Modelling Regional Income Convergence in EU-25

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Abstract

The paper investigates income disparities and convergence among the EU-25 countries and their NUTS-3 regions during the period 1995-2002. In the empirical analysis of the convergence processes we consider the effects of interactions among neighbouring regions implementing spatial econometrics techniques. We conclude that both the EU-15 and the new member states (NMS) experienced absolute regional income convergence during the EU pre-enlargement period. When national effects were included into convergence equations, there was no evidence for conditional convergence neither between EU-15 nor NMS regions. The results of the analysis indicate that EU regional policy should focus on overall cohesion by improving conditions for regional income convergence particularly within the member states.

Keywords: regional income disparities, regional convergence, EU regional policy, spatial econometrics

JEL: R11, O11, C23, C21

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1. Introduction

The European Union enlargement in May 2004 is accompanied by the challenging task – convergence. Convergence consists in bringing the economies of the new member states (NMS) up to the average levels of EU-15. This task, which is even more challenging than was the post-socialist transition, emphasises the necessity to combine economic growth with social and institutional development at the level of both the EU-25 countries and their regions.

The EU-25 that is now one of the world's most prosperous economic areas has large economic disparities between its member states and regions. Therefore income disparities and convergence in the EU-25 countries is continually important research field, giving additional information for development of the European Union regional policies. The essential argument for the EU regional policy is the insight that a balanced regional development is a prerequisite for social cohesion and increase of competitiveness of the countries and regions.

The paper explores regional income disparities and income convergence in three groups of countries: EU-25, EU-15 – the so-called old member states and the NMS – the countries that acceded in 2004. We analyze regional income disparities and convergence in EU-25 countries and their NUTS-3[1] level regions during the years 1995-2002. These years characterize a preparative period of the fifth enlargement (the so-called east enlargement) of the European Union that took place in 2004. During this period, which in the current paper is considered as the EU pre-enlargement period, the political decisions about the candidate and the acceding countries were made.[2]

In order to assess income convergence in EU-25 countries and their regions we use models of absolute and relative location and respectively both non-spatial and spatial econometrics techniques. While absolute location refers to the impact of being located at a particular point of space, the relative location refers to the effect of neighbourhoods. The respective non-spatial econometrics techniques ordinarily focus on models of absolute location while spatial econometrics techniques concentrate on models of relative location exploring spatial dependence. These two groups of estimation techniques are complementary.

[1] *NUTS - Nomenclature of Statistical Territorial Units of EUROSTAT.*

[2] The decisions about the candidate countries were made in 1997 (Luxembourg group) and 1999 (Helsinki group) and about the acceding countries in 2002.

In our paper we focus on the empirical testing of absolute (unconditional) and conditional convergence hypothesis using Eurostat regional GDP per capita data and implementing both non-spatial (simple OLS, including country dummies for capturing spatial heterogeneity) and spatial (Spatial Lag Models (SLM) and Spatial Error Models (SEM)) estimation techniques. We use GDP *per capita* in euro and purchasing power standards (PPS) of the NUTS-3 regions as the proxies of regional income level of the EU-25 countries.

The paper consists of six sections. In the section 2 a brief overview of theoretical framework and some empirical results of the previous convergence studies are given. Section 3 shortly explores income disparities in the EU-25 countries and their regions during the EU pre-enlargement period. Section 4 and 5 present a short overview of the methodology and the main results of the convergence analysis. Section 6 concludes.

2. Theoretical considerations and some empirical results of previous convergence studies

Economic theory does not give a unique answer to what is the direction of the income convergence processes. Both convergence and divergence (so-called negative convergence) may occur. There are both optimistic (mainly neoclassical growth theory) and pessimistic (mainly endogenous growth theory) theoretical models that try to explain convergence processes. The former predicts decrease of disparities of income levels because of decreasing returns to capital while the latter predicts persistent and even increasing inequality because of positive returns to scale. The integration theory, the classical trade theory and the New Economic Geography (NEG) do neither support clearly the convergence optimism nor the pessimism. NEG (Krugman 1991) claims that location is playing an important role in economic activity of the region. In addition to other factors economic situation of a region depends on its location and also on its neighbours. Poor regions have more chances for development if they are surrounded by the rich neighbours. NEG has highlighted, in particular, location and agglomeration externalities. These can arise because of knowledge spillovers, various market effects and input-output linkages between the firms operating at various spatial levels (e.g. regions, cities, district of cities, rural areas, etc).

Although theoretical literature has suggested the importance of location and agglomeration externalities as the key determinants of spatial concentration of economic activity and income (see also Krugman, 1991; Fujita *et al.*, 1999), the empirical literature has still been lagged behind the theoretical developments in exploring regional income disparities and

convergence.

Until the 1990s, the majority of empirical literature on the issue of income convergence has mainly been dealt with between countries' analysis. The results of studies indicate that the majority of countries and regions have become much richer during the past century, but those that have already been richer have gained considerably more. Therefore the gap between rich and poor ones has increased (see also Durlauf and Quah, 1999).

