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## Regional Convergence and Divergence Tendencies in Europe: Concepts and Recent Developments

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# **Regional Convergence and Divergence Tendencies in Europe: Concepts and Recent Developments**

**Sascha Sardadvar** \* \*\*

## **Abstract**

Recent empirical studies on regional economic growth have extended regressions on convergence to account for externalities and spatial dependencies. Most of these studies, however, set the focus on whether regional output levels display convergence trends and consequently tend to ignore persisting or widening disparities that may occur at the same time. This paper examines the simultaneous occurrence of regional convergence and divergence tendencies in Europe by applying a spatial econometric model specification that is derived from a neoclassical growth model. Depending on factor endowments and relative locations in space, divergence may occur within sub-groups of regions despite an overall observation of convergence. The observation area comprises 253 European regions of the EU and EFTA on the NUTS2 and equivalent level, with empirical results provided for an observation period from 2001 to 2007.

JEL classification: C31; C49; F43

Keywords: Regional Economic Growth; Neoclassical Growth Model; Spatial Econometrics

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# 1 Introduction

Economic growth and related issues continue to be heavily debated by both economists and politicians. It is difficult to overestimate the topic's relevance when considering the social and political consequences of income disparities, which are nothing else than the result of different growth rates. In the wake of influential papers by Baumol (1986) and Barro and Sala-i-Martin (1992), the issue of whether different economies converge to each other in terms of output has motivated a large number of studies, supported by the improved availability of required data: The 1990s and 2000s saw numerous studies for a wide range of samples, some of which focussed on regional economies (for an overview of the latter see Magrini, 2004). Recent contributions to the study of convergence of output or income to identical levels take externalities and spatial dependencies into account, applying spatial econometric techniques to provide insights into the interdependence of economies (López-Bazo and Fingleton 2006). In summary, one may conclude that if specific variables that distinguish the economies are accounted for, the finding of faster growth of currently backward economies tends to be robust (Islam 2003).

Apart from theoretical and methodological issues concerning growth regressions as such (for a comprehensive discussion see Acemoglu, 2009), the incidence of persisting disparities or even divergence tendencies between regions is a source of discontent. Models of new economic geography show theoretically how disparities may arise and therefore provide some explanation for empirical observations: Despite an overall development of the EU's regions towards convergence on a global scale, when focussing on intra-state developments or different spatial aggregation levels, the picture changes. Some studies find mixed results or evidence on divergence (Cheshire and Magrini 2000), the emergence of club-convergence (Fischer and Stirböck 2006) or processes of polarisation, where small groups of already wealthy regions shift further away from the rest (Fischer and Stumpner 2007), which has led some authors to question the concept of convergence in the first place (Keilbach 2000).

As noted by Magrini (2004), the traditional neoclassical model of growth which sets the basis for most growth regressions was developed as a model of closed economies. He criticises that the application of “virtually the same empirical methods originally developed to analyse convergence across nations ... have been used to examine the existence of

convergence processes at a sub-national level.” Bearing in mind that nations and regions are far from representing interchangeable concepts, the regional convergence approach should be rethought. Due to the fact that regions are naturally open, he argues for an explicit treatment of spatial interaction effects (Magrini 2004, p. 2779). So far only a handful of attempts have been carried out to introduce spatial dependence into a neoclassical growth model, among them notable contributions by Vayá et al. (2004) and Ertur and Koch (2007).

This paper is intended to firstly provide an overview of political and empirical concepts of convergence, and secondly to address both theoretical and empirical considerations on how convergence and divergence may occur simultaneously. Moreover, it deals with the question why this notion is of particular relevance in the context of regional economies. In order to do so, the focus is set on spatial dependence in the context of regional growth, both theoretically and empirically. It is shown how a neoclassical growth model can be used to take spatial dependence into account and how this may lead to temporary divergence tendencies. An empirical specification of the model is then applied to test regional developments in Europe. Thus, it provides an update and extension of the results of Sardadvar (2009) by using recent data from 2001 to 2007, including all new continental member states of the European Union. It is shown how open economies may temporarily diverge from each other as a result of differing factor endowments and respective relative locations in space: In fact, despite evidence on convergence within the whole observation area, divergence has occurred especially within the European Union’s new member states.

The paper is organised as follows: Section 2 is dedicated to theoretical, political and methodological issues, with Section 2.1 briefly discussing the circumstances under which convergence can be expected and how the latter affects the European Union’s regional policies. Section 2.2 provides an overview of the basic growth regression and its most commonly applied spatial econometric extensions. Section 2.3 introduces a spatial growth model that allows for both convergence and divergence tendencies. Section 3 focuses on empirics, where Section 3.1 presenting the spatial econometric model specification and the appropriate empirical application. Section 3.2 discusses and interprets the results and explores recent developments in detail. Final remarks can be found in the Conclusions.

## 2 Regional Development

This section discusses and reviews theoretical, political and methodological issues regarding the convergence debate. In Section 2.1, theoretical thoughts and their impact on European structural policy are discussed, followed by a review of commonly applied econometric model specifications for empirical tests in Section 2.2. After that, the basic structure of a neoclassical growth model with spatially constrained factor migration is presented in Section 2.3.

### 2.1 Theoretical Thoughts and European Policy

During the past ten years, questions regarding the issue of regional convergence have been extensively studied and debated. The literature distinguishes various types of convergence, of which the most important are (i)  $\beta$ -convergence, which occurs if economies with currently lower output per labour unit tend to grow faster, (ii)  $\sigma$ -convergence, which occurs if the cross-sectional dispersion of output per labour unit declines over time, and (iii)  $\gamma$ -convergence, if changes in the rankings of output levels per labour unit occur (Ramajo et al. 2008). Convergence hypotheses are usually derived from neoclassical growth theory, which provides at least three reasons to expect convergence between economies (Romer 1996): Firstly, most models predict convergence to a balanced growth path, where convergence will occur in the case of temporary disparities in spite of similar long run growth paths. Secondly, neoclassical production functions assume marginal productivity of physical capital to decline with rising stocks of physical capital, inducing lower attractiveness to new investments and hence slower output growth for economies with currently high stocks; since output is an increasing function of physical capital, economies with currently low levels of output will attract investments and consequently grow faster. Thirdly, as output is also a function of technology, economies with improved access to technology will *ceteris paribus* perform better – therefore, if the diffusion of knowledge changes in favour of those currently exhibiting relatively low levels of output, these economies will grow faster.

