‡</sup>, Matthias Türck<sup>§</sup>

### Zusammenfassung

Die Konvergenz von EU-Regionen stellt eine häufig untersuchte Fragestellung dar. Es gibt viele Studien zu der Thematik, die allerdings alle nicht die neuen Mitgliedsstaaten aus Osteuropa einbeziehen. Wir schätzen verschiedene Modelle für eine absolute Konvergenz und eine bedingte Konvergenz, die die unterschiedlichen wirtschaftlichen Bedingungen von den Mitgliedsstaaten einbezieht. Zuerst berechnen wir Modelle mit gleichen Regressionskoeffizienten für alle Regionen (stationäre Ansätze). Hier zeigt sich in fast allen Schätzungen eine langsame Konvergenz. Nur die Verbindung von räumlicher Filterung mit einem bedingten Konvergenzmodell, das länderspezifische Dummy-Variablen einbezieht, weist eine räumliche Divergenz aus. Als Zweites wird die geographically weighted regression (GWR) angewendet, die instationäre Regressionskoeffizienten benutzt. Dieser Ansatz belegt für die meisten Regionen eine räumliche Konvergenz. Nur einige Regionen scheinen sich von ihrem Steady State wegzubewegen.

### Abstract

Convergence of EU regions is an often examined research question. However, there are no studies available which include in their analysis the New Member States from the former Eastern Bloc. We estimate several models of absolute convergence and of conditional convergence taking into account the different initial conditions of the regions from each country. First, we calculate convergence models with equal convergence rates of every region (stationary approaches). We prove a convergence process with nearly all models between 1995-2003. Only the spatial filtering approach in combination with the inclusion of country specific dummy variables shows a significant divergent development. Second, we calculate a geographically weighted regression (GWR) approach, which uses instationary regression coefficients. This model gives evidence for a convergence of most regions. However, some regions seem to move away from their steady state.

JEL C21, R11, R58

Keywords: Regional Convergence, Spatial Econometrics, Europe

Schlüsselwörter: Räumliche Konvergenz, räumliche Ökonometrie, Europa

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<sup>†</sup> Prof. Dr. Hans-Friedrich Eckey, Economics Department, University of Kassel, Nora-Platiel-Str. 4, D-34109 Kassel, Germany. Telephone: +49-561-804/3045, Telefax: +49-561-804/3045, e-mail: eckey@wirtschaft.uni-kassel.de.

<sup>‡</sup> PD Dr. Thomas Döring, Economics Department, University of Kassel, Mönchebergstraße 19, D-34109 Kassel, Germany. Telephone: +49-561-804/2207, Telefax: +49-561-804/3045, e-mail: thomas.doering@uni-kassel.de.

<sup>§</sup> Matthias Türck, Economics Department, University of Kassel, Nora-Platiel-Str. 4, D-34109 Kassel, Germany. Telephone: +49-561-804/3044, telefax: +49-561-804/3045, e-mail: tuerck@wirtschaft.uni-kassel.de.

## 1. Introduction

Convergence and divergence of EU regions set up a politically important question, because EU policy strives for cohesion and convergence (Tondl 2004, Kramar 2006). The second article of the European Union Treaty specifies main goals of regional policy, for example a "harmonious and balanced development of economic activities", a "high degree of convergence of economic performance" and "economic and social cohesion and solidarity among Member States" (s. also Lammers 1998, p. 197 and Schwarze 2000, pp. 56). Michel Barnier, former commissioner responsible for regional policy, describes the aim of regional policy in the "third report on economic and social cohesion" as follows: "The purpose of this report (...) is to set out the European Commission's vision for the future of Europe's policy to reduce disparities and to promote greater economic, social and territorial cohesion" (European Commission 2004).

Convergence is not only a proclaimed goal. Note that the EU funds spend about 30 billion euros on convergence issues (Kramar 2006). There has been a discussion, especially recently, about the efficiency of these programmes (s. Rodriguez-Pose/Frutesi 2002, Midelfart-Knarvik/Overman 2002 and Südekum 2002). For political reasons and financial straits the examination of EU convergence is essential.

There are many studies dealing with regional convergence in Europe. Several researchers have examined absolute convergence. Absolute convergence arises, if regions converge to the same steady state value independently of their initial values. This basic neoclassical model of Barro and Sala-i-Martin (1990, 1991) has two main advantages: First, it is tested in many papers. Second, all needed variables are available for all regions including the New European Member States. In the following we report the results of recently conducted studies of absolute convergence in EU regions.

Cuadrado-Roura (2001) and López-Bazo (2003) analyse the absolute  $\beta$ -convergence for the period of 1977-1994 and of 1975-1996 respectively. They use the income per capita of EU regions and find only weak tendencies towards convergence. The absolute convergence rate is slower than 2 %. A very slow convergence process is also proved by Thomas (1996) for the period 1981-1992 and by Fingleton (2003a) for 1987-1997. Martin (2001) also calculates an absolute convergence model with the GVA per employee. He finds a lower convergence rate than Cuadrado-Roura (2001), but both researchers conclude that the convergence speed is diminishing. An extreme diminishing convergence speed is detected by Fagerberg and Verspagen (1996) for the period of 1950-1990 and the first six Member States (EU-6).

This result is not verified in the studies of Yin, Zestos and Michelis (2003, pp. 199), Niebuhr and Schlitte (2004) as well as Geppert, Happich and Stephan (2005) on the basis of EU-15 countries. In the absolute convergence model of Yin/Zestos/Michelis (2003) over the period of 1960-1995 and of Niebuhr/Schlitte (2004) for 1950-1998, the convergence speed is u-shaped. The minimum lies at the beginning of the 1980s. These results are in line with the studies of Geppert, Happich and Stephan (2005) as well as Basile/de Nardis/Girardi (2005). Geppert, Happich and Stephan (2005) detect an increase of the convergence process during the period 1986-2000. Basile, de Nardis and Girardi (2005) prove no significant absolute convergence during 1975-1985, but a significant value over the period 1985-1998.

Some researchers add to the absolute convergence model country specific dummy variables to measure the different initial conditions of Member States (within country

convergence). Normally the convergence rate decreases, if country effects are included. For example, Armstrong (1995), Fingleton (1999a), Fagerberg and Verspagen (1996), Tondl (1997, 2001), Cappelen et al. (2003a), Geppert, Happich and Stephan (2005) as well as Basile, de Nardis and Girardi (2005) estimate such models, and they prove either a slow or insignificant convergence process.

However, an estimation of a convergence regression based on cross section or panel data must take into consideration the spatial dependence of regions (Temple 1999, p. 130). This problem, which arises from migration of labour and human capital, technological and knowledge spillovers and commuter flows (cf. Rey/Janikas 2005, p. 158, Fingleton 2003b and Stough 1998), leads to a bias of OLS regression coefficients or to an invalidation of significance tests (cf. Anselin 1988, pp. 57, Fingleton 1999b and Cliff/Ord 1973, pp. 90). Note that Rey and Janikas have pointed out that "the development of spatially explicit methods for analysing regional economic convergence (...) has only recently begun to attract attention" (Rey/Janikas 2005, p. 156). The inclusion of a variable, which measures the spatial dependency, leads usually to lower absolute convergence rates (cf. for example Fingleton 1999a, Bräuninger and Niebuhr 2005, Carrington 2003, Le Gallo and Dall'erba 2006).

This study aims at examining  $\beta$ -convergence of Europe including the New Member States. Note that no researcher has measured convergence of the enlarged EU. We also take into consideration spatial autocorrelation and estimate different absolute convergence models and within country convergence approaches. Because the variation of parameters can lead to inconsistent estimators (Temple 1999, pp. 126), we aim at calculating in addition different convergence rates of EU regions with a geographically weighted regression. Only two papers use this approach in convergence studies (Bivand/Brunstad 2005, Eckey/Kosfeld/Türck 2005b), but none for an analysis of the cross-sectional convergence hypothesis of European regions.

This paper is structured as follows: In section 2 we describe the theoretical background of the  $\beta$ -convergence framework. Section 3 relies on the different methods to estimate the convergence equations. Section 4 displays the data. We will conclude with some summarising comments.

## 2. Convergence model

We use the neoclassical Solow-Swan model (s. Solow 1956 and Swan 1956) to analyse the convergence process. This approach leads to the classical model of absolute convergence (Barro/Sala-i-Martin 1990, 1991), which is often used and can be estimated with the regression framework. The basic neoclassical production with labour augmenting technological progress takes the form of type Cobb-Douglas

$$(1) \quad Y_t = K_t^\alpha \cdot (A_t \cdot L_t)^{1-\alpha} \text{ with } 0 < \alpha < 1,$$

where  $Y$  represents the output,  $K$  the stock of physical capital and  $A$  the level of technology and  $L$  the labour. This model assumes constant returns to scale. Dividing the production function (1) by  $A_t \cdot L_t$  yields the equation:

$$(2) \quad \tilde{y}_t = \tilde{k}_t^\alpha,$$

where the lower cases with tilde stand for the quantities per effective unit of labour, i. e.  $\tilde{y}_t = Y_t / (A_t \cdot L_t)$  and  $\tilde{k}_t = K_t / (A_t \cdot L_t)$ . Under the neoclassical assumptions of a closed economy with no public spending the growth rate of physical capital per effective unit can be expressed as:

$$(3) \quad \frac{\tilde{k}_t}{\tilde{k}_t} = s_k \cdot \frac{Y_t}{K_t} - \delta - n - g,$$

where  $s_k$  represents the saving rate,  $\delta$  the depreciation rate,  $n$  the growth rate of labour and  $g$  the rate of technological progress:

$$(4) \quad L_t = L_0 \cdot e^{nt}$$

and

$$(5) \quad A_t = A_0 \cdot e^{gt}.$$

Because of the key equation (3) the capital accumulation depends on the saving rate in a positive way, and there is a negative relationship between capital growth and the depreciation rate, the growth rate of labour as well as the rate of technological progress. If the investments are higher than  $\delta$ ,  $n$  and  $g$  together, then the capital stock grows (s. Islam 1995, pp. 1131 and Romer 1996, pp. 11).