Exploring income convergence processes of the world's countries during the recent 200 years, Dowrick and DeLong (2001) distinguished four periods that vary in direction of the process: income convergence or divergence. According to their research results, there has been no convergence of economic development in the second half of the 20th century. Overall inequality between world's countries has increased, convergence has occurred only in small groups (clubs) of economies, for example OECD countries after the II World War (see also Dowrick and Nguyen 1989), East Asia after the year 1960 (see World Bank 1994), regions of India in the end of 20th century (see Bajpai and Sachs 2000). These examples are in line with the club convergence hypothesis.[3]

The studies on regional income convergence have become particularly popular in the past 15 years (see also Table 1). As one of the pioneering studies on this issue Barro and Sala-i-Martin (1991) found significant evidence of economic convergence across 48 states in the USA (since 1880) and across 73 European regions (since 1950). Actually empirical results of several regional convergence studies vary. Neven and Gouyette (1994) have stressed that there are strong differences in the pattern of convergence across the sub-periods and across the subsets of regions. According to their study, there has been divergence (or stagnation) in the first half of the 1980s in Northern Europe and strong convergence afterwards. On the other hand, regions in Southern Europe converged in the beginning of the decade and at best stagnated thereafter.

[3] The term "club convergence`" can be tracked back to Baumol (1986) and its more rigorous formulation owes to Durlauf and Johnson (1995) and Galor (1996) (see overview of Nazrul Islam (Islam 2003) about the convergence debate). The idea of club-convergence rests on the models that yield multiple equilibriums (. Which of these equilibriums the economy will reach, depends on its initial position or some other attribute. A group of countries may approach a particular equilibrium if they share the initial location or attribute corresponding to that equilibrium. This produces club-convergence.

Table 1. The main empirical results of some regional income convergence studies

Authors	Data	Conclusion
Barro, Sala-i-Martin (1991)	48 USA states since 1880 and 73 European regions since 1950	Regional convergence in both samples
Neven, Gouyette (1994)	European Community 1975-1990	Differences in the pattern of convergence across sub-periods and across subsets of regions (see text)
Sala-i-Martin (1996)	USA: 48 States 1880-1990; Japan: 47 Prefectures 1955-1990; Europe: 5 nations, 190 regions 1950-1990; Canada: 10 Provinces 1961-1991	Regions tend to converge at a speed of approximately two percent per year in all data sets; interregional distribution of income in all countries has shrunk over time
López-Bazo, Valcarce, Corral, Caralt (1997)	GDP per worker: 129 EU regions, 1981 and 1983-1992; GDP *per capita*: 143 EU regions, 1980-1992	Convergence in productivity (GDP per worker) but not in living standards (GDP *per capita*)
Rey, Montouri (1998)	USA states 1929-94	Strong patterns of both global and local spatial autocorrelation. Rate of convergence is marginally lower when spatial dependence is considered
Tsionas (2000)	USA regions 1977-1996	Regional incomes in USA have not converged in the sample period
Baumont *et al* (2002)	138 European regions 1980-1995	Exist spatial dependence and spatial heterogeneity; positive spatial spillover effect
Bentzen ,Smith (2003)	Scandinavian countries 1970-1998	Regional incomes are converging towards the leading city or region in the respective countries
Lim (2003)	170 Economic Areas, as defined by the Bureau of Economic Analysis 1969-99	Strong evidence of spatial autocorrelation; rate of convergence is lower in spatial dependence models.
Arbia, Basile, Piras (2005)	92 Italian provinces, 1951-2000	Spatial autocorrelation which represents regional interaction effects; speed of convergence estimated by spatial lag model is lower than obtained with classical fixed-effect specification
Arbia, Piras (2005)	125 regions of 10 European countries 1980-1995	Taking in account of the spatial dependence among the spatial units reduces the speed of convergence but *beta* remains significantly negative.
Förster, Jesuit, Smeeding (2005)	Microdata of Luxembourg Income Study (LIS) for Czech Republic (1992, 1996), Hungary (1991, 1994), Poland (1992, 1995, 1999), and Russia (1992, 1996).	Regional income inequality is increasing in CEE countries; the winners are capital cities and major urban areas.

Source: composed by authors, based on the studies given in the table.

The majority of the earlier regional income convergence studies have mainly focused on traditional *beta*-convergence analysis in which the effects of spatial dependence are not

considered.[4] As pointed out by Quah (1995), the geographic entities are ordinarily treated as „isolated islands" in these studies. Taking into account that regional data cannot be regarded as independently generated because of the presence of similarities among neighbouring regions, the standard estimation procedures employed in many empirical studies can be invalid and lead to serious bias and inefficiency in the estimates of the convergence rate (see also Arbia *et al* 2005). Therefore it is also understandable that the amount of empirical literature for exploring regional income disparities, convergence and growth using spatial econometric techniques and examining spatial autocorrelation has remarkably increased during the recent decade (see also Abreu, et al, 2005). A short overview of the empirical convergence studies that also emphasize the importance of using spatial econometric techniques is presented in Table 1.

As we noticed from the revising the previous regional convergence studies, the empirical results vary considerably depending on the chosen methods of an analysis and on sample of the countries and periods. Thus neither economic theory nor previous empirical studies can give clear outlooks of regional income convergence processes in EU-25 countries and their regions. Therefore further empirical analysis using modern econometric tools is an important input for elaborating regional policy instruments.

3. Regional income disparities in EU-25 during the pre-enlargement period

The analysis of regional income disparities is conducted using Eurostat income data of the EU-25 countries and their 1214 NUTS-3 level regions during the period 1995-2002. We use GDP per capita in purchasing power standard (PPS) units and in EURO of the NUTS-3 regions. Eurostat publishes nominal income differences by sub-national units of their member states. Data on EU-25 are also available for the period before the EU eastward enlargement. Income differences have been converted to euros by use of PPP (purchasing power parities), but within each country the relative incomes of regions have simply been scaled to the average GDP *per capita* in euros on PPP basis. The adjusted data, which convert these regional nominal incomes to real regional incomes by taking account of the differing price levels within countries, are not available yet.[5]

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[4] *Beta*-convergence is defined as a negative relation between the initial income level and the income growth rate. The testing procedures of *beta*-convergence hypotheses are explained in the next sections of our paper.

