On beta and sigma convergence of Czech regions

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1. July 2013

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Abstract:
The aim of the article is to examine beta and sigma convergence of fourteen Czech regions during 1995-2009. Using real GDP per capita panel data from the Czech Statistical Office it was found that Czech regions σ-diverged in the period and this divergence was accelerating in time regardless of whether the capital city Prague was included among regions or not. Also, statistically significant β-divergence was present during the same period. There are two main possible reasons for the divergence: inequalities in foreign and domestic investments as well as the accumulation of human and physical capital in the most attractive regions, while less competitive regions were left behind. Policy implications necessary to reverse the situation include government's support of investments in poorer regions and also gaining more financial resources from European ESF and ERDF funds.

Keywords: β-convergence Czech Republic, Czech regions, divergence, GDP per capita, σ-convergence

JEL: R11, R12.

1 INTRODUCTION

Convergence (or divergence) of regions in terms of their GDP per capita (income) provides useful information about regions' competitiveness: if they are converging to the same level, it means that also their competitiveness is getting closer. On the other hand, if divergence occurs, than some of regions (with the higher competitiveness) accelerate while other are left behind. Then it would be interesting to explain reasons for such behavior.

The economical concept of convergence was introduced by Barro and Sala-i-Martín (1992 and 1995). They distinguish between *β-convergence* and *σ-convergence*. From neoclassical theory of economic growth it follows that national economics converge to the same level because of diminishing returns to physical capital, hence GDP growth is negatively related to the initial GDP per capita ('catch up effect'). Another force behind the convergence is technology spillover among countries. This type of convergence is called *β-convergence*.

The β-convergence is defined as follows (Barro and Sala-i-Martín, 1992):

$$\frac{1}{T}\log\left(\frac{Y_{i,T}}{Y_{i,0}}\right) = \alpha + \beta \log Y_{i,0} + \gamma Z_i + \varepsilon_i \qquad (1)$$

The average growth of GDP per capita (PPP) ($Y_{i,T}$ and $Y_{i,0}$) during T years is equal to a constant α and a linear combination of initial GDP per capita ($Y_{i,0}$) and a set of endogenous factors Z_i, ε_i is an error term. Index i denotes countries and β and γ are regression coefficients. The β-convergence occurs if $\beta < 0$.

The concept of *σ-convergence* arises also from the neoclassical theory of the economic growth, according to which countries converge to the same economic level (expressed as GDP per capita, PPP). Given a set of countries, if the variance (dispersion) σ^2 of their economic level declines during a given period, then there is *σ-convergence* among countries,

and countries are heading towards some 'steady and homogenous state' in the future. The force behind σ-convergence is mainly free trade, technology spillover and direct foreign investment (Smrčková, Vlček, Cvengroš, 2008).

The regions are sigma-convergent between time t and $t + k$ if the following condition is fulfilled:

$$\sigma_t^2 > \sigma_{t+k}^2 \tag{2}$$

For practical use σ-convergence is defined by the variation coefficient of GDP per capita (PPP) of a set of countries or regions in a given time:

$$V = \frac{s}{\bar{x}}, \tag{3}$$

In (3) s is the standard deviation $s = \sqrt{\sigma^2}$ and $\bar{x}$ is the arithmetic mean of GDP per capita (PPP) of a set of countries or regions.

As for the relationship between the two types of convergence, β-convergence (1) is necessary but not sufficient condition for σ-convergence (see Young, Higgins and Levy, 2004).

Both sigma and beta convergence were examined in many empirical studies, see e. g. Barro and Sala-i-Martin (1992 and 1995), Islam (1995), Sala-i-Martin (1996), Evans and Karras (1996a, 1996b), Evans (1997), Quah (1997), Lévy et al. (2004) or Smrčková et al. (2008).