Despite these expectations, standard neoclassical models do “not make the loose, and possibly wrong, statement that poor countries tend to grow faster than rich countries”

(Gandolfo 1997, p. 187). Nevertheless when considering regional economies, neoclassical economists such as López-Bazo (2003) or Barro and Sala-i-Martin (1995) point out that economically integrated regions that are part of a superordinate economy can be considered reasonably similar to expect convergence to identical output levels. This reasoning justifies tests for *absolute convergence* (unconditional convergence), which involves testing the hypothesis that poor economies tend to grow faster per capita than rich ones without conditioning on any characteristics of economies. In contrast, *conditional convergence* is a concept that allows for heterogeneity across economies, with the aim of testing the hypothesis that an economy grows faster the further it is from its own steady state. Therefore, when testing for conditional convergence, one may either hold variables constant that distinguish countries from each other, or group sets of countries that can be reasonably compared.

The concept of absolute convergence is of particular interest within the European Union. Convergence in the sense of higher growth rates for less developed regions represents an official objective of the EU as formulated in the 1980s by adding the title “Economic and Social Cohesion” to the EEC Treaty, declaring that it “shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions or islands, including rural areas” (*European Communities* 1987, Article 23). As a result, the financial framework of 1989 to 1993 experienced a relative and absolute increase of the funds provided for regional policy, with financial allocations to the Structural Funds reaching 20.5 billion ECUs in 1993 (price-level of 1993) (European Commission 2008, p. 9). Regional policy of the European Community has still grown in volume since then, where the current financial framework for 2007 to 2013 provides on average over 35 billion euros per year (price-level of 2004) (*European Council* 2006, Article 19) to “promote growth-enhancing conditions and factors leading to real Convergence for the least-developed Member States and regions” (*European Commission* 2006, p. 2, upper cases in the original), of which over 60 percent are destined for the twelve new member states and their regions.

In 1987, the internal market (nowadays referred to as *European Single Market*) was defined by the Single European Act as “an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured in accordance with the provisions of this Treaty” (*European Communities* 1987, Article 13, upper case in the original). It is worth mentioning that the convergence objective has been set out in the same

treaty. Seen through the lens of neoclassical growth theory, the conditions for convergence are eased by allowing capital and labour to settle where they expect advantageous conditions for their own benefits. On the other hand, although not made explicit in the Single European Act, it is commonly understood that the simultaneous strengthening of cohesion policy was intended to counterbalance negative effects that the completion of the internal market could have on some countries and regions. Such risks of “aggravated imbalances in the course of market liberalisation” were seen to be best alleviated by “adequate accompanying measures to speed up adjustments in structurally weak regions and countries” (*European Commission* 2008, p. 9).

The possibility of regional disparities emerging as an equilibrium outcome has gained some attention in recent years as new economic geography provides formal analyses of such processes. Models of new economic geography consider costs of spatial interactions and recognise how distance has an influence on the scope and type of both trade and factor migration. In addition, the possibility of clustering forces is considered, usually by assuming increasing returns to scale induced by agglomeration forces. A frequent result which is of particular interest in the context of European integration is spatial concentrations of economic activity as a consequence of lowered trade barriers. Models in the spirit of Paul Krugman’s (1991) core-periphery model explain various mechanisms of interrelated regions’ development, and show how interregional disparities may persist or even widen. However, models of new economic geography often become too complex to be analysed for more than two regions, and have so far been less successful in explaining prospects of growth and long-term development.

## **2.2 Empirical Specifications for Tests on Convergence**

The basic equation to test for absolute convergence has been suggested by Baumol (1986) and formally derived from the basic neoclassical growth model by Barro and Sala-i-Martin (1990) via a log-linearised approximation around the steady state. An empirical test of convergence based on a cross-sectional regression has the form

$$\frac{1}{t} \ln \left( \frac{q_{i,t}}{q_{i,0}} \right) = \alpha + \beta \ln q_{i,0} \quad (1)$$

where the left hand-side of the equation approximates output growth between points in time 0 and  $t$ ,  $q_i$  denotes output per labour unit of economy  $i$ ,  $\alpha$  is the intercept representing technological progress, and  $u_i$  is an error term capturing omitted variables.  $\beta$  is the critical coefficient which takes on negative values if convergence applies, implying that economies grow relatively slowly if their initial level of output is relatively high.

In the econometric specification of eq. (1) as derived from the Solow model with a Cobb-Douglas production function, the coefficients have the forms  $\alpha = g + [(1 - e^{-\tilde{\beta}t})/t] \ln q_0^*$  and  $\beta = (e^{-\tilde{\beta}t} - 1)/t$ , where  $q^*$  denotes steady state output per labour unit and  $g$  denotes technological progress; it follows that the speed of convergence can be derived as  $\tilde{\beta} = -\ln(1 + t\beta)/t$ . Eq. (1) can be extended to include additional explanatory variables:

$$\frac{1}{t} \ln \left( \frac{q_{i,t}}{q_{i,0}} \right) = \alpha + \beta_1 \ln q_{i,0} + \beta_2 x_1 + \beta_3 x_2 + \dots + u_i \quad (2)$$

where the  $x$ s capture other variables than initial output that are expected to determine the respective economies' steady states. Typical candidates are investments in physical and human capital, but also dummy variables (in the case of regions for instance their respective member states), industry structure, or estimates of available technology. The concept of  $\beta$ -convergence (see Section 2.1) is usually tested on a cross-sectional model, which is displayed in matrix form as

$$\mathbf{y} = \alpha \mathbf{1} + \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \quad (3)$$

where  $\mathbf{y}$  is an  $N \times 1$  vector of observations on the dependent variable of output growth for  $N$  economies,  $\mathbf{1}$  is an  $N \times 1$  vector of ones,  $\mathbf{X}$  is as an  $N \times p$  matrix of  $p$  explanatory variables (including initial output),  $\boldsymbol{\beta}$  is a  $p \times 1$  vector of regression coefficients and  $\mathbf{u}$  is a vector of independent and identically distributed (i.i.d.) errors with variance  $\sigma^2$ . Thus eq. (3) represents a specification for absolute convergence in the case where initial output is the only explanatory variable, whereas  $p > 1$  implies a test for conditional convergence.