[5] It should be noted that Eurostat warns against using PPP adjusted GDP values to calculate growth rates over years, but as we use the growth rates not for single countries but to compare growth rates between countries, it should be less valid for our case. On the other hand, GDP in Euros include also nominal convergence, causing potential overestimation on the real convergence.

Table 2 presents descriptive information about the sample of EU-25 countries NUTS-3 level regions that considered for the regional income disparity analysis.

Table 2. Data characterizing the groups of countries in EU-25 and NUTS-3 level regions, 2002

Group of countries	Number of regions	Population of the groups of countries (mio)	Average population of regions (tds)	Average population density in km^2	Regions' average GDP *per capita* (PPS, tds)*
EU-25	1214	453.8	374	116.6	21.2
EU-15	1091	379.5	348	120.3	23.2
NMS-10	123	74.2	604	100.5	11.0

Source: Eurostat, authors' computations; * - weighted by the population

The number of NUTS-3 regions in the NMS constitutes only 10% of the total number of the EU-25 regions; the respective share of the NMS countries' population is 16%. The average population of the NMS regions is twice as big as in EU-15 regions. Thus, by analysing regional income disparities and by developing policy measures for NUTS-3 regions also this fact beside of other information should be taken into consideration.

The average per capita GDP (weighed by the population of the regions) was twice bigger in the old member states than in the new ones in 2002. The data given in table 3 characterize heterogeneity of regional income levels in EU-25 and its groups of countries, the EU-15 and the NMS.

Table 3. Regional income disparities in EU-25 countries, 2002 (per cent of EU-25 average)

	Average	Minimum	Maximum	Variation coefficient*
EU-25	100.0	18.9 (Latgale, Latvia)	569.8 (Inner London West, UK)	0.039
EU-15	108.4	38.2 (Tamega, Portugal)	569.8 (Inner London West, UK)	0.040
NMS	51.8	18.9 (Latgale, Latvia)	152.8 (Prague, Czech Republic)	0.032

*Of ln (GDP per capita)

Source: *Eurostat*, authors' computations.

The income level of the poorest region (Tamega in Portugal) is almost 15 times lower than the respective income level of the richest region (Inner London West) of the EU-15. In the NMS

the respective gap indicator was 8: the poorest region is Latgale in Latvia and the richest one is Prague in the Czech Republic. The difference between the EU-15 and NMS poorest regions' income levels is about twofold, while the gap is almost fourfold between the richest regions. One should remember, however, that high-income regions have usually higher prices, but in the calculations of GDP in PPS the average of the country (not of region) is used. Thus, the real income disparities are likely to be less dramatic.

4. The methodology used for exploring regional income convergence

Traditional and widely used tool for testing convergence hypotheses is *beta*-convergence analysis. *Beta*-convergence (β-convergence) is defined as a negative relation between the initial income level and the income growth rate. If there runs the scenario that poorer economies grow faster than richer ones, there should also be a negative correlation between the initial income level and the subsequent growth rate. When discussing *beta*-convergence processes usually distinction between absolute convergence and conditional convergence is made. The absolute convergence hypothesis rests on the assumption that economies (countries, regions) converge towards the same steady state equilibrium. The conditional convergence hypothesis assumes that convergence occurs if some structural characteristics (like demographic situation, government policy, human capital, employment rate, and etc) have impact on income growth.

In this paper the following standard equation as a starting point for testing *beta*-convergence is estimated:

$$\ln\left(\frac{y_{i2002}}{y_{i1995}}\right) = \alpha + \beta \ln(y_{i1995}) + \sum_{j=1}^{N} \gamma_j d_{ji} + \varepsilon_i \qquad (1)$$

where

y_{i1995} – GDP *per capita* in EURO (or PPS) in region *i* in 1995 (base year),
y_{i2002} – GDP *per capita* in EURO (or PPS) in region *i* in 2002 (final year),
d_{ij} = 1 if region *i* belongs to country *j*, otherwise d_{ij} = 0,
α, β and γ_j parameters to be estimated,
ε_i – error term.

Country specific dummy variables d_{ij} are used to test the conditional convergence hypothesis, assuming that they control for country-specific factors, e.g. government policy, institutions, etc., that affect income growth in region *i*.

We estimate the equations both with and without country specific intercepts (corresponding to conditional and unconditional convergence hypothesis respectively) and both in PPS terms and EURO terms. We also test whether there is any difference among the old and new member states in convergence, by allowing different slope and intercept coefficients for the EU15 and the NMS. As we usually find that there is a difference between these groups of countries, we also estimate the models separately for the EU-15 and the new member states.

To take into account spatial effects we use a spatial weight matrix that consists of the inverse of the time to travel between the regions. Because of the necessary data are unavailable for some regions we have to restrict our sample to 824 regions. See Annex 1 for source data and technical details.

We first estimate equation (1) with ordinary least squares and test for presence of spatial effects using Lagrange Multiplier (LM) tests. If the presence of spatial effects is discovered, we continue estimating spatial lag (SLM) and spatial error models (SEM) using Maximum Likelihood (ML) method.[6] In a spatial error model the spatial dependence is restricted to error term, but we cannot distinguish the possible causes of spatial dependence (common shocks, institutions, national effects).