On the global level, the GDP data from World Bank and International Monetary Fund suggest that from 1980 to 1992 worlds' regions slightly diverged, but from 1992 to 2008 strong convergence occurred (Smrčková et al., 2008). Divergence during 1980s and early 1990s was caused by the decrease of GDP per capita in the developing countries from Africa, Latin America and Middle East, while developed countries experienced growth. The fall of communist block and the breakup of Soviet Union also contributed to the divergence, as transition economies of Eastern Europe and Asia declined severely for almost a decade.

In Europe, among OECD countries between 1970 and 2005 variation coefficient declined from 0.21 to 0.13, see Figure 1. However, on the regional scale the divergence prevails.

In the USA convergence across 3058 counties and 50 states were examined e.g. by Young et al. (2004). While they found evidence for β-convergence, σ-convergence was not found in the cross-section of counties and vast majority of states.

As mentioned earlier there is a vast literature on beta and sigma conference, but European studies mainly focus on states and large regions (NUTS I and II levels) of EU member states in the context of European integration, see e.g. Boldrin and Canova (2001), Marelli (2007), Novotný (2010) Nevima and Melecký (2011) or Ondoš (2011), and there are not many convergence studies concerning purely regions within a state's border (NUTS III level).

The aim of the article is to examine beta and sigma convergence of fourteen Czech regions during 1995-2009. The period was chosen to start briefly after the constitution of the Czech Republic in 1993 (after splitting the former state, Czechoslovakia) and the period was finished with the start of the global financial crisis.

The article is organized as follows: in Section 2 the data and method are described, in Section 3 results are presented and Section 4 provides discussion. Conclusions close the article.

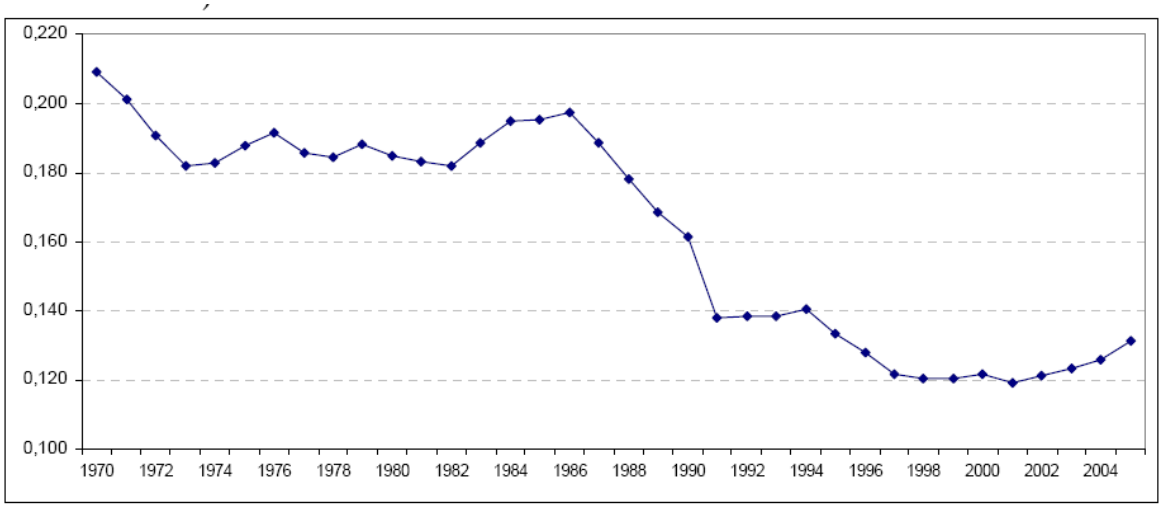

Figure 1. Sigma-convergence of EU-15 (without Luxembourg) given in variation coefficient of GDP per capita (PPP). Source: Smrčková et al. (2008).

2 THE DATA AND THE METHOD

For the evaluation of σ-convergence of Czech regions relative GDP (percentage level of the average EU GDP level) from the Czech Statistical Office (CSO) were used from 1995 to 2009. In this panel data relative values of GDP were employed for their illustrative nature. As the variation coefficient (3) is invariant to linear transformations, its value would be the same as for absolute values of GDP. The panel data are presented in Table 1. For the evaluation of β-convergence the same (but absolute) values of regional real GDP per capita were used from CSO database.