To analyse the convergence process, we must focus on the steady state, a situation, where the considered quantities each grow at constant rates. In the Solow model the steady state situation occurs, if the growth rate of capital is zero. Using a first-order Taylor series extension around the steady state (s. Romer 1996, pp. 21), one gets the growth rate of capital per effective unit  $\tilde{k}^*$ :

$$(6) \quad \tilde{k}_t - \tilde{k}^* = e^{-\lambda^* t} \cdot (\tilde{k}_0 - \tilde{k}^*).$$

The convergence rate  $\lambda^*$  shows how fast the convergence path is attained. The convergence rate in the neighbourhood of the steady state depends on the growth of labour force, the value of technological progress, the depreciation rate and the elasticity coefficient  $1 - \alpha$ :

$$(7) \quad \lambda^* = (n + g + \delta) \cdot (1 - \alpha).$$

Using the convergence rate, one can calculate the half life:

$$(8) \quad HL^* = \frac{-\ln(1/2)}{\lambda^*}$$

of the convergence process. That indicator shows the time distance until the differences between the initial value and the steady state value are halved.

However, one can show that the output in efficient units  $\tilde{y}$  attains the steady state with the same convergence rate  $\lambda^*$  as  $\tilde{k}$ :

$$(9) \quad \tilde{y}_t - \tilde{y}^* = e^{-\lambda^* t} \cdot (\tilde{y}_0 - \tilde{y}^*).$$

From equation (9) follows the absolute convergence model. The mathematical proof is given by Valdes (1999, pp. 45). Because the level of technology  $A$  is unknown, researchers use not the labour productivity per effective unit but per capita (denoted with lower cases without tilde) (cf. Abreu/de Groot/Florax 2005, p. 390):

$$(10) \quad (\ln y_t - \ln y_0) = gt + (1 - e^{-\lambda t}) \cdot \ln A_0 + (1 - e^{-\lambda t}) \cdot \ln y^* - (1 - e^{-\lambda t}) \cdot \ln y_0.$$

However, formula (10) can also be derived from the Ramsey-Cass model (s. Ramsey 1928 and Cass 1965). The details can be found in Barro/Sala-i-Martin 1990, pp. 6 and 2004, p. 111.

If we divide both side of (10) by  $t$ , we get the final equation of the absolute convergence model:

$$(11) \quad 1/t \cdot (\ln y_t - \ln y_0) = g + [(1 - e^{-\lambda t})/t] \cdot \ln A_0 + [(1 - e^{-\lambda t})/t] \cdot \ln y^* - [(1 - e^{-\lambda t})/t] \cdot \ln y_0.$$

In that model the rate of technological progress  $g$ , the initial level of technology  $A_0$  and the steady state value of labour productivity  $y^*$  are assumed to be equal in all regions (Barro/Sala-i-Martin 2004, pp. 462).

### 3. Regression equations

We want to study convergence of EU-regions over the time span of 1995 to 2002. Due to statistical reasons, we include only 23 of the 25 EU member countries.<sup>1</sup> This analysis is conducted on the basis of 233 NUTS-2 ("Nomenclature of Territorial Units for Statistics") regions. The European Commission has demarcated the administrative NUTS regions together with EUROSTAT.

However, the theoretical model has to be transformed into a regression equation for EU regions, which can be estimated with ordinary least squares (OLS) or Maximum Likelihood (ML). We use the absolute convergence equation (10) for the  $i$ th region,  $i = 1, 2, \dots, 233$ , to which a stochastic error term  $u_i$  is added (cf. Tondl 2001, pp. 66 and Barro/Sala-i-Martin 2004, p. 111 and pp. 462)

$$(12) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_1 + \beta_2 \cdot \ln y_{1995,i} + u_i$$

with

$$(13) \quad \beta_1 = g + (1 - e^{-8\lambda})/8 \cdot \ln A_0 + (1 - e^{-8\lambda})/8 \cdot \ln y^*$$

and

$$(14) \quad \beta_2 = (1 - e^{-8\lambda})/8.$$

If we assume that the countries have different initial conditions (s. Caselli/Esquivel/Lefort 1996, pp. 379), we must include dummy variables for the each Member State of the EU. Note that the estimation of every regression coefficient needs one degree of freedom. Thus, we add dummy variables of country groups (s. also Temple 1998 and Eckey/Kosfeld/Türck 2005a), which show similar economic conditions and are located nearby. Because East Germany still has a bad economic development compared to the Old Laender (s. DIW et al. 2004 and Bundesregierung 2005), we use a separate dummy variable for the New Laender:

- benelu: Belgium, The Netherlands and Luxembourg
- gewat: West Germany (including Berlin<sup>2</sup>) and Austria
- geo: East Germany
- fr: France
- ukir: United Kingdom and Ireland

<sup>1</sup> The standardisation of the contiguity matrix  $\mathbf{W}^*$  is not possible [s. (16)], if one region has no border with another region. Therefore, the EU Member States Cyprus and Malta are excluded. Islands are dropped from the analyses for the same reason.

<sup>2</sup> However, if Berlin is assigned to East Germany, the labour productivity growth of this region deviates strongly from the remaining regions of the New Laender. This may lead to estimation problems.

- iber: Spain and Portugal (Iberian Peninsula)
- it: Italy
- gr: Greece
- skand: Scandinavia including Denmark, Finland and Sweden
- new: New Eastern European Member States including Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia.

However, the inclusion of all ten dummy variables and the constant term would lead to perfect multicollinearity, which is also called the "dummy variable trap" (Greene 2003, p. 118). Thus, we exclude the dummy variable for West Germany and Austria. If the nine remaining dummy variables are denoted with  $D_k$ , the regression equation (12) reads:

$$(15) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_1 + \beta_2 \cdot \ln y_{1995,i} + \sum_{k=1}^9 \beta_{2+k} \cdot D_{ki} + u_i.$$

The models (12) and (15) can be estimated with ordinary least squares (OLS), if the error term is not autocorrelated. Spatially correlated OLS-residuals lead to an inefficiency of the OLS estimators or to invalid significance tests (Florax/Folmer 1992). However, the OLS estimation must be tested for spatial autocorrelation.

Spatial econometric methods use an exogenous spatial matrix. The easiest way to consider the spatial structure is to use a binary contiguity matrix  $\mathbf{W}^*$

$$(16) \quad w_{ij}^* = \begin{cases} 1, & \text{if } i \text{ und } j \text{ share a comon border and } i \neq j \\ 0 & \text{otherwise} \end{cases}.$$

This contiguity matrix  $\mathbf{W}^*$  is usually row-standardised, because this leads to a "natural interpretation" (Ord 1975, p. 121) of spatial effects. The standardised matrix  $\mathbf{W}$  consists of the elements

$$(17) \quad w_{ij} = \frac{w_{ij}^*}{\sum_{j=1}^{233} w_{ij}^*}.$$

Thus, each row of the spatial weight matrix  $\mathbf{W}$  sums to one. The most used test of spatial autocorrelation is the Moran's I test (Moran 1950a, Moran 1950b), which possesses power against several forms of autocorrelation (Anselin/Bera 1998). The Moran's I parameter is formally given by

$$(18) \quad I = \frac{\hat{\mathbf{u}}' \cdot \mathbf{W} \cdot \hat{\mathbf{u}}}{\hat{\mathbf{u}}' \cdot \hat{\mathbf{u}}} = \frac{233}{\sum_{i=1}^{233} \sum_{j=1}^{233} w_{ij}^*} \cdot \frac{\hat{\mathbf{u}}' \cdot \mathbf{W}^* \cdot \hat{\mathbf{u}}}{\hat{\mathbf{u}}' \cdot \hat{\mathbf{u}}},$$

where  $\hat{\mathbf{u}}$  denotes the vector of the OLS-residuals (Anselin 1988, pp. 101). If the Moran coefficient detects a significant autocorrelation and the null hypothesis of the robust LM(error)-test – no spatial dependence in the error term – is rejected<sup>3</sup>, a spatial error model would be appropriate:

<sup>3</sup> A spatial dependence of the exogenous variable  $\mathbf{W}y$  (spatial lag) could be the reason for a spatial autocorrelation as well. Mostly spatial lags are interpreted as spillovers (Döring/Schnellenbach 2006, Döring 2004). However, several researchers (cf. Egger/Pfaffermayr 2005 and Arbia/Elhorst 2005) have integrated a spatial lag model with a spatial lag in the exogenous variable in a neoclassical



$$(19) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_1 + \beta_2 \cdot \ln y_{1995,i} + \gamma \cdot \mathbf{W} \cdot \mathbf{u}_i + \varepsilon_i$$

or

$$(20) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_1 + \beta_2 \cdot \ln y_{1995,i} + \sum_{k=1}^9 \beta_{2+k} \cdot D_{ki} + \gamma \cdot \mathbf{W} \cdot \mathbf{u}_i + \varepsilon_i.$$

There are two reasons for a spatial dependence in the error term: measurement errors and the areal unit problem. In particular the areal unit problem is relevant, if regression analyses are conducted for administrative regions. In Europe, there are only data available for administrative units (NUTS level), which do not reflect the spatial structure of economic activities. Keilbach (2000, pp. 120) among others has recently shown that administrative units split functional regions, which provokes autocorrelation. Another way to treat regional autocorrelation in regression models is through spatial filtering. This approach, which was conducted by Griffith (1996, 2000), uses the binary contiguity matrix  $\mathbf{W}^*$ .<sup>4</sup> Let the dependent variable be the vector  $\mathbf{y}$ ,

$$(21) \quad \mathbf{y} = \begin{bmatrix} 1/8 \cdot (\ln y_{2003,1} - \ln y_{1995,1}) \\ 1/8 \cdot (\ln y_{2003,2} - \ln y_{1995,2}) \\ \vdots \\ 1/8 \cdot (\ln y_{2003,233} - \ln y_{1995,233}) \end{bmatrix},$$

then the regional autocorrelation of the dependent variable can be measured by

$$(22) \quad I = \frac{233}{\sum_{i=1}^{233} \sum_{j=1}^{233} w_{ij}^*} \cdot \frac{(\mathbf{y} - \bar{\mathbf{y}})' \cdot \mathbf{W}^* \cdot (\mathbf{y} - \bar{\mathbf{y}})}{(\mathbf{y} - \bar{\mathbf{y}})' \cdot (\mathbf{y} - \bar{\mathbf{y}})}.$$