In an influential paper by Le Gallo, Ertur and Baumont (2003), a comprehensive study of various possibilities to acknowledge for the role of space in growth regressions is provided. They suggest to use spatial econometric tools to improve on conventional growth regressions, arguing that this leads to more reliable estimates of the convergence rate by emphasising spillover effects in regional growth processes. In particular, they adapt the two most common spatial econometric model specifications, namely the *spatial lag model* and the *spatial error model*, in order to compare the results to those of conventional growth regressions as discussed above. A growth regression that applies the spatial lag model takes the form

$$\mathbf{y} = \rho \mathbf{W}\mathbf{y} + \alpha \mathbf{1} + \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \quad (4)$$

where  $\mathbf{W}$  is an  $N \times N$  spatial weight matrix that captures connectivity between the  $N$  economies, and  $\rho$  is a spatial dependence parameter.  $\mathbf{W}$  represents the basic concept in accounting for spatial dependence in empirical studies by capturing the neighbourhood of each spatial unit by non-zero elements: If two regions  $i$  and  $j$  are considered to be neighbours following a well-defined criterion, then  $w_{ij} = 1$ , else  $w_{ij} = 0$ . Note that  $\mathbf{W}$  is generally row standardised, in which case  $\sum_{j \neq i}^N w_{ij} = 1$  for each  $i$ , and the values of the spatially lagged variables  $\sum_{j \neq i}^N w_{ij} x_j$  equal the arithmetic mean for each  $i$ . Hence in eq. (4) the vector  $\mathbf{W}\mathbf{y}$  captures spatial lags of  $\mathbf{y}$ , and  $\mathbf{u}$  is a vector of i.i.d. errors with variance  $\sigma^2$ .

The second common spatial econometric model specification as applied by Le Gallo, Ertur and Baumont (2003) is usually referred to as the spatial error model and has the form

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad (5)$$

$$\boldsymbol{\varepsilon} = \rho \mathbf{W}\boldsymbol{\varepsilon} + \mathbf{u} \quad (6)$$

where eq. (6) can be expressed as  $\boldsymbol{\varepsilon} = (\mathbf{I}_N - \rho \mathbf{W})^{-1} \mathbf{u}$ , with  $\mathbf{I}_N$  being an  $N \times N$  identity matrix. The fact that in eqs. (5) and (6) spatial dependence is captured only via the errors leads to some dissatisfaction with results based on the spatial error models. Fingleton and López-Bazo (2006) point out that each spatial specification produces rather different interpretations and policy implications for the process of economic growth. According to this, studies of convergence in Europe have often ended up with a spatial error specification, despite the fact

that this indicates that spatial externalities are not substantive phenomena, but rather random shocks diffusing through space. LeSage and Fischer (2008) argue that the spatial error model can arise only if there are no omitted explanatory variables or if these are not correlated with included explanatory variables, which they consider as unlikely cases. They suggest applying the *spatial Durbin model* as “a natural choice over competing alternatives” (LeSage and Fischer 2008, p. 281), arguing that it nests most models used in the regional growth literature. The spatial Durbin model (common factor model) as an econometric specification includes both a spatially lagged dependent variable as well as spatially lagged explanatory variables and has the form:

$$\mathbf{y} = \rho \mathbf{W}\mathbf{y} + \alpha \mathbf{1} + \mathbf{X}\boldsymbol{\beta} + \mathbf{W}\mathbf{X}\boldsymbol{\chi} + \mathbf{u} \quad (7)$$

where  $\boldsymbol{\chi}$  is a  $p \times 1$  vector of regression coefficients, and  $\mathbf{W}\mathbf{X}$  captures the spatial lags of  $\mathbf{X}$ .

Le Gallo, Ertur and Baumont (2003) show how the inclusion of spatial dependencies improves the understanding of growth processes. Their study, however, lacks an underlying theoretical model. Despite recent advances in spatial econometrics and the implementation of spatial growth estimations, so far only a small number of authors has linked the acknowledged role of space to a neoclassical growth model: Vayá et al. (2004) consider a set of economies where spillover effects accelerate growth of the lesser developed, with all economies eventually arriving at identical steady-state levels of output. Ertur and Koch (2007) model a world economy by enhancing the standard neoclassical growth model (Solow model) for an economy’s relative location in space: Economies receive externalities from foreign economies that diminish with geographical distance, accelerating convergence of lagging behind economies as well as output growth of the whole world. A Taylor approximation of their model leads to a spatial Durbin model specification as in eq. (7). These two approaches demonstrate how the relative location in space may influence economic growth, but the focus remains primarily on the issue of convergence.

### 2.3 Convergence and Divergence in a Spatial Growth Model

A model that allows for temporary divergence between regional economies has been developed by Sardadvar (2009). Consider a neoclassical growth model in the spirit of Mankiw, Romer and Weil (1992) for a finite set of regional economies,  $i = 1, 2, \dots, N$ , over continuous time,  $t$ . Output per unit of effective labour  $q_{i,t}$  in each region  $i$  at time  $t$  is assumed to be produced via a Harrod-neutral Cobb-Douglas production function

$$q_{i,t} = k_{i,t}^a h_{i,t}^b \quad (8)$$

with the inputs physical capital per unit of effective labour  $k_{i,t}$  and human capital per unit of effective labour  $h_{i,t}$ ;  $a$  and  $b$  denote the factors' respective output elasticities. By assuming equally sized labour forces for each region and identical respective growth rates  $n$ , the differential equation modelling the evolution of the physical capital stock per unit of effective labour can be displayed as

$$\dot{k}_{i,t} = s_K \mu_t k_{i,t}^a h_{i,t}^b \prod_{j=1}^N \left( \frac{k_{i,t}^{a-1} h_{i,t}^b}{k_{j,t}^{a-1} h_{j,t}^b} \right)^{\lambda w_{ij}} - (n + g + d) k_{i,t} \quad (9)$$

where the dot over  $k$  denotes its derivation with respect to time, and the terms in parantheses equal marginal productivities of physical capital in all regions under consideration as derived from eq. (8).  $s_K$  is the saving rate of all regions,  $d$  is the rate of depreciation,  $\lambda$  is a measure of the degree of integration and  $\mu_t$  is a variable identical to all regions and defined in eq. (10) below. The connectivity term  $w_{ij}$  measures interdependence of two regions  $i$  and  $j$ ;  $w_{ij}$  takes on non-negative values if two respective regions  $i \neq j$  are considered to be neighbours. Furthermore the sum of all connectivity values for each region is standardised to equal one, so  $\sum_{j \neq i}^N w_{ij} = 1$ .