From Table 1 it is clear that the richest Czech region is Prague with the GDP per capita about 170 % of EU level in the late 2000s. None other Czech region is ranked above EU average. Prague is followed by Jihomoravský (76.7 %) and Středočeský region (73.7 %). On the bottom there are Karlovarský and Liberecký region, with GDP per capita slightly above 50 % of the EU level.

To examine σ-convergence for each year during 1995-2009 the variation coefficient (3) was calculated. Also, the linear regression (by OLS method) was performed to obtain a linear trend of the variation coefficient, the analysis was performed by statistical software Gretl and the linear regression was corrected for heteroscedasticity. For the examination of β-convergence the regression model (1) was used and the analysis was carried out in Gretl too. Results are presented in the next section.

Table 1. Regional relative GDP per capita (EU = 100 %). Source: CSO (2011).

Region **rok**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Praha	124.8	128	130	133	135.9	136.3	145.1	147.4	153.6	154.3	158.3	161.6	171.5	171.7	177
Středočeský	63.2	64.7	63.7	63.6	65	64.2	65.2	67.1	69	71.2	69.8	72.6	74.8	74	73.7
Jihočeský	68.5	71.2	68.7	66.4	64.8	62.8	63.3	63.3	65.3	67	68.3	69	68.5	67.6	69.3
Plzeňský	70.7	73.9	70.5	65.7	64.7	64.1	66.1	64.6	68.3	72.2	71.5	72.6	73.4	68.2	69.7
Karlovarský	68.4	67.9	63.6	59.7	58	57.2	55.8	57.1	58.6	58.2	57.1	55.2	56.8	55.3	54.3
Ústecký	69.4	70.6	65.1	61.2	59	55.7	55.7	55.8	60.3	61.7	61.6	62.5	63.2	64.4	64.1
Liberecký	66.3	67.5	66.3	61.9	62.1	61.1	61.6	61.6	59.2	60.2	63.6	62.5	61.5	58.5	55.8
Královéhr.	68.2	70.1	69.8	65.7	64.9	64.6	64.8	63.8	65.6	67.3	66.4	65.2	67.9	67.1	67.7

Pardubický	65.7	66.2	64.1	62.1	59.5	58.3	59	59	62.2	62.8	62.5	64.5	66.8	66.7	66.6
Vysočina	62.5	64.4	64.4	57.3	58	57.2	62	60.9	62.9	63.9	64.3	64.8	67.1	63.1	62.9
Jihomoravský	70.1	72.1	68.9	66.4	64.5	63.1	65	64.8	67.9	68.4	69	70.4	73.3	78.1	76.7
Olomoucký	61	64.3	61	56	55.3	54.3	54.6	54.3	56.1	58.7	57.5	57	59.2	60.4	60.5
Zlínský	65.6	64.3	65.2	61.1	58.6	57.1	58.1	58.1	59.9	59.6	61.2	62.6	65.2	68	66.7
Moravskosl.	64.1	67.1	63.3	58.2	55.9	53.5	54.8	54.2	56.7	61.4	64.2	64	67.2	69.3	65.5

3 RESULTS

3.1. Beta convergence of all regions

For the evaluation of β-convergence of Czech regions the regression model (1) was used with T = 14 years and Z_i = 0. Regression was performed and corrected for heteroscedasticity by statistical software Gretl. Basic results are shown in Table 2. Other features of the model include: adj. R^2 = 0.458, p-value of F-test 0.0047, Akaike's criterion 63.48 and Hannan-Quinn's criterion 63.36.
The coefficient β in the model was found positive and statistically significant at α = 0.01 level, thus β-divergence among regions occurred in the examined period. This means that richer regions in 1995 were getting even richer during 1995-2009, and vice versa. Possible explanation for such development is discussed in Section 4.