However, we may rewrite the formula of the Moran coefficient using a matrix  $\mathbf{C}$ :

$$(23) \quad I = \frac{233}{\sum_{i=1}^{233} \sum_{j=1}^{233} w_{ij}^*} \cdot \frac{\mathbf{y}' \cdot \mathbf{C} \cdot \mathbf{y}}{(\mathbf{y} - \bar{\mathbf{y}})' \cdot (\mathbf{y} - \bar{\mathbf{y}})}.$$

This matrix  $\mathbf{C}$ ,

$$(24) \quad \mathbf{C} = (\mathbf{I} - \mathbf{1} \cdot \mathbf{1}' / 233) \cdot \mathbf{W}^* \cdot (\mathbf{I} - \mathbf{1} \cdot \mathbf{1}' / 233)$$

with  $\mathbf{I}$  as the 233-dimensional identity matrix and  $\mathbf{1}$  as a 233-by-1 vector of ones, is of main importance for the spatial filtering procedure. The eigenvectors of  $\mathbf{C}$  contain the spatial effects. Regressing a georeferenced variable on the eigenvectors leads to residuals, which represent the spatially filtered values of the georeferenced variable. However, we can extract  $n$  eigenvectors of the symmetric matrix  $\mathbf{C}$ . Because it is impossible to estimate a regression with all 233 eigenvectors as independent variables, the substantial eigenvectors must be selected. If there are  $p$  substantial eigenvectors, we have to filter the initial labour productivity,

$$(25) \quad \ln y_{1995,i} = \beta_0 + \sum_{\ell=1}^p \beta_{\ell} \cdot E_{\ell i} + (\ln y_{1995,i})^*,$$

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growth regression (s. also Le Gallo/Dall'erba 2006, p. 273). But the authors of this paper think that spatial externalities are difficult to interpret in neoclassical models.

<sup>4</sup> If the standardised Matrix  $\mathbf{W}$  is used, the extraction of eigenvectors can cause problems, because the Matrix  $\mathbf{C} = (\mathbf{I} - \mathbf{1} \cdot \mathbf{1}' / n) \cdot \mathbf{W} \cdot (\mathbf{I} - \mathbf{1} \cdot \mathbf{1}' / n)$  is not symmetric.

where the residuals of that model  $(\ln y_{1995,i})^*$  are the filtered initial values of labour productivity. The Griffith eigenfunction decomposition leads to the following growth regression:

$$(26) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_1 + \beta_2 \cdot (\ln y_{1995,i})^* + \sum_{\ell=1}^p \beta_{\ell+2} \cdot E_{\ell i} + u_i$$

or

$$(27) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_1 + \beta_2 \cdot (\ln y_{1995,i})^* + \sum_{k=1}^9 \beta_{2+k} \cdot D_{ki} \\ + \sum_{\ell=1}^p \beta_{\ell+11} \cdot E_{\ell i} + u_i.$$

We use two criteria to find substantial eigenvectors. First, we calculate the Moran coefficient using formula (23) and the  $j$ th eigenvalue instead of  $y$ . Let the largest positive or negative Moran coefficient be  $I_{\max}$ . Then Griffith (2003, p. 107) suggests, that the eigenvalues should be used, if the corresponding absolute value of the fraction between the  $j$ th Moran coefficient and  $I_{\max}$  exceeds the threshold value of 0.25:

$$(28) \quad \left| \frac{I}{I_{\max}} \right| > 0.25.$$

Second, we calculate a stepwise regression using equations (26) and (27) as well as the eigenvectors, which fulfil condition (28) (cf. Griffith 2003, p. 119 and Eckey/Kosfeld/Türck 2006). Note that this method is applicable, because the eigenvectors are orthogonal and uncorrelated (Getis/Griffith 2002, p. 135). The georeferenced variable which we want to filter is explained by the eigenvectors. But they are only included if they have a significant influence on the georeferenced variable. After adding each eigenvector the algorithm proves, if all eigenvectors in the equation still have a substantial influence, otherwise they are removed.

An important contribution to growth empirics is the paper of Quah (1993), which mentions the "Galton's Fallacy problem" as part of absolute convergence analyses (s. also Biss 1999, pp. 10). Quah shows theoretically that the existence of convergence clubs – regions converging to the same steady state – might lead to a bias of global measured convergence rates.<sup>5</sup> But there is empirical evidence for European convergence clubs, too (s. for example Quah 1996, Bianchi 1997, López-Bazo et al. 1999, Margini 1999 and Castro 2003).

If there are convergence clubs, one should estimate different convergence rates of European regions. However, some researchers have calculated models with threshold values of regional convergence or regionally different speeds of convergence (s. for example Canova/Marcet 1995, Bivand/Brunstad 2005, Funke/Niebuhr 2005a, Juessen 2005, Huang 2005, Eckey/Kosfeld/Türck 2005b and Le Gallo/Dall'erba 2006). The neglect of spatial varying regression coefficients (spatial nonstationarity) can provoke spatial autocorrelation (Brunsdon/Fotheringham/Charlton 1998, Fotheringham/Brunsdon/Charlton 2000, p. 24) and lead to inconsistent estimators (Temple 1999, p. 126 and Dobson/Ramlogan/Strobl 2006, p. 156). A main reason why regression coefficients might vary over space is that not only countries but also regions have different initial economic conditions. In Germany for example there are urban agglomeration with high

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<sup>5</sup> One speaks of global convergence rates, if we have an equal regression coefficient for all regions.

labour productivity and growth of this variable, like Hamburg, Munich, Frankfurt etc., whereas other districts like northern Hesse and Schleswig-Holstein have low initial values und growth rates.

A variability of the intercept makes also sense, because regions might have different initial levels of technology and growth rates of technological progress (s. Islam 1995, p.1134, Islam 2003, p. 311, Barro/Sala-i-Martin 2004, pp. 462, Abreu/de Groot/Florax 2005, p. 390 and Dobson/Ramlogan/Strobl 2006, pp. 155).

A new approach to include a spatial variation of the regression coefficients is the geographically weighted regression (GWR). This approach, which has been developed by Brunson, Charlton and Fotheringham in the past ten years (Brunson/Fotheringham/Charlton 1998, p. 957), is similar to the ordinary least squares estimation. This model is written by the form

$$(29) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_{1i} + \beta_{2i} \cdot \ln y_{0i} + u_i$$

or

$$(30) \quad 1/8 \cdot (\ln y_{2003,i} - \ln y_{1995,i}) = \beta_{1i} + \beta_{2i} \cdot \ln y_{0i} + \sum_{k=1}^9 \beta_{2+k} \cdot D_{ki} + u_i.$$

Equation (30) with country specific dummies is called mixed GWR model, because some regression coefficients are locally different and others not (Fotheringham/Brunson/Charlton 2000, pp. 65). Note that the current software of GWR models cannot estimate mixed regression models. Another point is that the different initial conditions of the EU countries are "captured" by the locally different regression coefficients  $\beta_{1i}$  and  $\beta_{2i}$ . Thus, we only estimate model (29).

In the calibration process the variables are weighted in accordance with the distance  $d_{ij}$  between them. We use the Gaussian distance decay function to measure the weighting schema  $v_{ij}$  between region  $i$  and region  $j$ :

$$(31) \quad v_{ij} = e^{-0,5 \cdot (d_{ij}/\text{bandwidth})^2}.$$

The bandwidth shows the degree to which the distances are smoothed. We minimise the Akaike Information Criterion (AIC) to compute the bandwidth (Fotheringham/Brunson/Charlton 2000, pp. 56; Fotheringham/Charlton/Brunson 1998, p. 1910). The weights  $v_{ij}$  are elements of a diagonal weighting matrix

$$(32) \quad \mathbf{V}_i = \begin{bmatrix} v_{i1} & \dots & 0 & 0 \\ 0 & v_{i2} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & v_{in} \end{bmatrix},$$

which is used to estimate the regression coefficients with weighted least squares (WLS):

$$(33) \quad \hat{\boldsymbol{\beta}}_i = (\mathbf{X}' \cdot \mathbf{V}_i \cdot \mathbf{X})^{-1} \cdot \mathbf{X}' \cdot \mathbf{V}_i \cdot \mathbf{y}.$$

In equation (33) the two-dimensional vector  $\hat{\boldsymbol{\beta}}_i$  is an array of both regression coefficients  $\hat{\beta}_{1i}$  and  $\hat{\beta}_{2i}$  for the  $i$ th region. The matrix  $\mathbf{X}$  contains a unit vector in the first column and the initial values of labour productivity in the second column.

#### 4. Data

We examine regional convergence in Europe over the period of 1995-2003. Because of restricted availability of data our analysis is limited to this period. The values on NUTS-

2 level are extracted from EUROSTAT regional data base. The record covers 233 regions of 23 EU countries. The descriptive statistics of the variables are shown in Table 1.