We estimate the following spatial lag model:

$$\ln(\frac{y_{i2002}}{y_{i1995}}) = \alpha + \rho\left[W \cdot \ln(\frac{y_{2002}}{y_{1995}})\right]_i + \beta \ln(y_{i1995}) + \sum_{j=1}^{N} \gamma_j d_{ji} + \varepsilon_i , \qquad (2)$$

where

ρ is spatial autocorrelation coefficient,

W – weight matrix,

$\left[W \cdot \ln(\frac{y_{2002}}{y_{1995}})\right]_i$ is i-th element of the vector of weighted growth rates of other regions.

We also estimate the following spatial error model:

$$\ln(\frac{y_{i2002}}{y_{i1995}}) = \alpha + \beta \ln(y_{i1995}) + \sum_{j=1}^{N} \gamma_j d_{ji} + \varepsilon_i , \qquad \text{and } \varepsilon_i = \lambda\left[W \cdot \varepsilon\right]_i + u_i \qquad (3)$$

where

λ is spatial autocorrelation coefficient,

$\left[W \cdot \varepsilon\right]_i$ is i-th element from the vector of weighted errors of other regions,

[6] All estimations are done in *Stata*. We use tools for spatial data analysis in *Stata* (ado files *spatwmat*, *spatreg, spatdiag*, etc) written by Maurizio Pisati (University of Milano), version 1.0. Stata Technical Bulletin 60 (2001).

u_i is normally independently distributed random term.

We test whether $\rho = 0$ or $\lambda = 0$ using ML-based tests.

From the estimate of β we can derive two indicators often used to characterize *beta*-convergence – the speed of convergence and the so-called half-life.

The speed of convergence measures how fast economies converge towards the steady state and we calculate it using the following formula[7]:

$$s = -\ln(1+\beta)/T \tag{4}$$

where T is the number of periods.

The half-life is defined as the time necessary for the economies to fill half of the initial gap of income inequalities and we calculate it as follows:

$$\tau = -\ln(2)/\ln(1+\beta/T) \tag{5}$$

Of course, we should be rather careful by drawing conclusions on speed of convergence and half-life as data come from relatively short time period (1995-2002).

We follow the argumentation presented by Anselin and Florax (1995) that if LM test for spatial lag is more significant than LM test for spatial error, and robust LM test for spatial lag is significant but robust LM test for spatial error is not, then the appropriate model is the spatial lag model. Conversely, if LM test for spatial error is more significant than LM test for spatial lag and robust LM test for spatial error is significant but robust LM test for spatial lag is not, then the appropriate specification is the spatial error model. Because we often encounter situations when this decision rule cannot be strictly applied, we present all estimation results in the Annex 2 and Annex 3.

5. The modelling results

The estimation results of the convergence equations 1-3 are summarized in the Table 4 (see Annex 2 and Annex 3 for details). The results for EU15 and NMS are presented both without country dummies (absolute convergence) and with the country dummies (conditional convergence), and GDP per capita estimated in euros and PPS.

Two main preliminary conclusions can be drawn from the estimated models.

[7] Note that if the dependent variable is defined as average growth (as found often in the empirical literature), the formulas are slightly different (modifying the slope coefficient). Speed of convergence: $s = -\ln(1+T\beta)/T$

First, there was absolute convergence in EU, meaning that the regions with lower GDP per capita grew with higher speed during the period 1995-2002. The speed of regional income convergence was higher for EU15 than for NMS. However, in most specifications we found that there was no evidence for conditional convergence between the EU15 regions. Moreover, there were signs of conditional divergence for the new member states. It means that although there was an overall regional income convergence in the EU, there was no convergence within the countries, or even the regional disparities grew within the new member states during the EU pre-enlargement period (1995-2002).

Second, there is strong evidence for spatial effects. LM tests on our OLS specifications indicated a clear spatial dependence. When spatial effects are taken into account, the speed of convergence is slightly higher when GDP in euros is used and about the same when GDP in PPS is used.

Table 4. *Beta*-convergence (absolute and conditional) in EU-15 and NMS regions in 1995-2002

	Linear model (OLS)		Spatial error model		Spatial lag model	
Values in EUR						
Country dummies	No	Yes	No	Yes	No	Yes
GDP per capita 1995	-0.214*** (0.016)	-0.017 (0.013)	-0.228*** (0.017)	-0.032 (0.017)	-0.264*** (0.015)	-0.0376** (0.016)
NMS x GDP per capita 1995	0.028 (0.041)	0.142** (0.041)	0.037 (0.042)	0.154*** (0.041)	0.062 (0.044)	0.1595*** (0.040)
R^2	0.393	0.855	0.393	0.849	0.479	0.858
Speed of convergence - EU15	0.034	0.002	0.037	0.005	0.044	0.005
Half-life – EU15	22.3	293.0	20.9	150.0	18.0	128.7
Speed of convergence - NMS	0.029	-0.017	0.030	-0.016	0.032	-0.016
Half-life - NMS	25.7		25.1		23.7	
Value in PPS						
GDP per capita 1995	-0.097*** (0.015)	-0.016 (0.013)	-0.085*** (0.015)	-0.033* (0.016)	-0.091*** (0.016)	-0.036* (0.016)
NMS x GDP per capita 1995	0.082** (0.030)	0.142*** (0.041)	0.072* (0.029)	0.155*** (0.041)	0.077** (0.030)	0.158*** (0.041)
R^2	0.125	0.430	0.125	0.413	0.127	0.438
Speed of convergence - EU15	0.015	0.002	0.013	0.005	0.014	0.005
Half-life – EU15	49.7	295.4	56.7	148.2	53.0	134.4
Speed of convergence - NMS	0.002	-0.017	0.002	-0.016	0.002	-0.016
Half-life - NMS	323.1		372.9		346.2	