Table 2. The regression model (1). Source: author.

	coefficient	error	p-value	significance
const	–0.143094	0.0456928	0.00867	***
$\log Y_{i,0}$	0.0393356	0.0113671	0.00471	***

3.2. Sigma convergence of all regions

For the evaluation of σ-convergence of all 14 regions of the Czech Republic, the data from Table 1 were employed. The variation coefficient (3) was evaluated for each year, and is shown in Figure 2. As can be seen, with the only exception of the year 2004, the variation coefficient was non-decreasing during examined period, thus sigma divergence of Czech regions was accelerating in time.
Simple linear regression corrected for heteroscedasticity has the form $y = 0.0114x - 22.502$; where x is a year and y is a variation coefficient. Both regression coefficients, hence the upward trend of the variation coefficient, are strongly statistically significant, see Table 3. Other features of the model: adj. R^2 = 0.9321, p-value of F-test 3.54e-09, Akaike's criterion 48.85 and Hannan-Quinn's criterion 48.83.

Table 3. Simple linear regression model, all regions. Source: author.

	coefficient	error	p-value	significance
const	-22.5023	1.64490	4.28e-09	***
year	0.0113975	0.000820322	3.54e-09	***

To fit the data presented in Figure 2 (and Figure 3 thereinafter) also other then linear trend can be used. For example cubic function $y = 0.0001x^3 - 0.6155x^2 + 1233.7x - 824255$, where x is a year and y is a variation coefficient, provides better fit of the data with determinacy

coefficient R^2 = 0.9698, but the point of both figures is to illustrate upward trend of variation coefficient in time, not to find the best numerical approximation.

From Table 1 it is evident that Prague diverged from other regions during 1995-2009. Naturally a question rises, whether the divergence would occur if Prague was excluded from the list of regions. The answer to this question is provided in the next subsection.

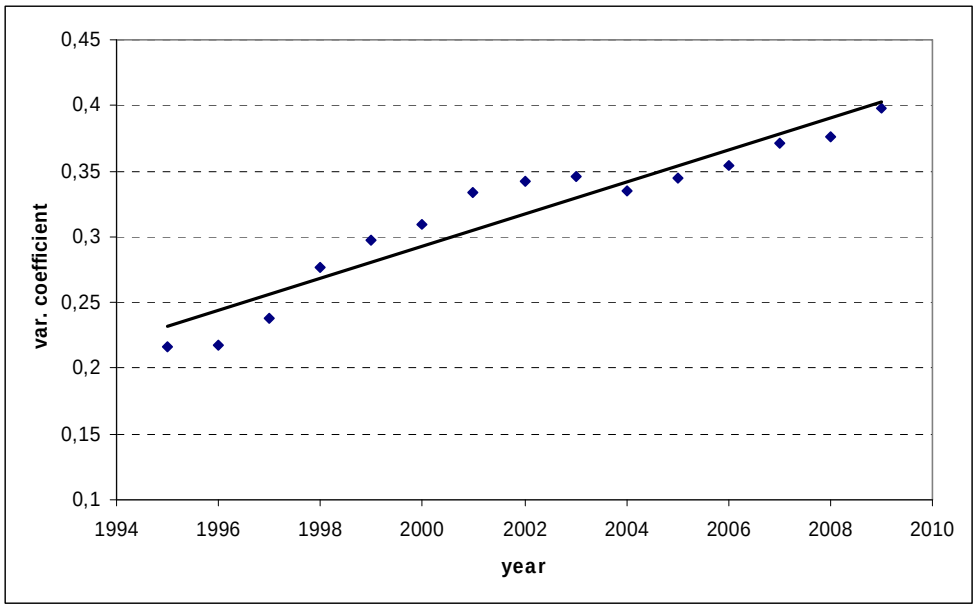

Figure 2. The evolution of variation coefficient, all regions. Source: author.