Table 1: Descriptive statistics

Variable	Mean	Standard deviation	Minimum	Maximum
Gross domestic product (Y) 1995 (in m. €)	28698	34956	2046	335628
Gross domestic product (Y) 2003 (in m. €)	41706	49099	3553	448534
Labour force (L) 1995 (in 1,000)	779	659	54	4962
Labour force (L) 2003 (in 1,000)	826	723	59	5343
Labour productivity 1995 (Y/L)	36.048	17.149	2.971	67.641
Labour productivity growth between 1995 and 2003	0.046	0.032	-0.003	0.168

We use the indicator labour productivity, because several studies show a higher explicative power in convergence studies of this indicator than of the income per capita (see for example Eckey/Kosfeld/Türck 2005b and Basile/Nardis de/Girardi 2005). Labour productivity is defined as the fraction of domestic product (GDP) and labour force (L). Labour productivity growth has a quite high range between -0.3 % and 16.8 % (s. Table 1).

Fig. 1 displays the distribution of labour productivity growth in 233 EU regions across and within country groups. Each box plot is calculated for one country group. The boxes show the interquartile range, which is measured by the third quartile minus the first quartile. The horizontal line inside the boxes represents the median. The other two horizontal lines show the position of the adjacent values of the whiskers. The whiskers are defined as 1.5 times the interquartile range plus/minus the first or the third quartile. Outlining values [extreme values designated with a circle and outliers symbolised with an asterisk (\*)] are located outside the adjacent values. Extreme values are between 1.5 and 3 box-lengths from the box ends. Outliers lay beyond 3 times of the interquartile range from the box ends.

From Fig. 1 follows, that there is quite a high variation of growth rates between country groups. Countries in the centre of the EU (Belgium, The Netherlands, Luxembourg West Germany, Denmark and Austria) have the lowest growth rates, whereas Greece, the United Kingdom and especially the New Member States show high growth rates. Differences between growth rates within the country groups are small. There are only eight extreme values, which show a quite high or a quite low growth rate in comparison with the other regions in the same country group. Outliers are missing.

Fig. 1: Box plots of labour productivity growth

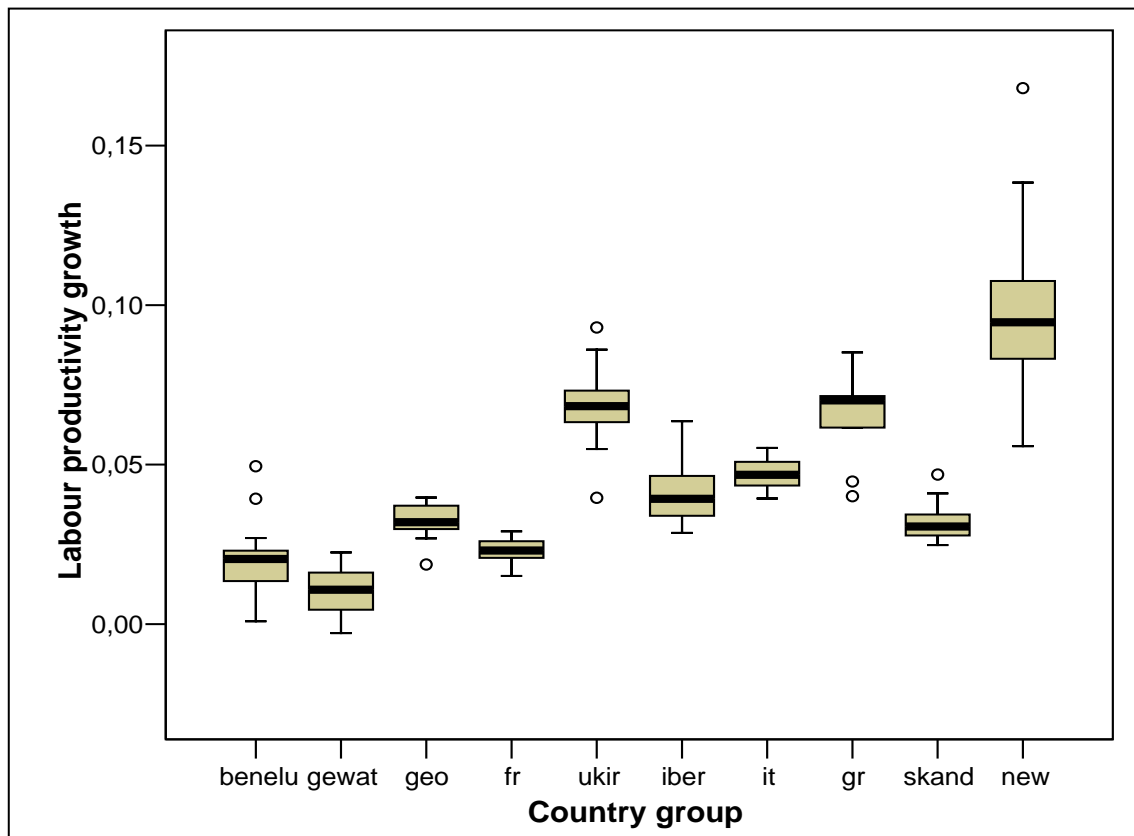
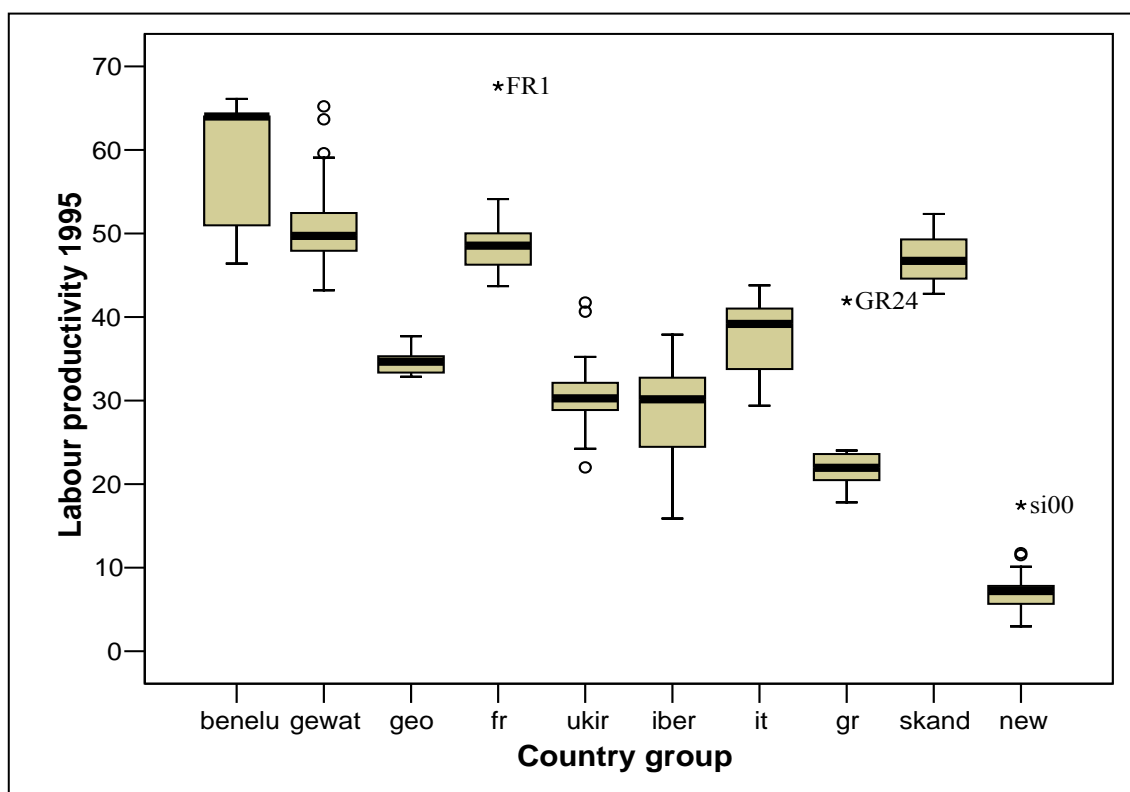


Fig. 2 contains the initial values of labour productivity in the EU (in 1,000 € per employee). Note that there is quite a high variation between the country groups. The lowest initial values are found in the New Member States, which show the highest growth rates. Contrariwise, these analyses show that regions with the highest initial values are located in countries, which have only small growth rates. However, this is only a small hint of convergence. The box plots reveal six extreme values and three outliers. The outliers are located around Paris ("fr10"), in the centre of Greece ("gr24") as well as in the former Yugoslavian Republic (Slovenia or "si00").<sup>6</sup>

<sup>6</sup> Outliers are especially a problem of growth regression, if researchers work with small datasets (s. Durlauf/Johnson/Temple 2005, p. 640). So this problem is of minor importance for our record including 233 regions. However, we estimate control calculations excluding the outliers, which show a very small effect on the regression coefficients.

