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CONVERGENCE ANALYSIS AMONG THE TEN EUROPEAN TRANSITION ECONOMIES*

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Abstract

This paper presents the analysis of sigma (σ) and beta (β) convergences of per capita GDP among the 10 European countries which accessed the European Union in 2004. Our results confirm the existence of both types of convergence in the second half of the 1990s and the 2000s. Generally, the poorer and new EU member states grew faster than the richer new EU member states. As a result, the income gap between these two groups of countries has narrowed although it still remains quite large. The convergence occurred at the rate of 4.2% during the period 1992-2006 and 7.0% and 9.6% during the sub periods 1995-2006 and 2002-2006, respectively.

Keywords: economic growth, economic convergence, transition economies, European Union.
JEL Classification: F02, F43, O11, O19

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I. *Introduction*

In this paper, we analyse the real economic convergence among the 10 European countries (EU-10) that accessed the European Union (EU) in 2004. This group includes 8 Central and Eastern European countries (CEE-8): the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the Slovak Republic and Slovenia; as well as two island countries from the Southern Europe: Cyprus and Malta. We focus on two concepts of real economic convergence: beta (β) convergence and sigma (σ) convergence.

The initial period of transition was characterised by drastic fall in output; high inflation and rising unemployment for all eight CEE countries (see e.g. Fischer et al., 1998a; Berg et al., 1999; and Fischer and Sahay, 2000); examples include a real GDP growth of about -40% in Latvia in 1992. For most of other countries, the recession finished in 1993 or 1994 (except for Poland and Slovenia, where the recession ended earlier, in 1991 and 1992 respectively). At the beginning of 1990s, inflation had soared, with some countries experiencing hyper-inflations. However, by the end of the 1990s, inflation fell to one-digit or low two-digit levels. Among the new member countries, stabilisation policy became successful leading to positive economic growth.

Conventional literature asserts that trade liberalisation and increased economic integration with more developed countries bring higher growth to the transition economies (Viner, 1950). Low income countries often have a lower capital-labour ratio and have higher rates of return to factors. Thus, they are expected to converge to the levels of income and standard of living of more advanced economies. The convergence mechanism depends on the nature of movement of labour towards higher wages and capital towards higher returns on investment.

The Heckscher-Ohlin (HO) model of international trade predicts two kinds of benefits. In the first place, economic integration promotes competitiveness and growth, reduces general price level, and consequently, increases aggregate welfare. In the second place, that integration promotes convergence to the returns to factors of production (labour, capital and land) and ultimately in the standard of living. Although some losses are also not uncommon, both for the less and more developed economies, the benefits of economic integration are thought to be greater than the losses. Ben-David (1996), for example, puts the evidence of convergence in the relative standard of living among a group of countries, which have strong trading relations. Convergence fails where countries are not integrated into the same trading networks. As predicted by the Factor Price Equalisation (FPE) theorem, the wages of low and unskilled workers are expected to increase in less developed countries and decline in more developed countries, but wages of highly skilled workers are expected to increase in the latter and decline in the former group of countries.

Among the EU countries, following effective integration, the accession EU-10 countries are expected to grow faster than the core EU-15 countries. According to Fischer et al. (1998b), economic growth in the low income countries depends on two sets of factors; in the first place, on factors directly related to the transition process, which can be further separated into initial conditions and reform policies. In the second place, according to neoclassical growth theory, it depends on the determinants of long-run growth; for example, technical progress and factor accumulation. In the first set of factors, initial conditions do have a significant effect at the beginning of transition; but that their importance declines rapidly (see e.g. deMelo et al., 1997;

Havrylyshyn et al., 1998; and Berg et al., 1999). DeMelo et al. (1997) find that initial conditions do matter significantly, but the adverse effect of unfavourable initial conditions can be overcome by strict commitment to reform policy.

The β-convergence hypothesis is based on the neoclassical models of economic growth. These models predict that absolute convergence occurs only if the economies concerned are homogenous meaning that they approach the same steady-state. If the countries are heterogeneous, absolute convergence need not take place and the conditional convergence hypothesis should be tested.

The enlarged European Union consists of very different countries. On the one hand, western European countries are highly developed market economies. On the other hand, the transition countries from Central and Eastern Europe are middle income and market-oriented economies. Thus, when analysing the absolute convergence in the whole EU area, one basic assumption of the same steady-state is not satisfied and the results obtained may be misleading. The EU-10 group, however, is more homogenous, except for the small economies of Malta and Cyprus. Moreover, the new EU member states from the CEE area have the same post-war history. They were centrally planned economies until the 1980s and now undertaking similar macroeconomic and structural reforms towards market economy[1]. All of them were expected to reduce income disparities with EU-15 and among themselves.

Here, we briefly review the homogeneity of the EU-10 countries among themselves and with reference to two other groups of countries: the former EU members (EU-15) and the other transition economies of Eastern Europe and central Asia (TR-20)[2]. The comparison is based on six macroeconomic variables for the period 1992-2006 (Table 1).

Among the EU-10, EU-15 and TR-20 countries, as expected, EU-15 countries possess much homogenous characteristics. However, the comparison between EU-10 and other transition economies of Eastern Europe and Central Asia (TR-20), EU-10 group reveals higher degree of homogeneity except in case of one variable — credit to the private sector. Otherwise, the most frequently used socio-economic indicators, such as, gross fixed capital formation, shares of major economic activities in GDP do have relatively small standard deviation among EU-10 countries as compared to TR-20 countries (Table 1). Therefore, the EU-10 countries are expected to exhibit some income-level convergence as the neoclassical theory of economic growth predicts.