3.3. Sigma convergence of all regions without Prague

In this section only 13 regions were considered (without Prague). The variation coefficient (3) was evaluated for each year, and is shown in Figure 3. As can be seen, the variation coefficient was much smaller (indicating more homogeneity among regions) and it declined in three years: 1997, 2005 and 2007.

Simple linear regression corrected for heteroscedasticity has the form $y = 0.0033x - 6.558$; where x is a year and y is a variation coefficient. Both regression coefficients, hence the upward trend of the variation coefficient, are strongly statistically significant, see Table 4. Other features of the model: adj. R^2 = 0.9337, p-value of F-test 3.03e-09, Akaike's criterion 65.99 and Hannan-Quinn's criterion 65.98.

According to the model sigma divergence among Czech regions was accelerating even without the capital city Prague. Possible explanation for this development is discussed in the next section.

Table 4. Simple linear regression model, all regions without Prague. Source: author.

	coefficient	error	*p*-value	significance
const	-6.55811	0.470232	3.38e-09	***
year	0.00330883	0.000235128	3.03e-09	***

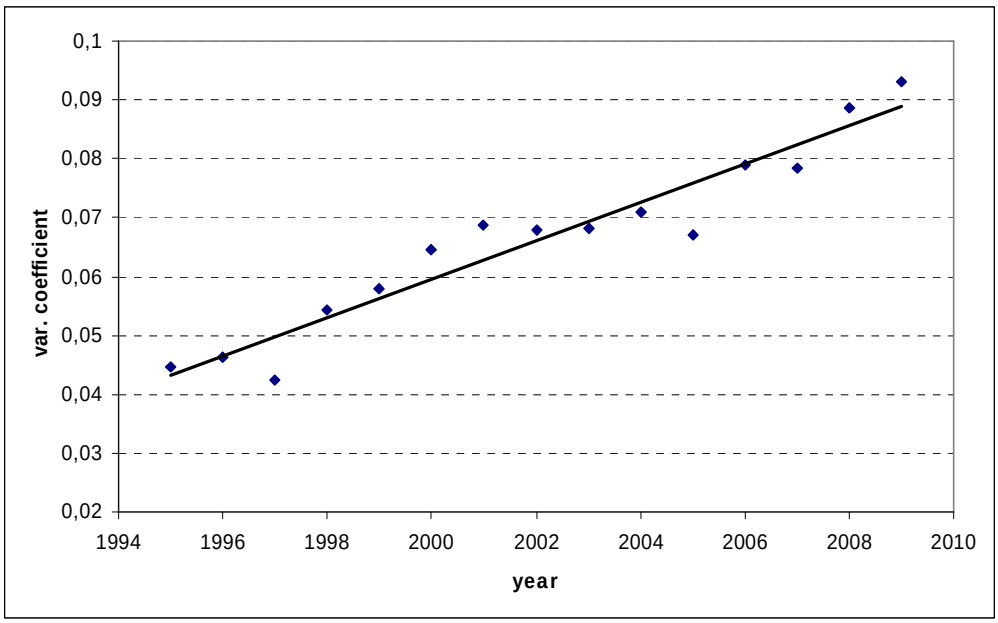

Figure 3. The evolution of variation coefficient, all regions without Prague. Source: author.

4 DISCUSSION

The main result of this study is that there was found (highly statistically significant) both beta and sigma divergence among Czech regions during 1995-2009. Beta divergence means that richer regions in 1995 were getting even richer during examined period, while poorer ones were lagging behind. Also, sigma divergence occurred among regions (with or without the capital city Prague), and this trend was growing with time. When Prague was included among Czech regions, 2004 was the only year when variation coefficient declined in comparison with the preceding year. When Prague was excluded from the list of regions, decline of variation coefficient was observed in 1997, 2005 and 2007. Reason behind the declines in these particular years is rather unclear, as 1997 was a year of economic crisis (GDP declined annualy by –0.7 %) , while in 2005 and 2007 the Czech Republic experienced strong economic growth (by 6.8 % and 5.7 % of GDP annualy).