Fig. 2: Box plots of initial labour productivity



## 5. Estimation of convergence

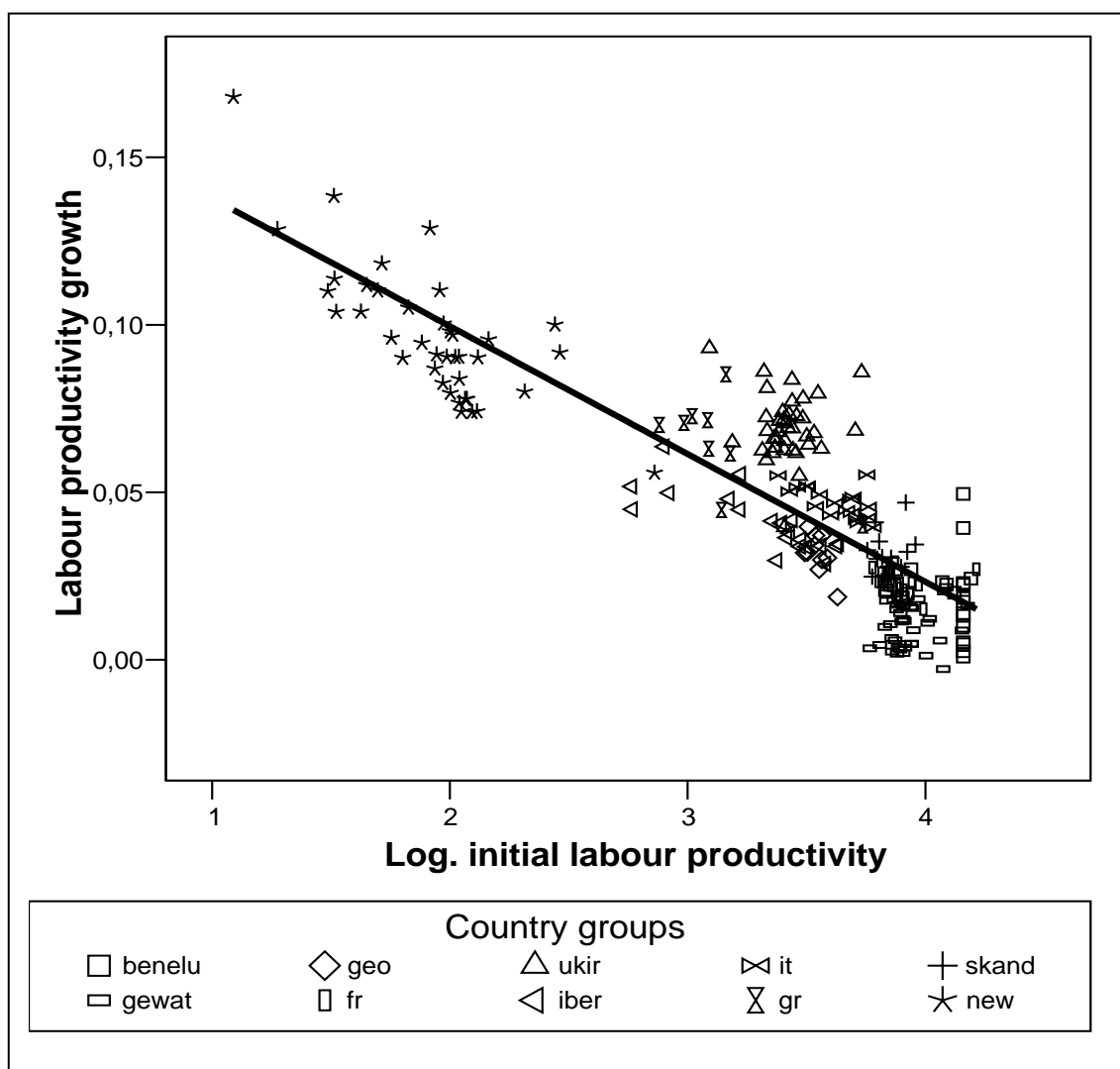
### 5.1 Basic model

In a first step we examine the absolute convergence model [cf. formula (12)]. It is important to test, if the association between the variables is linear. Note that some studies show no clear relationship between both variables (Durlauf/Johnson/Temple 2005). If the assumption of linearity is violated, the regression line would not fit to the data.

Fig. 3 plots the logarithm of the initial labour productivity against the average labour productivity growth. This scatterplot supports the hypothesis of the expected negative relationship between both variables. If labour productivity in the base year 1995 rises, then the average labour productivity growth has a tendency to decrease and vice versa. The negative approximately linear relationship implies that the OLS regression line slopes down.

We use different markers to identify the points of the country groups. From Fig. 3 follows that the values in the scatterplot are clustered by these groups. The lowest initial values and the highest growth rates are found in the New Member States. These points are located in the left upper corner of the diagram. The points portraying the United Kingdom and Ireland are positioned in the middle of the scatterplot. The highest initial values and the lowest growth rates belong to Germany and Austria ("gewat") as well as the Low Countries ("benelu").

Fig. 3: Scatterplot of the growth regression



However, it is necessary to test if the regression model is appropriate and if the regression coefficients are significant. Table 2 summarises the estimation results of this absolute convergence model. First, we calculate the OLS estimation. The global F-test shows that the explained fraction of the variance of the dependent is significant. Both regression coefficients have the expected sign, but the Moran coefficient proves autocorrelation. Thus, the regression coefficients are biased or the significance tests are invalid (s. Anselin 1988, pp. 57).

Note that the robust LM(error) test suggests calculating a spatial error model. One reason for the spatial dependence in the error term is the areal unit problem. Another reason might be that relevant variables are omitted. A spatial error autocorrelation in convergence studies of European regions is also detected by other researchers (s. for example Le Gallo/Dall'erba 2006).

Second, we calculate model (19). The results of the Maximum Likelihood (ML) estimation of the spatial error model are provided in the second column of Table 2. The significance of the likelihood ratio test shows that the spatial error model is fitted. The ratio between explained and total variance is 0.665. All three regression coefficients are significant at the 1% level. The spatial error parameter  $\gamma$  measures the effect of this

error or stochastic component. Note that the intercept and the slope in the OLS and the spatial error model are nearly the same. That indicates a robustness of the estimations.

The significant slope confirms the absolute convergence hypothesis. The regression coefficient for the initial labour productivity corresponds to a speed of convergence of

$$(34) \quad \lambda = \ln(1 - \hat{\beta}_1) = \ln[1 - (-0.036)] = \ln(1.036) = 0.035 [\hat{=} 3.5 \%$$

and a half life of

$$HL = \frac{-\ln(1/2)}{\lambda} = \frac{0.693}{0.035} = 19.8.$$

Therefore, it takes 19.8 years for the EU regions to reach half of the distance from its initial level to the steady state value.

This convergence speed of 3.5 % is quite high compared with the studies of the absolute convergence process in different countries. Barro and Sala-I-Martin (1990, 1991, 1992) for example find convergence rates around two per cent (s. also Durlauf/Johnson/Temple 2005, pp. 585 and Dobson/Ramlogan/Strobl 2006). The 2%-rate of convergence is also "discovered as a 'natural constant" (Abreu/de Groot/Florax 2005, p. 390). Researchers, who use regions from 15 European countries, usually detect absolute convergence rates in the 1990<sup>th</sup> even below two per cent (s. Yin/Zestos/Michelis 2003 and Cuadrado-Roura 2001 amongst others).

How can we explain the convergence rate of 3.5 %? We can state two reasons for this relatively fast convergence process: First, there is empirical evidence for a rising convergence speed of EU regions in comparison with the 1980s (cf. for example Niebuhr/Schlitte 2004, Geppert/Happich/Stephan 2005, Yin/Zestos/Michelis 2003 and Basile/de Nardis/Girardi 2005). If this trend has continued, then the results are plausible. Second, no other researcher has yet examined the convergence process of regions from 23 European countries. There is empirical evidence of different economic conditions of the New Member States compared with EU-15 (s. Dall'erba et al. 2005). Perhaps the high economic growth rates and low initial values cause the high convergence rates.

Table 2: Absolute convergence of labour productivity

	OLS estimation		ML estimation	
	Regression coefficient	t-value	Regression coefficient	z-value
const.	0.176**	35.928	0.169**	21.323
ln y <sub>95</sub>	-0.038**	- 27.044	- 0.036**	- 16.000
$\gamma$			0.692**	14.160
global tests	R <sup>2</sup> = 0.760; F = 731.400**; I = 0.643**; LM(error) = 57.319**; LM(lag) = 0.134		R <sup>*2</sup> = 0.665; L = 143.052**	

Notes: R<sup>2</sup>: coefficient of determination; R<sup>\*2</sup>: pseudo coefficient of determination; F: empirical F-value; I: empirical value of the Moran's I statistics; L: empirical value of the likelihood ratio test; LM(error): empirical value of the robust LM(error) test; LM(lag): empirical value of the robust LM(lag) test; \*\*: significant at the 1 % level; \*: significant at the 5 % level; (\*): significant at the 10 % level



Second, differences in the convergence process between European countries are well documented (cf. Cuadrado-Roura 2001 and Bräuning/Niebuhr 2005 et al.). National borders still have an effect on the initial conditions of regions (s. also Fig. 3). This "national effect" is included, if we estimate model (15). The Moran coefficient is highly significant, but the robust test of a spatial lag and a spatial error model are not significant at the 5 % level. Thus, there is a spatial autocorrelation in equation (15), which can not be treated with a spatial dependency in the dependent variable or in the error term.

Table 3 shows that the coefficient of determination is quite high. All dummy variables are significant and have a positive value. The regression coefficients must be referred to the omitted dummy variable of Germany and Austria ("gewat"). The remaining countries have significantly higher growth rate than Germany and Austria. The slope is nearly the same as in the models of Table 2. However, the results should be considered carefully because of the significant Moran coefficient.