Robust standard errors in the parentheses under the estimated coefficients
p-values in the parentheses under test-statistics.
Significance levels - *** - p<0.001, ** - p<0.01, * - p<0.05

Source: authors' estimations based on data from *Eurostat;* see details in Annex 1. More information about the full set of the estimated convergence equations see in Annexes 2 and 3.

Half-time: $\tau = -\ln(2)/\ln(1+\beta)$

Our results are somewhat in contradiction with some earlier studies, which have found that taking into account spatial effects reduces convergence (see also Table 1; Rey, Montouri (1998), Lim (2003), Arbia, Basile, Piras (2005)). But we should take into considerations that the empirical results based on applying spatial and non-spatial estimation techniques are not fully comparable. However, the coefficient β in the SLM is another one than the respective coefficient in the OLS-model. While the latter is a measure of the direct marginal effects of a change in dependent variable only, the former also includes the indirect and induced effects of the spatial multiplier process. Similarly, the nature of the spatial effects captured by the SEM is also a global one and follows a spatial multiplier process across the whole sample of regions (see also Abreu et al. 2005 pp. 30-32). The estimations are also sensitive to a variety of factors such as the design of the weight matrix, the regional level of aggregation and the cross-section itself.

The empirical results allow us to presume that the catching-up of the NMS at the national level seems to be driven mainly by the few high growth regions. These results are also in accordance with the findings of Niebuhr and Schlitte (2004), which are based on the NUTS-2 level data of GDP *per capita* (Euro) during the period 1995-2000. Also the findings of several other studies indicated that the high growth regions coincide essentially with highly competitive agglomerations and thus, the regions that already marked by a relatively high GDP *per capita* (see Tondl and Vuksic, 2003). The decline of income disparities between the counties is often accompanied by the increasing regional disparities within the member states stressing the necessity to improve conditions for economic growth at both the national as well regional level.

6. Conclusions

The results of the EU-25 regional income levels' analysis during the EU pre-enlargement period (1995-2002) show significant regional disparities in both the old and new member states – the candidate countries during the pre-enlargement period. Income disparities were considerably higher in the EU-15 countries than in the new member states, but in the latter ones the growth of disparities was remarkable during the period under observation. Of course, by analysing regional disparities of the EU-15 and NMS and also by developing regional policy measures it should be taken into consideration that the number of NUTS-3 regions in the NMS constitutes only 10% of the total number of the EU-25 regions, at the same time the average population of the NMS regions is twice as big as in EU-15 regions.

We noticed that not only the income disparities were large, also the speed of regional income convergence processes was slow as shown by *beta*-convergence analysis. The average speed of absolute convergence in terms of euros and in PPS units was higher for the EU15 than for the NMS. There was no evidence for conditional convergence (models with country dummies) neither between the EU15 regions nor the NMS regions. Moreover, there were signs of conditional divergence for the new member states. It means that although there was an overall convergence in the EU, there was no convergence within the countries. The regional income disparities even grow within the NMS.

Thus, the results of analysis assert continuing importance of the European Union and its member states' regional policies for reducing regional income disparities in both old and new member states. The EU regional policy should focus on overall cohesion by improving conditions for economic growth in the member states. The primary task of the EU member states' regional policies should be the implementing of policy measures that are focused on the declining of regional income disparities within the countries. In a country level it is possible to better specify whether the increase of regional income disparities accompanying with economic growth is a normal self-balancing process or it may become dangerous to cohesion of society and lower in a long run country's competitiveness. It is important to create conditions for the poorer regions to stimulate their economic growth by taking over the innovations of the richer regions. Systematic investments into local human capital and improvement of labour flexibility are unavoidable policy means that support regional development.

In addition to country-specific dummies many other factors that may affect regional income level (for instance employment rate, changes in the amount and age structure of working-age population, innovations, etc) should be considered in our further analysis.

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Annex 1. Description of data

GDP per capita

The GDP *per capita* is from general and regional statistics database of Eurostat, extracted on November 2005. We use GDP *per capita* in Purchasing Parity Standard (PPS) units (PPP adjusted) and at current marked prices, in ECU up to 12.12.1998 and in EUR from 01.01.1999. GDP in PPS is calculated using country-specific (not regional) PPP conversion rates, which means that within-country variation of prices is not taken into account.

In *sigma*-convergence analysis (variation of GDP) we use 1214 NUTS 3 regions. Because of data problems, we use 824 regions in *beta*-convergence analysis (growth models). We have excluded the regions of Cyprus, Malta and Latvia, because we had no data to construct the weight matrix. We also use NUTS 2 level data for Poland and so-called "planning regions" for Germany for similar reasons. Finally, we did not have information on 8 oversees regions (4 in France and 4 in Spain), but they hardly have any significant interactions with the other regions in EU.