Both findings of beta and sigma divergence of Czech regions are in accord with other empirical convergence studies. For example Smrčková et al. (2008) found sigma convergence of regions in Slovakia, UK, Greece, Poland or Sweden between 1996 and 2004. This and similar studies indicate that there is convergence on macro-level (level of countries), but divergence on micro-level (regions, districts or counties). Within national borders rich regions tend to grow faster and are getting richer, while on the national level differences among countries decrease, and poorer countries catch up with the richer ones. Explanation of this evolution is rather difficult. Main reasons behind the divergence might be following:

1.) Different level of direct foreign investment in regions, see Table 5. The capital city Prague attracted much more foreign investment than other regions, about 22 % in 2009, while the population of Prague constitutes only 12 % of Czech population. On the other hand, Moravskoslezský region with a population equal to Prague's attracted only 14.5 % of foreign investments when compared to the capital city. Inequalities in foreign investments might be one of the most important reasons behind regional disparity (not only) in the Czech Republic.

Just to briefly illustrate close relationship between foreign investment and economic level, consider regional direct foreign investments in Table 5 and GDP per capita of regions in Table 1 for 2009. Pearson's correlation coefficient between the two variables $r = 0.98$ (statistically significant at $\alpha = 0.01$ level). The same strong correlation ($0.97 \leq r \leq 0.99$) was found in all years between 2000 and 2009. From a political point of view, the regional foreign investment inequalities can be largely attributed to missing or at least ineffective national cohesion policy during examined period. On contrary, convergence on national level is strongly supported by the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund.

2.) The accumulation of national physical and human capital in capital cities or large agglomerations with high-quality infrastructure, large and attractive markets and production/ innovation/research facilities. Within national borders, physical capital tends to accumulate in centers, as they are more attractive not only for foreign investors, but also for domestic ones. Also human capital is attracted into areas, where people can utilize their knowledge. This process is enhanced by no barriers for migration within national borders, so the differences among regions enlarge. However, on the interstate level there are many barriers such as different language, culture, politics, legislation, etc., so the process of capital accumulation is not so substantial, hence beta and sigma convergence on national level is observed more frequently.

3.) The historically determined existence of economic centers (such as Prague) naturally concentrating capital: these centers did accumulate capital in the past and will continue to do so in future. Due to spillover effects also regions close to centers (such as Středočeský region) participate on centers' growth, while more distant regions are left behind. This can be illustrated by the data in Table 1: regions, which experienced relative decline of GDP per capita (compared to the EU average) between 1995 and 2009, lie rather on Czech periphery (far from the three largest cities: Prague, Brno and Ostrava) and include Plzeňský, Karlovarský, Ústecký, Liberecký, Královéhradecký and Olomoucký region.

To quantify how much these and other determinants such as regional infrastructure, education level of inhabitants, environment, etc., actually contribute to beta or sigma divergence more empirical studies from various parts of the world as well as theoretical studies (containing econometric models) are necessary.

Table 5. The direct foreign investment in Czech regions per capita (in thousands of CZK). Source: Portál Inovace (2011).

Region	2000	2009	change (in %)
Praha	328.9	953.6	304
Středočeský	87.2	220.9	282
Jihočeský	49.6	130.5	268
Plzeňský	60.3	125	215
Karlovarský	34.5	72	211
Ústecký	73.7	124.2	170
Liberecký	36.8	133.2	370
Královéhradecký	31	65.1	211
Pardubický	44.1	76.6	176
Vysočina	27.8	113.1	403
Jihomoravský	45.2	116.1	260
Olomoucký	27.8	52	187
Zlínský	34	66.9	195
Moravskoslezský	28.8	138.2	469

5 CONCLUSIONS

In this article beta and sigma convergence of Czech regions during 1995-2009 was examined. Results indicate that Czech regions were diverging during the period regardless of whether Prague was included among regions or not, and the sigma divergence was growing with time almost linearly. Also, beta divergence among regions was found during the period. The same result – the divergence on the scale of regions or counties – was documented in other empirical studies across EU and the USA. However, on the larger scale of countries (or blocks of countries) the situation is usually reversed and beta and sigma convergence occurs.