The  $N$  regional economies jointly form a superordinate economy which is assumed to be closed or equivalently to always run a balanced current account. Then the superordinate economy's net investment at  $t$  must equal the sum of all net investments of all regions at  $t$ , as captured by  $\mu_t$ :

$$\mu_t = \frac{\sum_{i=1}^N q_{i,t}}{\sum_{i=1}^N \left( q_{i,t} \prod_{j=1}^N \left( \frac{k_{i,t}^{a-1} h_{i,t}^b}{k_{j,t}^{a-1} h_{j,t}^b} \right)^{\lambda w_{ij}} \right)} > 0 \quad (10)$$

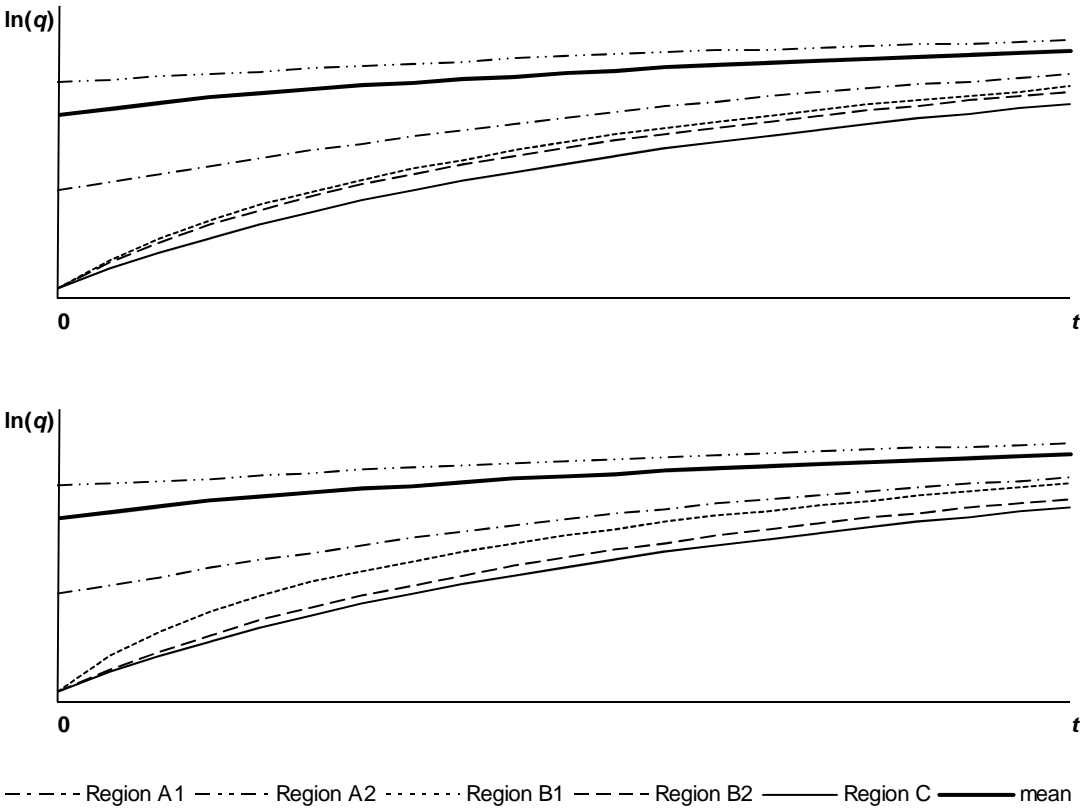
From eq. (10) it can be seen that  $\mu_t$  will always be greater than zero, since all terms and hence both the nominator and the denominator must be positive. Human capital in region  $i$  changes over time as given by the following equation:

$$\dot{h}_{i,t} = s_H q_{i,t} - (n + g + d) h_{i,t} \quad (11)$$

As before the dot over the variable denotes its derivation with respect to time, thus the evolution of human capital is determined by the fraction of output  $s_H$  invested in education, which is considered to be identical in all regions. All regions converge to identical steady states of factor endowments and output levels in the long run. However, the regions face different conditions concerning growth in the short run and medium run, that is, as long as  $h_{i,t}$  and  $k_{i,t}$  are different to their steady-state levels, and also in the case when they equal their steady-state levels but those of the other regions do not. Growth from one period to the next depends on a region's own current values of both types of capital, and those of the other regions according to the integration parameter  $\lambda$  and the connectivity term  $w_{ij}$ . For any  $w_{ij} = 0$ , the corresponding region is influenced indirectly in the next or subsequent periods since all regions are assumed to be indirectly connected to each other.

Figure 1 provides a closer look at the development of five regions in the medium run, derived from calibration of the model to a superordinate economy that consists of twelve regions. In the upper diagram, region A1 is highly developed, region A2 is below the mean of all regions (i.e. below output of the superordinate economy), and regions B1, B2 and C have identical very low initial levels of output. Both regions A1 and A2 are neighbours to other regions with relatively high levels of output which are not plotted in the graph. Furthermore, region A1 is a neighbour to B1, and region A2 is a neighbour to B2, while region C is not part of the superordinate economy and therefore stays on its own.

**Figure 1: Theoretically Derived Divergence Trends**



The upper graph shows how both A2 and B1 benefit from their wealthier neighbours and converge to the mean, while A1 continues to grow, but does so more slowly. We also observe that B2 benefits from being a neighbour to a neighbour of a wealthier neighbour compared to C, which starts with initial conditions but has no neighbours. Putting things together, we observe *convergence* on a global scale, but *divergence* within the regions B1, B2 and C.

The lower diagram of Figure 1 displays the same five regions starting with the same initial levels of output as in the upper diagram, but this time the initial factor endowments of B1 and B2 are different: B1 has a higher level of human capital, while B2 has a higher level of physical capital. Consequently, B1 attracts more investments and grows even faster than in the upper graph, and again we observe convergence on a global scale, but divergence within the regions B1, B2 and C for a considerable amount of time. Furthermore, the mean of all regions and therefore the output level of the superordinate economy is slightly higher in the lower graph for any  $t \neq 0$ .

### 3 Empirics

After having shown how convergence and divergence tendencies may occur at the same time, this section provides an appropriate econometric specification and empirical results. Section 3.1 presents the spatial econometric model specification and discusses data availability as well as the construction of appropriate spatial weight matrices. Section 3.2 provides results from the regression approach as well as from different measures of regional disparities, concluding that a focus on the issue of convergence versus divergence is too narrow to get the complete picture.