2. Construction of weight matrix

Our weight matrix is based on the travel time of freight vehicles between the centers of regions.[8] As border impediments are included the travel time from the region *i* to the region *j* and *vice versa* may not be the same. If this is the case then the average travel time is used. An element w_{ij} of distance matrix W is calculated as follows:

$$w_{ij} = w_{ji} = \frac{1}{1/2\,(time_{ij} + time_{ji})} \qquad \text{(A1)}$$

Table A1. EU-25 countries and number of regions used in the models

Country	Classification	Number of regions used
Austria	NUTS 3	35
Belgium	NUTS 3	43
Czech Republik	NUTS 3	14
Germany	Planning regions	97
Denmark	NUTS 3	15
Estonia	NUTS 3	5
Spain	NUTS 3	48
Finland	NUTS 3	20
France	NUTS 3	96
Greece	NUTS 3	51
Hungary	NUTS 3	20
Ireland	NUTS 3	8
Italy	NUTS 3	103
Lithuania	NUTS 3	10
Luxembourg	NUTS 3	1
Netherlands	NUTS 3	40
Poland	NUTS 2	16
Portugal	NUTS 3	28
Sweden	NUTS 3	21
Slovenia	NUTS 3	12
Slovakia	NUTS 3	8
United Kingdom	NUTS 3	133
Total		824

[8] We like to thank Carsten Schürmann for the generous provision of the travel time data.

Annex 2. Estimation results of econometric models – data in Euros

Table A2. Linear model (OLS estimates), GDP in EUR

	EU				EU15		NMS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	2.401*** (0.095)	0.114 (0.131)	2.391 (0.149)	1.414 (0.211)	2.391*** (0.149)	0.341* (0.132)	2.178*** (0.312)	-0.446 (0.326)
Dummy for new member states (NMS)			-0.214 (0.343)	-1.186*** (0.329)				
GDP_1995	-0.215*** (0.010)	0.006 (0.013)	-0.214*** (0.016)	-0.017 (0.013)	-0.214*** (0.016)	-0.017 (0.013)	-0.187*** (0.038)	0.125** (0.040)
NMS* GDP_1995			0.028 (0.041)	0.142** (0.041)				
Country dummies	No	Yes	No	Yes	No	Yes	No	Yes
Number of obs.	824	824	824	824	739	739	85	85
F- stat	459.48 (p=0.000)		151.77 (p=0.000)		189.23 (p=0.000)		23.88 (p=0.000)	65.49 (p=0.000)
R^2	0.392	0.851	0.393	0.855	0.213	0.811	0.312	0.838
Tests for spatial error	+		+		+		+	
Moran's I	129.827 (p=0.000)	9.610 (p=0.000)	133.635 (p=0.000)	9.929 (p=0.000)	139.541 (p=0.000)	10.210 (p=0.000)	61.678 (p=0.000)	-1.116
Lagrange multiplier	6999.510 (p=0.000)	9.056 (p=0.003)	7145.118 (p=0.000)	9.928 (p=0.002)	7452.461 (p=0.000)	11.291 (p=0.001)	45.349 (p=0.000)	0.091 (p=0.763)
Robust Lagr. multip	6822.117 (p=0.000)	6.814 (p=0.009)	6952.642 (p=0.000)	7.104 (p=0.009)	7189.292 (p=0.000)	8.315 (p=0.004)	53.353 (p=0.000)	0.902 (p=0.342)
Tests for spatial lag		+		+		+		+
Lagrange multiplier	179.420 (p=0.000)	12.420 (p=0.000)	194.434 (p=0.000)	18.122 (p=0.000)	279.667 (p=0.000)	17.511 (p=0.000)	1.317 (p=0.251)	5.764 (p=0.016)
Robust Lagr. multip	2.027 (p=0.155)	10.178 (p=0.001)	1.959 (p=0.162)	15.298 (p=0.001)	16.499 (p=0.000)	14.535 (p=0.000)	9.320 (p=0.002)	6.575 (p=0.010)
Speed of convergence	0.035	-.0009	0.034[#]	0.002[#]	0.034	0.002	0.029	-0.017
Half-life	22.2		22.3[#]	293.0[#]	22.3	293.0	25.6	

Robust standard errors in the parentheses under the estimated coefficients; p-values in the parentheses under test-statistics.
Significance levels - *** - p<0.001, ** - p<0.01, * - p<0.05
[#] - speed of convergence and half-life for EU15

Table A3. Spatial error model, GDP in EUR

	EU				EU15		NMS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	2.492*** (0.104)	0.033 (0.040)	2.528*** (0.169)	0.502** (0.169)	2.623*** (0.171)	0.501** (0.170)	1.348*** (0.228)	-0.339* (0.133)
Dummy for new member state (NMS)			-0.295 (0.352)	0.181 (0.983)				
GDP_1995	-0.224*** (0.011)	0.015*** (0.003)	-0.228*** (0.017)	-0.032 (0.017)	-0.237*** (0.018)	-0.031 (0.017)	-0.184*** (0.029)	0.141*** (0.030)
NMS* GDP_1995			0.037 (0.042)	0.154*** (0.041)				
Country dummies		yes		yes		yes		yes
Squared correlation	0.392	0.847	0.393	0.849	0.213	0.803	0.312	0.835
Skewness/Kurtosis tests for Normality	- (0.000)	43.07 (0.000)	- (0.000)	35.38 (0.000)	- (0.000)	34.27 (0.000)	9.35 (0.009)	7.08 (0.029)
Lambda	0.016* (0.008)	0.843*** (0.186)	0.017* (0.008)	0.123* (0.050)	0.029*** (0.008)	0.123* (0.052)	-0.795** (0.255)	-1.011 (0.682)
Tests for lambda=0								
Wald test	4.126 (p=0.042)	20.657 (p=0.000)	4.520 (p=0.034)	6.081 (p=0.014)	13.725 (p=0.000)	5.682 (p=0.017)	9.684 (p=0.002)	2.200 (p=0.138)
LM test	6999.510 (p=0.000)	9.056 (p=0.003)	7145.118 (p=0.000)	9.928 (p=0.002)	7452.461 (p=0.000	11.291 (p=0.001)	45.349 (p=0.000)	0.091 (p=0.763)
Speed of convergence	0.036	-0.002	0.037[#]	0.005[#]	0.039	0.005	0.029	-0.019
Half-life	21.3		20.9[#]	150.0[#]	20.1	154.5	26.0	