Table 3: Conditional convergence of labour productivity

	Regression coefficient	t-value
const.	0.149**	11.136
ln y <sub>95</sub>	-0.035**	-10.422
benelu	0.014**	5.768
geo	0.008*	2.264
fr	0.011**	4.505
ukir	0.041**	15.134
iber	0.009**	2.721
it	0.026**	9.286
gr	0.026**	6.067
skand	0.019**	6.359
new	0.016*	2.283
global tests	R <sup>2</sup> = 0.919; F = 252.742**; I = 0.080**; LM(error) = 0.030; LM(lag) = 3.632(*)	

Notes: R<sup>2</sup>: coefficient of determination; F: empirical F-value; I: empirical value of the Moran's I statistics; LM(error): empirical value of the robust LM(error) test; LM(lag): empirical value of the robust LM(lag) test; \*\*: significant at the 1 % level; \*: significant at the 5 % level; (\*): significant at the 10 % level

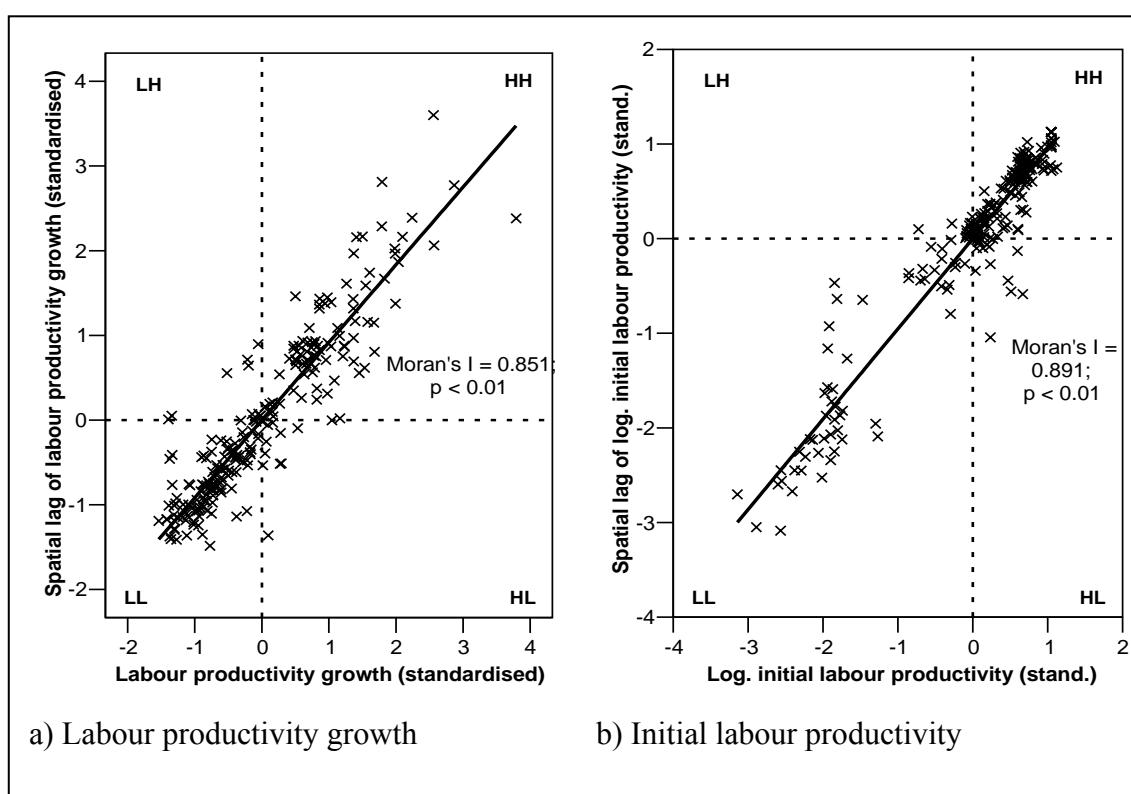
## 5.2 Spatial filtering approach

Another possibility to deal with spatial autocorrelation is to involve a spatial filtering procedure. We use the Moran coefficient to test the metric variables of spatial autocorrelation. The Moran coefficient is equal to the slope of the regression, where y is regressed on the spatial lag of this variable  $\mathbf{W}y$ . The Moran coefficient reveals a significant autocorrelation of both basic variables – labour productivity growth and logarithm of initial labour productivity (s. Fig. 4).

The spatial dependency is often visualised in a Moran scatterplot (Anselin 1995; Anselin 1996 and Dall'erba 2005). From Fig. 4 it follows that the regions are

characterised by positive spatial association between the labour productivity growth and the spatial lag of this variable. The same can be said of the logarithm of initial labour productivity. If the basic variable has below (above) average values, the spatial lag is mostly below (above) average as well. So, regions are usually localised in the quadrants LL or HH (H stands for high values and L for low values). If the basic variable is high, the average of the variable from the neighbouring regions takes mostly a great value, too. Only 9.9 % (14.1 %) of the regions lay in the quadrant HL or LH of Fig. 4 a (Fig. 4 b) and show an atypical spatial association. However, there are no observations which have a Cook's distance above 1 with a high influence on the regression analyses.

Fig. 4: Moran scatterplots and regression lines

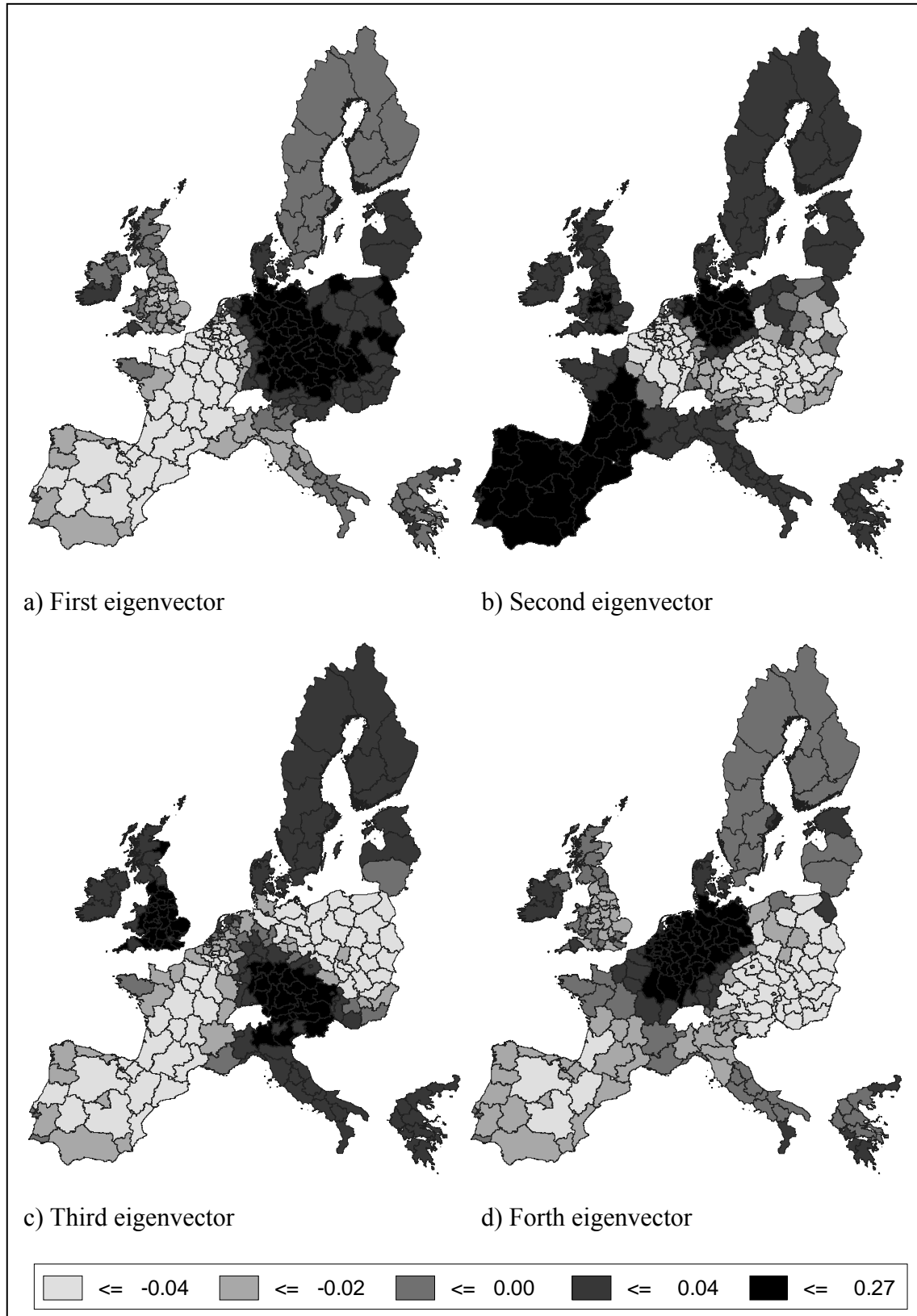


Because the initial labour productivity and the labour productivity growth are spatially autocorrelated (cf. Fig. 4), we have to filter both variables using equations (25) and (26). All 233 eigenvectors of the matrix  $C$  are extracted using Mathematica. The Moran coefficient of most eigenvectors has a positive sign. However, a few eigenvectors are assigned to a negative coefficient. That indicates a negative association, which can not be interpreted as spillover effects. The main reason for a negative spatial association is the areal unit problem. Openshaw and Taylor (1979, p. 142) showed many years ago that the definition of borders has an influence on spatial analyses. Recently, Keilbach (2000, pp. 120) has provided evidence that the use of administrative units can lead to a spatial autocorrelation. Note that Griffith (2003, pp. 58) has found some eigenvectors of regions in Puerto Rico, which are negatively autocorrelated.

The spatial structure of the first four eigenvectors, which have an extreme positive autocorrelation, is given in Fig. 5. The values of the eigenvectors increase with increasing darkness of the grey tone. All vectors show a clear structure. The maximum of the first and the fourth eigenvectors display a peak in German and Polish regions. The greater the distance to that peak, the weaker the values are. By contrast, the third

eigenvector has two centres with high values, located in the south of Germany, in Austria and in the north of Italy as well as in England. The three peaks of the second eigenvector can be found in the Iberian Peninsula, in Germany and around London.

Fig. 5: Spatial structure of the first four eigenvectors



Note that 172 eigenvectors fulfil inequality (28). They are candidates for the spatial filtering procedure. First, we have to filter the initial labour productivity and in a second step the labour productivity growth. The results of the filtering procedure of initial labour productivity are reported in Table 6 in the appendix. 39 eigenvectors are significant, and the stepwise procedure includes them in the regression equation. The residual vector of this estimation contains the values of the initial labour productivity without spatial components.

The estimation of formula (26) using stepwise regression is given in the first column of Table 4. The coefficient of determination shows a high share of explained variance. This result is confirmed by the F-test, which is highly significant. The inclusion of several eigenvectors and the filtering of initial labour productivity eliminate the spatial dependency in the error term. Therefore, the model is unbiased and the significant tests can be interpreted.