Regional disparities might occur due to the accumulation of physical and human capital in natural national centers, such as capital cities, large agglomerations, university or research centers equipped with the better infrastructure, thus leaving less attractive regions behind. Another reason stems from unequal foreign or domestic investment. Again, more attractive regions including the capital city attract more investors willing to spend their money and to utilize their know-how. Lower mobility of human and physical capital in the Czech Republic might also contribute to regions' inequalities.

As it is desired by national governments and also EU Commission to reduce differences among regions in EU, national governments should support foreign and domestic investments in poorer regions to stimulate their competitiveness, growth and attractiveness. Also, poorer regions can gain significant help from EU funds such as ESF and ERDF, as convergence of NUTS II and NUTS III regions is one of EU priorities.

As for the future research, it would be interesting to examine convergence during and after the financial crisis, and to compare the development in the Czech Republic with the evolution of other Central European transition economies.

References

Barro, R. Sala-i-Martin, X. (1992). Convergence. *Journal of Political Economy* (100), pp. 223-251.

Barro, R, Salla-i-Martin, X. (1995). *Economic growth*. McGraw-Hill.

Boldrin M., Canova F. (2001). Inequality and convergence in Europe's regions: Reconsidering European regional policies. *Economic Policy*, 32, pp. 205-245.

Czech Statistical Office. (2011). http:/www.czso.cz/.

Evans, P., Karras, G. (1996a). Do Economies Converge? Evidence from a Panel of U.S. States. *Review of Economics and Statistics* (78), pp. 384-388.

Evans, P., Karras, G. (1996b). Convergence Revisited. *Journal of Monetary Economics* (37), pp. 249-265.

Evans, P. (1997). How Fast Do Economies Converge? *Review of Economics and Statistics* (36), pp. 219-225.

Portál inovace. (2011). http://www.portal-inovace.cz/cz/technologicky-profil-lk/zahranicni-obchod/zahranicni-investice/

Islam, N. (1995). Growth Empirics: A Panel Data Approach. *Quarterly Journal of Economics* (110), pp. 1127-1170.

Marelli, E. (2007). Specialisation and Convergence of European Regions. *The European Journal of Comparative Economics*, vol. 4, n. 2, pp. 149-178.

Nevima, J., Melecký, L. (2011). The β-Convergence Analysis of the Visegrad Four NUTS 2 Regions. In *Mathematical Models and Methods in Modern Science*. Puerto De La Cruz, Tenerife, Spain: WSEAS Press, pp. 48-53.

Novotný, J. (2010). Regionální ekonomická konvergence, divergence a další aspekty distribuční dynamiky evropských regionů v období 1992-2006, *Politická ekonomie* 2, pp. 166-184

Ondoš, S. (2011). The Question of Regional Convergence in the Central European Economies. *Region Direct – European Regional Science Association*, pp. 1-18.

Quah, D.T. (1997). Empirics for Growth and Distribution: Stratification, Polarization and Convergence Clubs. *Journal of Economic Growth* (2), pp. 27-59.

Sala-i-Martin, X. (1996). Regional Cohesion: Evidence and Theories of Regional Growth and Convergence. *European Economic Review* (40), pp. 1325-1352.

Smrčková, G., Vlček, I., Cvengroš, F. *Reálná konvergence – souvislosti a příčiny*. Výzkumná studie Ministerstva Financí ČR, 3/2008.

Young, A. T., Higgins, M. J., Levy, D. (2004). Sigma-Convergence versus Beta-Convergence: Evidence from U.S. County-Level Data. *Journal of Money, Credit and Banking*, Blackwell Publishing, vol. 40, n. 5, pp. 1083-1093.