#### 3.1 Spatial Econometric Model Specification

A Taylor approximation of the model of Section 2.3 leads to a spatial econometric model specification of the form

$$\ln q_{i,t} - \ln q_{i,0} = \alpha + \beta_1 \ln q_{i,0} + \beta_2 \ln h_{i,0} + \chi_1 \sum_{j \neq i}^N w_{ij} \ln q_{j,0} + \chi_2 \sum_{j \neq i}^N w_{ij} \ln h_{j,0} + \rho \sum_{j \neq i}^N w_{ij} \ln \varepsilon_{j,0} \quad (12)$$

where technological progress has been reintroduced and is captured by  $\alpha = gt$ , where  $q_0$  and  $h_0$  are the initial levels of output per labour unit and human capital per labour unit, and  $\varepsilon$  is a measure of deviations from steady states. The coefficients are unambiguously either positive or negative, with  $\beta_1 = (-1 + e^{-\gamma t}) < 0$ ,  $\beta_2 = (1 - e^{-\gamma t})(\gamma_2 / \gamma_1) > 0$ ,  $\chi_1 = (1 - e^{-\gamma t}) > 0$ ,  $\chi_2 = -(1 - e^{-\gamma t})(\gamma_2 / \gamma_1) < 0$ , and in addition we have the unambiguously positive  $\rho = (-e^{-\gamma t})(1 / \gamma_1)$  and  $\varepsilon_i = -\gamma_1 \ln(q_i / q^*) + \gamma_2 \ln(h_i / h^*)$ .  $\gamma_1$  and  $\gamma_2$  result from the theoretical model which are both unambiguously positive, with  $\gamma_1 = (1 - (a + b) + \lambda(1 - a))(n + g + d) > 0$  and  $\gamma_2 = b\lambda(n + g + d) > 0$ .

Even though  $\gamma_1$  resembles the well-known speed of convergence as found in the specifications presented in the previous section, a reference to a speed of convergence would be misleading: Since the endowments with production factors at 0 both within region  $i$  and any region  $j$  enter eq. (12), divergence is possible. In particular, from the betas in eq. (12) it is expected that region  $i$ 's output growth will be negatively influenced by its own output level, positively influenced by its neighbours' output levels, positively influenced by its own

human capital endowments, and negatively influenced by its neighbours' human capital endowments. Rewritten in matrix form, eq. (12) can be expressed as

$$\mathbf{y} = \alpha\mathbf{1} + \mathbf{X}\boldsymbol{\beta} + \mathbf{W}\mathbf{X}\boldsymbol{\chi} + \boldsymbol{\varepsilon} \quad (13)$$

$$\boldsymbol{\varepsilon} = \rho\mathbf{W}\boldsymbol{\varepsilon} + \mathbf{u} \quad (14)$$

A specification like this it is reminiscent of the spatial Durbin model as displayed in eq. (7), as it includes a spatial lag of the explanatory variables as well as spatially dependent disturbances. Probably due to its reminiscence of the spatial Durbin model it is has been referred to as *spatial Durbin error model* (LeSage and Pace 2009), though it does not include a spatially lagged dependent variable. As noted in Section 2.2, the spatial Durbin model nests both the spatial lag model and the spatial error model, but this does not apply here. Furthermore, an estimation based on ordinary least squares is not efficient, which is why estimations are based on the maximum likelihood principle (Anselin 2001).

The observation period of this study is 2001 to 2007, and it relies solely on official data as provided by Eurostat<sup>1</sup>. Output is measured by gross regional product per economically active person, while human capital is estimated as the ratio of the number of persons with tertiary education to the number of economically active persons. Given that the economic entities under consideration either use the same currency or follow a regime of freely exchangeable currencies, and since the variables of interest are relative growth rates rather than growth rates as such, it does no harm to rely on nominal values. Therefore, output and output growth are measured in euros at current market prices. The observation area consists of the European Union's regions on the NUTS2<sup>2</sup> level, plus seven Norwegian regions and Switzerland. Islands that consist of only one region have been excluded, which makes a total of 253 regions (the complete list of regions is given in the Appendix).

The most conventional way to capture the neighbourhood relations in a spatial weight matrix is to define regions as neighbours if they share a common physical border, in which case  $w_{ij} > 0$ . In addition, results will be given for neighbour structure based on the concept of a set of  $\tilde{k}$ -nearest neighbours, where a region  $j$  is assigned to region  $i$  as a neighbour if its

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<sup>1</sup> as of March 31, 2010

<sup>2</sup> NUTS is short for *Nomenclature des Unités Territoriales Statistiques* and serves as the European Union's regional classification

distance is the  $\tilde{k}$  th order smallest distance between two regions  $i$  and  $j$ , so that each region has exactly  $\tilde{k}$  neighbours. This results in an asymmetric spatial weight matrix where each row has the same number of nonzero elements. To capture economic distance rather than geographic distance,  $\tilde{k}$ -nearest neighbours are based on road travel times by car between NUTS2 regions as calculated and provided by Schürmann and Talaat (2000). For each calculation the corresponding spatial weight matrix is row-standardised so that  $\sum_{j \neq i}^N w_{ij} = 1 \forall i$ . As discussed above, it follows from row standardisation that the elements of the vector  $\mathbf{WX}$  in the  $i$ th row correspond to the arithmetic mean of the variables' values in neighbouring regions for each  $i$ .

### 3.2 European Developments from 2001 to 2007

Estimation results by maximum likelihood for the spatial econometric specification as given in eqs. (13) and (14) can be found in Table 1 for five weight matrices. While the results in the most left-hand column refer to the matrix based on physical contiguity, the results in the other columns refer to weight matrices based on car travel times, and are given for 5, 6, 7 and 8 nearest neighbours. In all cases all coefficients are significant and have the expected signs, except for initial output in neighbouring regions, where the coefficient is not significant and slightly negative. The measures of the log-likelihood, the Akaike information criterion and the Schwarz information criterion all indicate that the matrix based on five nearest neighbours provides the better fit of the model. The Wald test is the square of the asymptotic standard error test and rejects the absence of spatial dependence in all cases.

We have a positive and highly significant constant and a positive and highly significant spatial autocorrelation coefficient in all cases. Furthermore, on a global scale there are strong indicators for convergence: The negative coefficient for initial output corresponds to the indicator for  $\beta$ -convergence as discussed in Section 2.2, which could be interpreted as a further indicator for convergence – regions with relatively low initial levels of output have grown faster. This, however, is not the complete story, as the negative influence of human capital in neighbouring regions acts as a counterweight: As shown by the theoretical model, the availability of human capital within one region has a positive effect on attractiveness to investments in physical capital, which in turn will raise output.