Table 4: Absolute convergence of labour productivity

	Model without dummies		Model with dummies	
	Regression coefficient	t value	Regression coefficient	t value
const.	0.046**	79.842	0.011**	8.406
( $\ln y_{1995,i}$ )*	-0.030**	-10.355	0.008**	3.232
benelu			0.013**	5.568
geo			0.021**	6.398
fr			0.007**	2.785
ukir			0.061**	31.833
iber			0.038**	15.697
it			0.029**	10.945
gr			0.052**	17.264
finse			0.019**	7.010
new			0.085**	47.797
significant eigenvectors	E2,E4,E7,E122,E22,E1,E150,E20,E17,E6,E38,E85,E28,E132,E16,E130,E113,E111,E134,E15,E21,E128,E42,E25,E91,E5,E27,E172,E44,E53,E166,E147,E137,E9,E14,E49,E68,E74,E84,E13,E29,E88,E23,E32,E139,E131		E9,E6,E122,E172,E12,E48,E166,E15,E182,E16,E150,E38,E68,E24,E132,E11,E97,E154,E74,E85,E131,E164,E130,E137,E128,E142,E169,E8,E21,E151,E36,E123,E43,E88,E19,E73,E89,E52	
global tests	$R^2 = 0.939$ ; $F = 60.378^{**}$ ; $I = -0.092$		$R^2 = 0.958$ ; $F = 87.753^{**}$ ; $I = -0.045$	

Notes:  $R^2$ : coefficient of determination; F: empirical F-value; I: empirical value of the Moran's I statistics; \*\*: significant at the 1 % level; \*: significant at the 5 % level; (\*): significant at the 10 % level

The estimation returns regression coefficients, which are both significant different from zero. The negative value of the slope confirms the convergence hypothesis. The speed of convergence

$$\lambda = \ln(1 - \hat{\beta}_1) = \ln[1 - (-0.030)] = \ln(1.030) = 0.030 [\hat{=} 3.0 \%$$

is only a bit slower than in the spatial error model (cf. second column of Table 2). That result underlines the stability of the absolute convergence process, which is proved using different examining methods.

However, we must consider the different initial conditions of the countries, especially of the New EU Member States (s. Dall'erba, S. et al. 2005). If we include the country specific dummy variables and substantial eigenvector, then the coefficient of determination and the F-tests show a better fit. The Moran coefficient underlines that the spatial filtering is successful. No spatial dependency is detected. The positive regression coefficients of the dummy variables show that Germany and Austria have the weakest growth rates. Especially the New Member States show a positive economic development.

However, the slope is significant, but no convergence process is proved. If we consider the different economic conditions of the EU countries (within country convergence), we can not find a convergence process. Instead EU regions seem to diverge at the rate of

$$\lambda = \ln(1 - \hat{\beta}_1) = \ln[1 - 0.008] = \ln(0.992) = -0.008 [\hat{=} -0.8 \%].$$

A divergent development of conditional convergence is detected by some researchers (s Durlauf/Johnson/Temple 2005 and Baumol 1986), if the examined regions are relatively homogenous (cf. Abreu/de Groot/Florax 2005, p. 395). The EU regions are, compared with world wide studies, quite equal. But there is no proof of divergence of European regions in other studies, if the initial labour productivity and country specific dummy variables are used as regressors.

The reason for the contradictory result compared with the estimation of section 5.1 must be a measurement artefact. Perhaps the intracountry differences of initial economic conditions are too high to find convergence. Thus, we must include the special conditions of every region using a GWR approach.

### 5.3 GWR estimation

Note that there is empirical evidence of an economic gap between well developed urban centres and rural areas, which is widening (Kramar 2006). If there are regional disparities, we have to calculate spatially varying convergence rates. We estimate such models using the geographically weighted regression (GWR) adopting the Gaussian weighting function and the Akaike Information Criterion (AIC) to calibrate the parameters. The tests and the basic descriptive statistics are given in Table 5.

Table 5: Absolute convergence of the labour productivity

Coefficient	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Global OLS
$\hat{\beta}_{0i}$ or $\hat{\beta}_0$	-0.276	0.105	0.168	0.182	0.456	0.176**
$\hat{\beta}_{1i}$ or $\hat{\beta}_1$	-0.118	-0.042	-0.037	-0.018	0.081	-0.038**
$R_i^2$ or $R^2$	0.103	0.424	0.726	0.888	0.999	0.760**
AIC = -1269; Bandwidth = 1.482; Global test of nonstationarity: F = 9.762**						

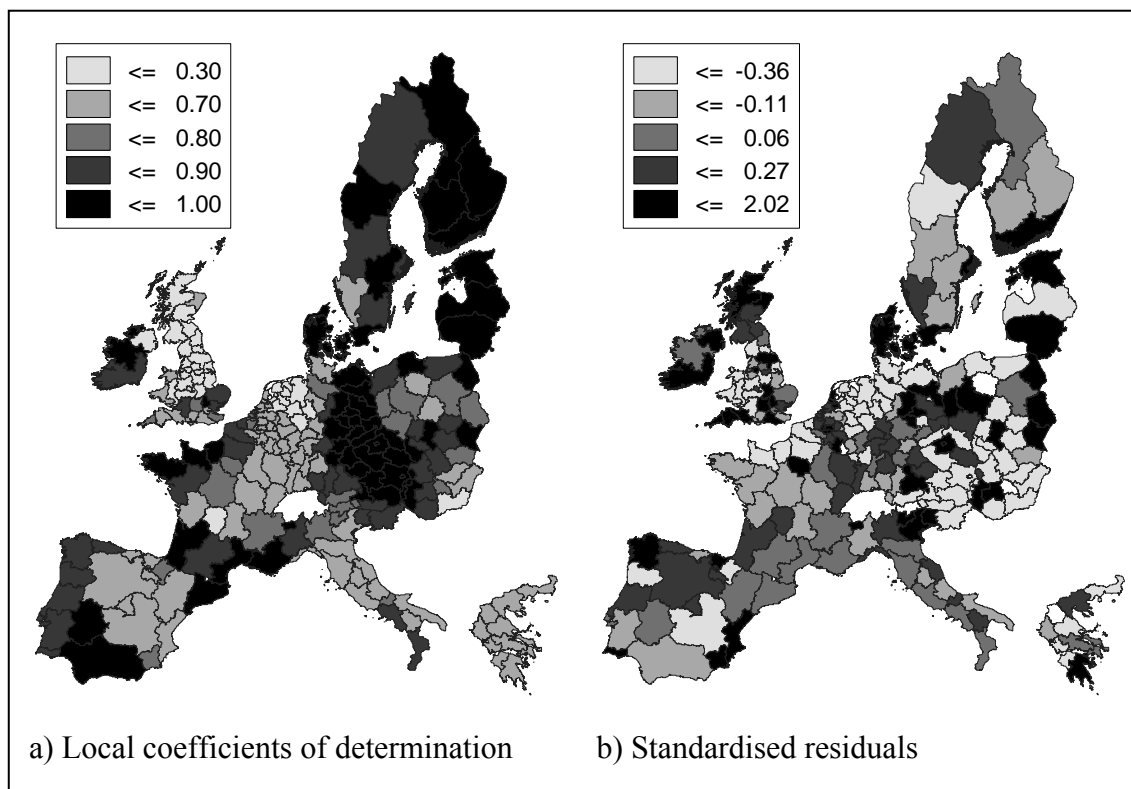
Notes:  $R^2$ : coefficient of determination;  $R_i^2$ : local coefficient of determination; F: empirical F-value; \*\*: significant at the 1 % level; \*: significant at the 5 % level; (\*): significant at the 10 % level

Let us make some general considerations on the validity of the GWR model. The F-Test of instationarity of both regression coefficients together is highly significant. The local

coefficient of determination proves the model fit for every region. The proportion of explained variation is only in some British and German regions below 30 %. In more than 75 % of the regions we have a local coefficient of determination, which is higher than 0.424. In particular, the estimation in the New Member States as well as in Scandinavia has a high explanatory power (s. Fig. 5a).

Outliers are a key issue of the GWR approach, because they have a high influence on the calibration procedure. We use the standardised residuals to detect outliers (s. Fig. 5b). Because no absolute value of the standardised residuals exceeds the threshold value of 3 (s. Fotheringham/Brunsdon/Charlton 2000, pp. 73), we do not have to remove any observation from the analysis.

Fig. 6: Fit of the GWR model



However, there are tests of instationarity for every regression coefficient as well. A Monte Carlo simulation procedure suggests estimating locally different intercepts as well as regionally varying slopes. The test is significant at the 1 % level for both regression coefficients.