Robust standard errors in the parentheses under the estimated coefficients; p-values in the parentheses under test-statistics.
Significance levels - *** - p<0.001, ** - p<0.01, * - p<0.05
[#] - speed of convergence and half-life for EU15

Table A4. Spatial lag model, GDP in EUR

	EU				EU15		NMS	
	(1)	(2)	(3)	(4)	(1)	(2)	(1)	(2)
Intercept	2.535*** (0.095)	0.081*** (0.003)	2.690*** (0.144)	0.833*** (0.123)	2.636*** (0.139)	0.079*** (0.003)	2.252*** (0.323)	0.084*** (0.008)
Dummy for new member state (NMS)			-0.533 (0.364)	-1.317*** (0.326)				
GDP_1995	-0.247*** (0.010)	-0.009 (0.015)	-0.264*** (0.015)	-0.0376** (0.016)	-0.258*** (0.015)	-0.036* (0.015)	-0.190*** (0.038)	0.124*** (0.038)
NMS* GDP_1995			0.062 (0.044)	0.1595*** (0.040)				
Country dummies		yes		Yes		yes		yes
Squared correlation	0.479	0.853	0.479	0.858	0.386	0.816	0.322	0.844
Skewness/Kurtosis tests for Normality	62.70 (0.000)	43.00 (0.000)	64.09 (0.000)	40.80 (0.000)	52.59 (0.000)	36.58 (0.000)	9.62 (0.008)	7.66 (0.022)
Rho	0.579*** (0.053)	0.184* (0.078)	0.590*** (0.053)	0.221*** (0.078)	0.673*** (0.050)	0.223** (0.081)	-0.508 (0.612)	0.575 (0.335)
Tests for rho=0								
Wald test	117.741 (p=0.000)	5.542 (p=0.019)	117.741 (p=0.000)	8.092 (p=0.004)	182.258 (p=0.000)	7.527 (p=0.006)	0.688 (p=0.407)	2.942 (p=0.086)
LM test	179.420 (p=0.000)	12.420 (p=0.000)	179.420 (p=0.000)	18.122 (p=0.000)	279.667 (p=0.000)	17.511 (p=0.000)	1.317 (p=0.251)	5.764 (p=0.016)
Speed of convergence	0.041	0.001	0.044[#]	0.005[#]	0.043	0.005	0.030	-0.017
Half-life	19.3	558.3	18.0[#]	128.7[#]	18.4	132.7	25.2	

Robust standard errors in the parentheses under the estimated coefficients; p-values in the parentheses under test-statistics.
Significance levels - *** - p<0.001, ** - p<0.01, * - p<0.05
[#] - speed of convergence and half-life for EU15

Annex 3. Estimation results of econometric models – data in PPS

Table A5. Linear model (OLS estimates), GDP in PPS

	EU				EU15		NMS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	1.219*** (0.108)	0.218 (0.129)	1.247*** (0.148)	0.440*** (0.131)	1.247*** (0.148	0.440*** (0.130)	0.535* (0.229)	-0.901* (0.364)
Dummy for new member states (NMS)			-0.712** (0.271)	-1.081** (0.363)				
GDP_1995	-0.094*** (0.011)	0.007 (0.013)	-0.097*** (0.015)	-0.016 (0.013)	-0.097*** (0.015)	-0.016 (0.013)	-0.015 (0.026)	0.125** (0.040)
NMS* GDP_1995			0.082** (0.030)	0.142*** (0.041)				
Country dummies		yes		Yes		yes		yes
Number of obs.	824	824	824	824	739	739	85	85
F- stat	69.01 (p=0.000)							
R^2	0.104	0.416	0.125	0.430	0.079	0.416	0.004	0.488
Tests for spatial error	+	+	+		+	+/-	+	
Moran's I	30.254 (p=0.000)	9.511 (p=0.000)	32.860 (p=0.000)	9.832 (p=0.000)	33.041 (p=0.000)	10.106 (p=0.000)	36.312 (p=0.000)	-1.118
Lagrange multiplier	373.269 (p=0.000)	8.786 (p=0.003)	429.133 (p=0.000)	9.652 (p=0.002)	416.409 (p=0.000)	10.983 (p=0.001)	16.163 (p=0.000)	0.091 (p=0.763)
Robust Lagr. multip	381.936 (p=0.000)	6.819 (p=0.009)	436.722 (p=0.000)	6.934 (p=0.008)	419.470 (p=0.000)	8.147 (p=0.004)	16.701 (p=0.000)	1.379 (p=0.240)
Tests for spatial lag				+		+/-		+
Lagrange multiplier	2.854 (p=0.091)	6.706 (p=0.010)	1.264 (p=0.261)	11.543 (p=0.001)	0.001 (p=0.978)	11.044 (p=0.001)	0.116 (p=0.733)	4.252 (p=0.039)
Robust Lagr. multip	11.522 (p=0.001)	4.739 (p=0.029)	8.852 (p=0.003)	8.824 (p=0.003)	3.062 (p=0.080)	8.209 (p=0.004)	0.654 (p=0.419)	5.541 (p=0.000)
Speed of convergence	0.014	-0.001	0.015[#]	0.002[#]	0.015	0.002	0.002	-0.017
Half-life	51.4		49.7[#]	295.4[#]	49.7	295.4	329.9	