**Table 1: Regression Results**

	<b>Physical contiguity</b>	<b>5 nearest neighbours</b>	<b>6 nearest neighbours</b>	<b>7 nearest neighbours</b>	<b>8 nearest neighbours</b>
<b>Constant</b>	1.202 (0.000)	1.311 (0.000)	1.291 (0.000)	1.352 (0.000)	1.488 (0.000)
<b>Initial output</b>	-0.205 (0.000)	-0.218 (0.000)	-0.215 (0.000)	-0.201 (0.000)	-0.182 (0.000)
<b>Human capital</b>	0.081 (0.001)	0.120 (0.000)	0.111 (0.000)	0.099 (0.000)	0.088 (0.002)
<b>W initial output</b>	-0.016 (0.562)	-0.048 (0.169)	-0.038 (0.311)	-0.051 (0.198)	-0.066 (0.111)
<b>W human capital</b>	-0.131 (0.002)	-0.151 (0.006)	-0.152 (0.012)	-0.160 (0.014)	-0.197 (0.005)
<b>Spatial autocorr.</b>	0.649 (0.000)	0.732 (0.000)	0.728 (0.000)	0.739 (0.000)	0.760 (0.000)
<b>Residual variance</b>	0.0097	0.0090	0.0503	0.0105	0.0108
<b>LIK</b>	211.69	221.32	210.60	205.69	202.35
<b>AIC</b>	-409.36	-428.65	-406.12	-397.38	-390.69
<b>BP</b>	88.08 (0.000)	77.78 (0.000)	93.60 (0.000)	110.39 (0.000)	121.52 (0.000)
<b>Wald</b>	154.53 (0.000)	246.38 (0.000)	209.21 (0.000)	201.42 (0.000)	219.50 (0.000)

Notes: Calculations have been carried out with R using the `spdep` package by Bivand (2008); p-values are in parentheses; LIK and SIC refer to the values of the maximised log-likelihood and the Akaike information criterion, respectively (see Anselin 1988). BP is the spatially adjusted version of the Breusch-Pagan test for heteroskedasticity, using the squares of explanatory variables (see Anselin 1988); Wald is the square of the asymptotic standard error.

Table 2 displays trends for the whole observation area by applying four indicators, with results given for each year: The standard deviation of the natural logarithms of gross regional product per economically active person; the corresponding weighted standard deviation where the regional share of all economically active persons is taken as class frequency; the Gini coefficient of gross regional product per economically active person where again the regional share of all economically active persons is taken as class frequency; and the share of those regions which are or which contain capital cities (excluding regions that are identical to countries). The numbers of both unweighted as well as weighted standard deviation show a clear trend towards  $\sigma$ -convergence, as the former has fallen from 0.79 to 0.61, and the latter has fallen from 0.83 to 0.61. The Gini coefficient is in line with these results, having fallen from 0.29 to 0.25. Despite these clear trends, capital regions' share of total output has risen from 18.5% to 19.7%.

**Table 2: Convergence Trends within the Observation Area**

	2001	2002	2003	2004	2005	2006	2007
<b>Unweighted standard dev.</b>	0.787	0.764	0.746	0.725	0.679	0.652	0.614
<b>Weighted standard dev.</b>	0.832	0.793	0.765	0.742	0.683	0.648	0.606
<b>Gini coefficient</b>	0.288	0.284	0.278	0.274	0.266	0.259	0.250
<b>Share of capital regions</b>	0.185	0.188	0.189	0.190	0.194	0.194	0.197

Notes: Measures of weighted standard deviation and Gini coefficient treat relative sizes of economically active persons as class frequencies.

Let's set the focus on NUTS2 regions within countries as sub-samples. Now the same four indicators provide evidence of both convergence and divergence. Out of the 20 countries of the sample that contain at least two NUTS2 regions, unweighted standard deviation has risen in 12 countries<sup>3</sup>, weighted standard deviation has risen in 13 countries<sup>4</sup>, the Gini coefficient has risen in 11 countries<sup>5</sup>, and the capital region's share has risen in 13 countries<sup>6</sup>. Divergence tendencies are prevalent especially in the European Union's new member states: As can be seen from Figure 1, indicators of divergence point upwards in each country for almost each case. For instance, weighted standard deviation within Bulgaria has risen from 0.17 to 0.30, within Hungary it has risen from 0.29 to 0.34, within Slovakia it has risen from 0.27 to 0.33. These results indicate that a process of convergence – if there is one at all – by no means applies to any group of economies within a particular observation period.

In summary, the negative coefficient of human capital in neighbouring region serves as a potential answer to the question why divergence processes occur despite overall trends of convergence. Defined as consisting of the abilities, skills and knowledge of particular workers, human capital is rival and excludable and hence available only once at each time and place. Its existence in connection with spatially constrained capital mobility explains why

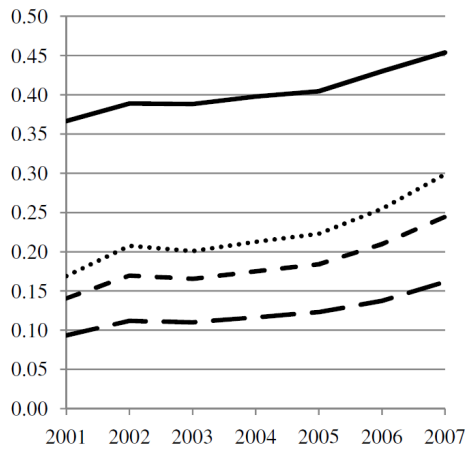
<sup>3</sup> Austria, Bulgaria, Czech Republic, Spain, France, Greece, Hungary, Ireland, Poland, Portugal, Slovakia, Sweden

<sup>4</sup> Austria, Bulgaria, Czech Republic, France, Greece, Hungary, Ireland, Poland, Portugal, Slovakia, Sweden, United Kingdom

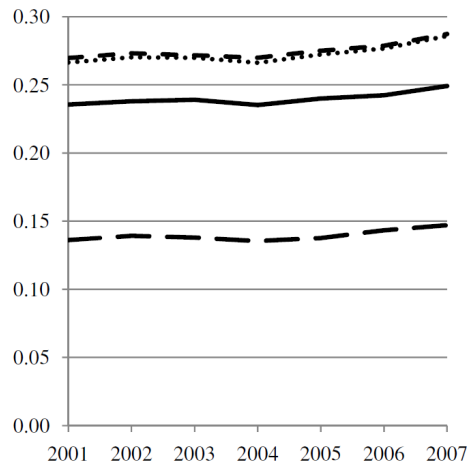
<sup>5</sup> Bulgaria, Czech Republic, France, Greece, Hungary, Ireland, Portugal, Slovakia, Sweden, United Kingdom