The intercept covers the range between -0.276 and 0.456 (cf. Table 5). So there are different values of the initial level of technology and/or of growth rates of technological progress in European regions. The slope has a negative sign in most regions, which indicates a convergence process. Note that the speed of convergence varies between

$$\lambda_{\min} = \ln(1 - \hat{\beta}_{1,\max}) = \ln(1 - 0.081) = \ln(0.919) = -0.084 [\hat{=} -8.4 \%$$

and

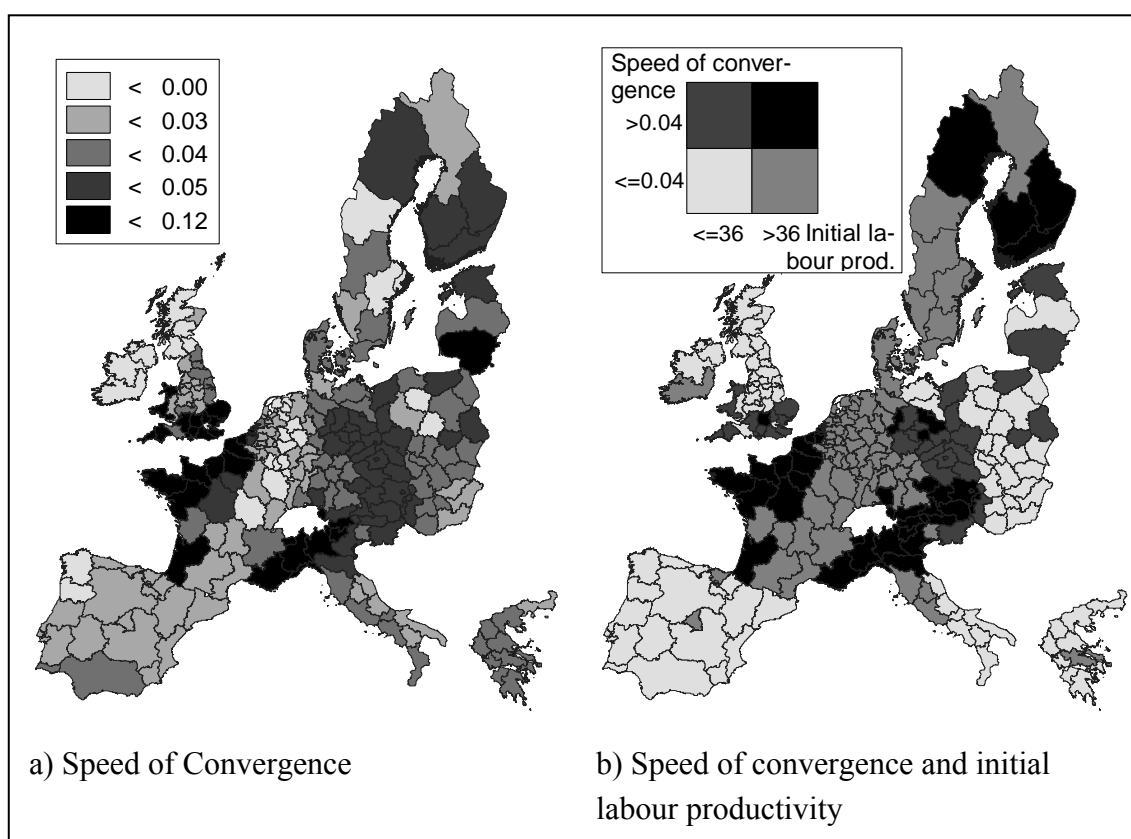
$$\lambda_{\max} = \ln(1 - \hat{\beta}_{1,\min}) = \ln[1 - (-0.118)] = \ln(1.118) = 0.112 [\hat{=} 11.2 \%].$$

The convergence speed of 28 regions shows a negative value. The diverging regions are not located in a special area. Instead they are distributed all over the EU, for example in

Ireland, Belgium, The Netherlands, United Kingdom, Germany and Poland (s. Fig. 7a). These regions move away from their steady state value of labour productivity. However, a divergence process using GWR is detected for some German regions using an extended Solow-Swan model with human capital (Eckey/Kosfeld/Türk 2005b).

The highest convergence rates are found in some French and British regions at the English Channel, Latvia as well as in northern Italian regions. Although the New Member States have the highest growth rates, they seem to have a great distance to their steady state values. Nevertheless, together with the regions of the Iberian Peninsula, Greece and south Italy they have the lowest initial values (cf. Fig. 7b).

Fig. 7: Speed of Convergence



However, the contradictory convergence results using the conditional convergence model seems to be a statistical artefact that arises for instationarity reasons. The instationary convergence rates can explain these different values of  $\lambda$  found in section 5.1 and 5.2. Some regions are converging and others not. Thus, the stationary analyses with country specific dummy variables are not stable.

## 6. Conclusion

There are many studies dealing with the issue of convergence in the EU. In most articles a small convergence rate is proved (s. section 1). However, no researcher has examined the EU convergence process including the New Member States. We use a basic neoclassical model of Barro and Sala-i-Martin (1990, 1991) to study convergence of 23 European regions. We exclude Malta and Cyprus from the analysis because of statistical reasons (s. footnote <sup>1</sup>).

We find absolute convergence using a spatial error model and a spatial filtering approach. However, the convergence rates are quite high. If we add country specific dummy variables to take into account the different initial conditions of Member States, the results are contradictory. The OLS estimation suggests a slow convergent and the spatial filtering approach a divergent development.

This measurement artefact can be explained by the results of the geographically weighted regression (GWR) approach. These findings suggest that there is no unit convergence rate all over Europe. We detect even considerably different half lives of regions from one Member State. Although most areas are converging, we find some regions, which will not achieve their steady state value. These diverging regions are spread all over the EU. They are the key reason for the contradictory results mentioned above.

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## Appendix

Table 6: Spatial filtering of initial labour productivity (stepwise regression)

	Regression coefficient	t-value
const.	3.392**	228.664
E2	6.079**	26.848
E1	-3.443**	-15.207
E5	3.431**	15.154
E4	-3.415**	-15.081
E7	3.229**	14.259
E132	1.977**	8.730
E22	1.599**	7.064
E150	1.579**	6.976
E122	1.325**	5.854
E21	1.234**	5.449
E28	-1.194**	-5.273
E17	-1.175**	-5.191
E20	1.169**	5.164
E38	1.160**	5.122
E85	-1.144**	-5.051
E44	-1.017**	-4.494
E3	1.010**	4.462
E15	-0.982**	-4.338
E111	0.931**	4.113
E53	0.888**	3.923
E130	0.841**	3.716
E134	-0.821**	-3.624
E137	0.812**	3.585
E42	0.798**	3.522
E27	-0.752**	-3.323
E16	-0.749**	-3.310
E18	-0.729**	-3.218
E25	0.708**	3.128
E113	0.680**	3.003
E125	-0.645**	-2.850
E36	0.607**	2.682
E49	-0.577*	-2.549
E128	-0.551*	-2.432
E147	0.537*	2.370
E14	-0.517*	-2.285

	Regression coefficient	t-value
E155	-0.491*	-2.167
E166	0.490*	2.163
E8	-0.470*	-2.074
E31	-0.450*	-1.986
global tests	$R^2 = 0.921$ ; $F = 57.312^{**}$	

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

Table 7: Absolute convergence model with spatial filtering (stepwise regression)

	Regression coefficient	t-value
const.	0.046**	79.842
$(\ln y_{1995,i})^*$	-0.030**	-10.355
E2	-0.273**	-30.741
E4	0.225**	25.283
E7	-0.112**	-12.621
E122	-0.087**	-9.843
E22	-0.084**	-9.447
E1	0.072**	8.137
E150	-0.064**	-7.192
E20	-0.062**	-7.024
E17	0.058**	6.571
E6	-0.057**	-6.384
E38	-0.056**	-6.338
E85	0.054**	6.081
E28	0.052**	5.800
E132	-0.051**	-5.780
E16	0.051**	5.687
E130	-0.049**	-5.537
E113	-0.045**	-5.061
E111	-0.045**	-5.017
E134	0.044**	4.926
E15	0.043**	4.846
E21	-0.038**	-4.293
E128	0.036**	4.014
E42	-0.035**	-3.971
E25	-0.033**	-3.751
E91	0.033**	3.742
E5	-0.033**	-3.678
E27	0.032**	3.631

	Regression coefficient	t-value
E172	-0.030**	-3.369
E44	0.029**	3.287
E53	-0.028**	-3.178
E166	-0.027**	-3.075
E147	-0.027**	-3.040
E137	-0.027**	-2.999
E9	-0.025**	-2.785
E14	0.024**	2.717
E49	0.022*	2.524
E68	-0.022*	-2.494
E74	0.021*	2.381
E84	0.021*	2.322
E13	-0.020*	-2.307
E29	0.020*	2.243
E88	-0.020*	-2.265
E23	-0.019*	-2.157
E32	0.019*	2.127
E139	2.047*	0.018
E131	1.991*	0.018
global tests	$R^2 = 0.939$ ; $F = 60.378^{**}$ ; $I = -0.092$	

Notes:  $R^2$ : coefficient of determination; F: empirical F-value; I: empirical value of the Moran's I statistics; \*\*: significant at the 1 % level; \*: significant at the 5 % level; (\*): significant at the 10 % level

Table 8: Conditional convergence model with spatial filtering (stepwise regression)

	Regression coefficient	t-value
const.	0.011**	8.406
$(\ln y_{1995,i})^*$	0.008**	3.232
benelu	0.013**	5.568
geo	0.021**	6.398
fr	0.007**	2.785
uk_ir	0.061**	31.833
iber	0.038**	15.697
it	0.029**	10.945
gr	0.052**	17.264
skand	0.019**	7.010
new	0.085**	47.797
E9	-0.051**	-5.610
E6	-0.056**	-5.042
E122	-0.031**	-4.050



	Regression coefficient	t-value
E172	-0.030**	-4.030
E12	-0.025**	-2.957
E48	0.025**	3.299
E166	-0.026**	-3.456
E15	0.026**	3.343
E182	-0.022**	-2.963
E16	0.027**	3.548
E150	-0.024**	-3.221
E38	-0.025**	-3.279
E68	-0.021**	-2.808
E24	-0.027**	-2.951
E132	-0.022**	-2.940
E11	-0.021**	-2.809
E97	0.019**	2.518
E154	0.021**	2.816
E74	0.018**	2.453
E85	0.021**	2.769
E131	0.019*	2.565
E164	0.019*	2.553
E130	-0.018*	-2.417
E137	-0.018*	-2.436
E128	0.017*	2.362
E142	0.020*	2.719
E169	0.017*	2.333
E8	0.029*	2.567
E21	-0.017*	-2.249
E151	0.018*	2.363
E36	0.016*	2.181
E123	-0.016*	-2.149
E43	0.016*	2.111
E88	-0.015*	-2.093
E19	-0.016*	-2.066
E73	0.015*	2.053
E89	0.015*	2.008
E52	0.015*	1.980
global tests	$R^2 = 0.958$ ; $F = 87.753^{**}$ ; $I = -0.045$	

Notes:  $R^2$ : coefficient of determination; F: empirical F-value; I: empirical value of the Moran's I statistics; \*\*: significant at the 1 % level; \*: significant at the 5 % level; (\*): significant at the 10 % level

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