Robust standard errors in the parentheses under the estimated coefficients; p-values in the parentheses under test-statistics.
Significance levels - *** - p<0.001, ** - p<0.01, * - p<0.05
[#] - speed of convergence and half-life for EU15

Table A6. Spatial error model, GDP in PPS

	EU				EU15		NMS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	1.089*** (0.110)	0.293 (0.192)	1.123*** (0.142)	0.604*** (0.161)	1.176*** (0.145)	0.604*** (0.163)	0.535* (0.232)	-0.582** (0.203)
Dummy for new member state (NMS)			-0.622* (0.263)	4.379 (3.936)				
GDP_1995	-0.081*** (0.011)	-0.001 (0.020)	-0.085*** (0.015)	-0.033* (0.016)	-0.090*** (0.015)	-0.032 (0.016)	-0.015 (0.033)	0.131*** (0.030)
NMS* GDP_1995			0.072* (0.029)	0.155*** (0.041)				
Country dummies	No	Yes	No	Yes	No	Yes	No	Yes
Squared correlation	0.104	0.405	0.125	0.413	0.079	0.358	0.004	0.455
Skewness/Kurtosis tests for Normality	- (0.000)	37.15 (0.000)	- (0.000)	35.41 (0.000)	- (0.000)	34.29 (0.000)	2.85 (0.240)	6.05 (0.049)
lambda	-0.034* (0.014)	0.157 (0.112)	-0.027* (0.013)	0.101* (0.040)	-0.015 (0.012)	0.101* (0.041)	0.003 (0.652)	-0.893 (0.483)
Tests for lambda=0								
Wald test	6.060 (0.014)	1.983 (0.159)	4.434 (0.035)	6.467 (0.011)	1.674 (0.196)	5.986 (0.014)	0.000 (0.996)	3.422 (0.064)
LM test	373.269 (0.000)	8.786 (0.003)	429.133 (0.000)	9.652 (0.002)	416.409 (0.000)	10.983 (0.001)	16.163 (0.000)	0.091 (0.763)
Speed of convergence	0.012	0.000	0.013[#]	0.005[#]	0.013	0.005	0.002	-0.018
Half-life	59.7	6967.4	56.7[#]	148.2[#]	53.5	152.3	331.4	

Robust standard errors in the parentheses under the estimated coefficients; p-values in the parentheses under test-statistics.
Significance levels - *** - p<0.001, ** - p<0.01, * - p<0.05
[#] - speed of convergence and half-life for EU15

Table A7. Spatial lag model, GDP in PPS

	EU				EU15		NMS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	1.166*** (0.111)	0.295* (0.139)	1.200*** (0.150)	0.611*** (0.138)	1.248*** (0.149)	0.568*** (0.144)	0.525* (0.236)	-0.922** (0.339)
Dummy for new member state (NMS)			-0.666* (0.270)	-1.273*** (0.359)				
GDP_1995	-0.086*** (0.012)	-0.006 (0.015)	-0.091*** (0.016)	-0.036* (0.016)	-0.097*** (0.016)	-0.035* (0.016)	-0.014 (0.026)	0.124** (0.038)
NMS* GDP_1995			0.077** (0.030)	0.158*** (0.041)				
Country dummies	No	Yes	No	Yes	No	Yes	No	Yes
Squared correlation	0.107	0.421	0.127	0.438	0.079	0.387	0.005	0.498
Skewness/Kurtosis tests for Normality	- (0.000)	43.20 (0.000)	- (0.000)	40.88 (0.000)	- (0.000)	36.67 (0.000)	2.81 (0.245)	8.15 (0.017)
rho	-0.068 (0.045)	0.168 (0.093)	-0.045 (0.044)	0.219* (0.092)	0.001 (0.044)	0.220* (0.096)	0.110 (0.548)	0.458 (0.426)
Tests for rho=0								
Wald test	2.265 (0.132)	3.296 (0.069)	1.046 (0.306)	5.661 (0.017)	0.001 (0.981)	5.227 (0.022)	0.040 (0.841)	1.154 (0.283)
LM test	2.854 (0.091)	6.706 (0.010)	1.264 (0.261)	11.543 (0.001)	0.001 (0.978)	11.044 (0.001)	0.116 (0.733)	4.252 (0.039)
Speed of convergence	0.013	0.001	0.014[#]	0.005[#]	0.015	0.005	0.002	-0.017
Half-life	55.9	788.2	53.0[#]	134.4[#]	49.6	139.6	335.9	

Robust standard errors in the parentheses under the estimated coefficients; p-values in the parentheses under test-statistics.
Significance levels - *** - p<0.001, ** - p<0.01, * - p<0.05
[#] - speed of convergence and half-life for EU15