<sup>6</sup> Bulgaria, Czech Republic, France, Greece, Hungary, Ireland, Italy, Poland, Portugal, Slovakia, Sweden, United Kingdom

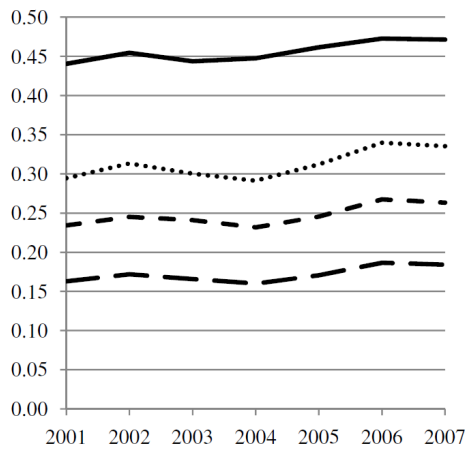
**Figure 2: Empirically Derived Divergence Trends**



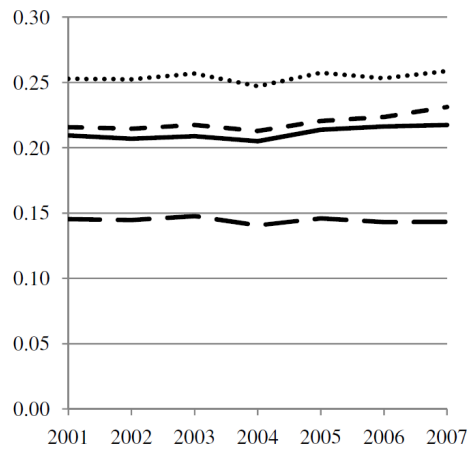
Bulgaria



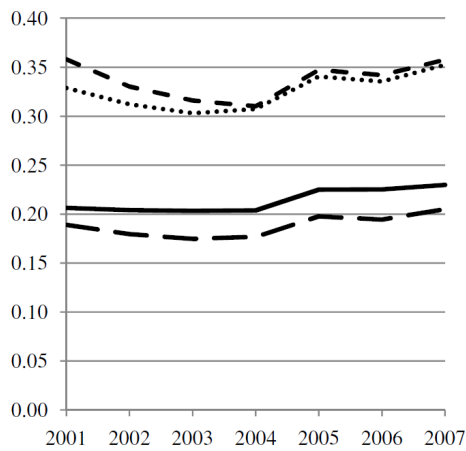
Czech Republic



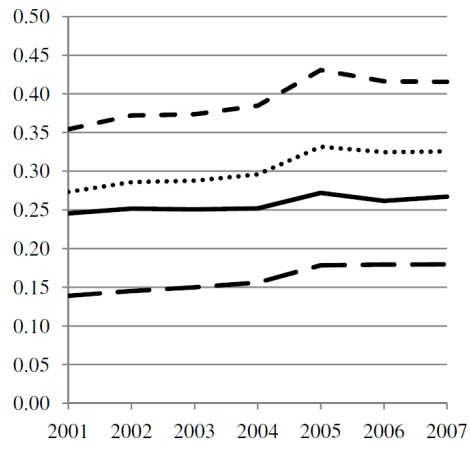
Hungary



Poland



Romania



Slovakia

— • unweighted standard deviation    ..... weighted standard deviation    - - - Gini coefficient    ——— share of capital region

investments do not flow immediately from highly productive European regions to less productive ones. Instead it may even widen disparities in cases where regions with high endowments with physical capital remain attractive to interregional investment decisions as long as their endowments with human capital are also high. Furthermore, one would also expect a higher attractiveness to migration decisions of carriers of human capital if a region is already highly endowed with human capital, either simply because such a region is wealthier in the first place and hence provides higher wages, or possibly because demand for human capital is higher due to the economic structure of such regions. As explained by Myrdal (1957) more than 50 years ago, if agglomeration effects are at work, these may even lead to an increasing inflow of both physical and human capital and hence to a widening gap of production levels.

## **Conclusions**

Unconditional convergence of economies with differing initial output levels is not what neoclassical growth theory predicts. However, useful results are provided by empirical tests on convergence. Such growth regressions usually lead to the conclusion that economies which are reasonably similar to each other converge to similar levels of output. In the context of regional economies the universal validity of such a conclusion has been challenged: Theoretically, models of new economic geography have shown how inequality may constitute an equilibrium outcome. Empirically, evidence can be found on the divergence of regional economies as parts of an superordinate economy, where the latter may be a national economy or an economic community such as the European Union. Recent years have seen growing interest in considering spatial dependencies within growth processes, both theoretically and empirically. These approaches provide new insights into questions of spatial dependencies and externalities, but still concentrate on the convergence issue.

In this paper it is shown that the simultaneous occurrence of convergence and divergence tendencies neither contradicts neoclassical growth theory, nor is it at odds with the assumption or political objective of long-run convergence. The theoretical model presented enhances neoclassical growth theory by considering the amount of fixed capital formation to depend on current marginal productivity of physical capital relative to other regions, which in

turn is dependent on the current endowments with physical and human capital. Actual investments in physical capital in one region are determined by current endowments and combinations of production factors in all regions under consideration, taking the region's relative location in space into account. It is shown that under these circumstances the process of convergence is not linear. On the contrary, some regions will experience periods of divergence in the medium run, depending on their own and other regions' initial endowments and composition of production factors.

If one accepts that processes of divergence may occur in the medium run, a test for the speed of convergence would be misleading. The spatial econometric specification derived from the theoretical model corresponds to what has been referred too as a *spatial Durbin error model* and focuses on the mutual influence of initial economic conditions as the determinants of growth. An empirical test with the application of five different spatial weight matrices reveals the negative influence of a high initial output level on output growth, which is in line with the convergence hypotheses. The test has also identified the positive influence of human capital endowments, but only if these are found within one region, as high human capital endowments within neighbouring regions have a negative influence on output growth, possibly leading to divergence. On the one hand, a closer look at the data shows clear trends of convergence within the whole observation area, as the applied indicators of standard deviation, weighted standard deviation, Gini coefficient and the capital region's share of total output all point downwards. On the other hand, the very same indicators clearly point upwards in every one of those new member states of the European Union that consist of at least two NUTS2 regions, namely Bulgaria, the Czech Republic, Hungary, Poland, Romania and Slovakia. It follows that regions already lagging behind the European mean fall further behind their national peers, challenging both future research and structural policy.

## Appendix: Regions of the Observation Area

The study covers the continental European territory of the EU and the EFTA on the NUTS 2 level (EU) and equivalent level (EFTA) as classified by the EU. Due to lack of data, the classification used in this study deviates slightly from the official classification as of January 2010, where in particular the NUTS2 regions of Denmark, Slovenia and Switzerland have been merged into one region that is identical to the corresponding NUTS0 region. The following list contains the official names of all included regions sorted alphabetically by the corresponding nation states:

- Austria (9 regions): Burgenland; Niederösterreich; Wien; Kärnten; Steiermark; Oberösterreich; Salzburg; Tirol; Vorarlberg
- Belgium (11 regions): Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest; Prov. Antwerpen; Prov. Limburg (BE); Prov. Oost-Vlaanderen; Prov. Vlaams-Brabant; Prov. West-Vlaanderen; Prov. Brabant Wallon; Prov. Hainaut; Prov. Liège; Prov. Luxembourg (BE); Prov. Namur
- Bulgaria (6 regions): Severozapaden; Severen tsentralen; Severoiztochen; Yugoiztochen; Yugozapaden; Yuzhen tsentralen
- Czech Republic (8 regions): Praha; Střední Čechy; Jihozápad; Severozápad; Severovýchod; Jihovýchod; Střední Morava; Moravskoslezsko
- Denmark (1 region): Danmark
- Estonia (1 region): Eesti
- Finland (4 regions): Itä-Suomi; Etelä-Suomi; Länsi-Suomi; Pohjois-Suomi
- France (21 regions): Île-de-France; Champagne-Ardenne; Picardie; Haute-Normandie; Centre; Basse-Normandie; Bourgogne; Nord – Pas-de-Calais; Lorraine; Alsace; Franche-Comté; Pays de la Loire; Bretagne; Poitou-Charentes; Aquitaine; Midi-Pyrénées; Limousin; Rhône-Alpes; Auvergne; Languedoc-Roussillon; Provence-Alpes-Côte d'Azur
- Germany (38 regions): Stuttgart; Karlsruhe; Freiburg; Tübingen; Oberbayern; Niederbayern; Oberpfalz; Oberfranken; Mittelfranken; Unterfranken; Schwaben; Berlin; Brandenburg; Bremen; Hamburg; Darmstadt; Gießen; Kassel; Mecklenburg-Vorpommern; Braunschweig; Hannover; Lüneburg; Weser-Ems; Düsseldorf; Köln;

Münster; Detmold; Arnsberg; Koblenz; Trier; Rheinhessen-Pfalz; Saarland; Chemnitz; Dresden; Leipzig; Sachsen-Anhalt; Schleswig-Holstein; Thüringen

- Greece (9 regions): Anatoliki Makedonia, Thraki; Kentriki Makedonia; Dytiki Makedonia; Thessalia; Ipeiros; Dytiki Ellada; Sterea Ellada; Peloponnisos
- Hungary (7 regions): Közép-Magyarország; Közép-Dunántúl; Nyugat-Dunántúl; Dél-Dunántúl; Észak-Magyarország; Észak-Alföld; Dél-Alföld
- Ireland (2 regions): Border, Midland and Western; Southern and Eastern
- Italy (19 regions): Piemonte; Valle d'Aosta/Vallée d'Aoste; Liguria; Lombardia; Provincia Autonoma Bolzano-Bozen; Provincia Autonoma Trento; Veneto; Friuli-Venezia Giulia; Emilia-Romagna; Toscana; Umbria; Marche; Lazio; Abruzzo; Molise; Campania; Puglia; Basilicata; Calabria
- Latvia (1 region): Latvija
- Lithuania (1 region): Lietuva
- Luxembourg (1 region): Luxembourg (Grand-Duché)
- Netherlands (12 regions): Groningen; Friesland; Drenthe; Overijssel; Gelderland; Flevoland; Utrecht; Noord-Holland; Zuid-Holland; Zeeland; Noord-Brabant; Limburg (NL)
- Norway (7 regions): Oslo og Akershus; Hedmark og Oppland; Sør-Østlandet; Agder og Rogaland; Vestlandet; Trøndelag; Nord-Norge
- Poland (16 regions): Łódzkie; Mazowieckie; Małopolskie; Śląskie; Lubelskie; Podkarpackie; Świętokrzyskie; Podlaskie; Wielkopolskie; Zachodniopomorskie; Lubuskie; Dolnośląskie; Opolskie; Kujawsko-Pomorskie; Warmińsko-Mazurskie; Pomorskie
- Portugal (5 regions): Norte; Algarve; Centro (PT); Lisboa; Alentejo
- Romania (8 regions): Nord-Vest; Centru; Nord-Est; Sud-Est; Sud-Muntenia; Bucuresti-Ilfov; Sud-Vest Oltenia; Vest
- Slovakia (4 regions): Bratislavský kraj; Západné Slovensko; Stredné Slovensko; Východné Slovensko
- Slovenia (1 region): Slovenija
- Spain (15 regions): Galicia; Principado de Asturias; Cantabria; País Vasco; Comunidad Foral de Navarra; La Rioja; Aragón; Comunidad de Madrid; Castilla y

León; Castilla-La Mancha; Extremadura; Cataluña; Comunidad Valenciana;  
Andalucía; Región de Murcia

- Sweden (8 regions): Stockholm; Östra Mellansverige; Sydsverige; Norra Mellansverige; Mellersta Norrland; Övre Norrland; Småland med öarna; Västsverige
- Switzerland (1 region): Schweiz
- United Kingdom (37 regions): Tees Valley and Durham; Northumberland and Tyne and Wear; Cumbria; Cheshire; Greater Manchester; Lancashire; Merseyside; East Riding and North Lincolnshire; North Yorkshire; South Yorkshire; West Yorkshire; Derbyshire and Nottinghamshire; Leicestershire, Rutland and Northamptonshire; Lincolnshire; Herefordshire, Worcestershire and Warwickshire; Shropshire and Staffordshire; West Midlands; East Anglia; Bedfordshire and Hertfordshire; Essex; Inner London; Outer London; Berkshire, Buckinghamshire and Oxfordshire; Surrey, East and West Sussex; Hampshire and Isle of Wight; Kent; Gloucestershire, Wiltshire and North Somerset; Dorset and Somerset; Cornwall and Isles of Scilly; Devon; West Wales and the Valleys; East Wales; North Eastern Scotland; Eastern Scotland; South Western Scotland; Highlands and Islands; Northern Ireland



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