In this paper, we study the degree of per capita income convergence among the EU-10 countries, using the econometric method. Our analysis is based on the International Monetary Fund data (*World Economic Outlook Database, September 2006*) and covers the 1992-2006 period.

The rest of this paper is organised as follows. Section II presents the concepts of β and σ convergences. It is followed by the theoretical background of convergences, especially with reference to Solow's neoclassical growth model. Moreover, we review some of the most recent works on real economic convergences. Section III presents our empirical findings. Section IV concludes the paper.

[1] For an in-depth analysis on structural reforms in the post-socialist countries, see Vojinović and Oplotnik (2008).

[2] TR-20 group includes Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, FYR Moldova, Montenegro, Romania, Russian Federation, Serbia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

TABLE 1. EU-10 AND THE OTHER TRANSITION COUNTRIES (TR-20) COMPARED WITH EU-15 (1992-2006)

Variable	Cyprus	Czech. Rep.	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Slovak Rep.	Slovenia	EU-10		EU-15		TR-20	
											st. dev.	avg.	st. dev.	avg.	st. dev.	avg.
Gross fixed capital formation (% of GDP)	20.0	28.0	27.6	21.9	21.7	22.0	23.9	19.8	28.5	22.9	3.1	23.6	2.2	20.3	5.0	21.1
Life expectancy at birth, total (years)	78.1	74.4	70.2	71.1	69.3	70.8	77.7	73.3	73.1	75.3	2.9	73.3	0.9	77.8	3.3	69.7
Agriculture, value added (% of GDP)	5.5	4.1	6.4	5.7	6.6	9.2	3.1	5.8	4.6	3.6	1.7	5.5	1.5	2.9	9.4	20.6
Services value added (% of GDP)	70.0	55.9	64.8	62.5	66.9	57.6	61.3	60.9	62.9	60.0	4.0	62.3	4.9	69.4	9.0	47.0
Domestic credit to private sector (% of GDP)	191.0	52.8	27.9	33.4	29.8	20.6	104.6	24.5	43.0	36.7	50.4	56.4	22.5	94.0	11.7	17.8
Index of economic freedom	70	68	74	62	65	65	62	60	60	59	5	64	6	68	6	50

Data for the individual countries represent for the period 1992-2006 (for some countries, the average covers shorter period, depending on data availability).
EU-10: new EU member countries (except Bulgaria & Romania), EU-15: former EU members, TR-20: the remaining transition countries (including Bulgaria & Romania).
Source: Own calculations based on Eurostat, Heritage Foundation, and EBRD data.

II. *Process and Measure of Convergence*

1. σ Convergence

σ convergence occurs when income differentiation between economies decreases over time. The dispersion of income levels can be measured by standard deviation, variation, or the coefficient of variation (CV) of GDP per capita among economies. In our analysis we use the coefficient of variation of GDP per capita at PPP (purchasing power parity), which is given by:

$$CV=\frac{\text{standard deviation}}{\text{mean}}. \tag{1}$$

In order to verify the σ convergence hypothesis, we estimate the trend line of the dispersion in income levels among countries:

$$CV(y_t)=\alpha_0+\alpha_1 t+\varepsilon_t. \tag{2}$$

The explained variable is the coefficient of variation of GDP per capita levels among the economies while the explanatory variable is the time variable: $t=1,\ldots,15$ for the period 1992-2006; ε_t is the error term. If parameter α_1 is negative, σ convergence exists.

2. β Convergence

β convergence occurs when less developed countries grow faster than more developed countries, meaning that there is a negative relationship between initial income level and its growth rate. β convergence can be broadly classified into conditional and absolute (unconditional) convergences. If the per capita outputs of different countries converge to their respective states upon the control of the determinants of the steady state, we get 'conditional convergence' (Mankiw et al., 1992). Absolute convergence, however, refers to a process when per capita outputs exhibit a tendency towards a convergence, even if we do not control other factors that might affect evolution of output.

β convergence is a necessary but not the sufficient condition for σ convergence. It is possible that the countries reveal β convergence but not a σ one.[3] In this study, we analyse both absolute and conditional β convergence.

The absolute β convergence is analysed based on the cross-sectional data: the average annual GDP growth rate for a given period is regressed against the GDP level from the initial level. We start with the cross-sectional data because it is free of the distortions caused by business cycles as well as various demand-side and supply-side random shocks, both internal and external, that deviate the economy from a path towards the steady-state.

Furthermore, we also calculate the speed of conditional β convergence based on the panel data — annual GDP growth rates regressed against the GDP levels from the previous year. This will help reinforce our conclusion stemming from the unconditional convergence.

In order to verify the absolute β convergence hypothesis based on cross-sectional data, we estimate regression in the form:

$$\frac{1}{T}\log\frac{y_{i,T}}{y_{i,0}}=\alpha_0+\alpha_1\log y_{i,0}+\varepsilon_i, \tag{3}$$

where $\log y_T$ and $\log y_0$ are the natural logarithms of GDP per capita at PPP in country i in the last and the first year of the period under analysis, respectively; α_0 is a constant; ε_i is the error term; and T indicates the duration of the period.[4]

In order to verify the conditional β convergence hypothesis based on panel data, we estimate the following regression model:

$$\log y_{i,t}-\log y_{i,t-1}=\alpha_0+\alpha_1\log y_{i,t-1}+\sum_{k=1}^{n}\phi_k X_{kt}+\varepsilon_{i,t}, \tag{4}$$

where $\log y_{i,t}$ is the natural logarithm of GDP per capita at PPP in country i at time t, α_0 is a constant, X_{kt} represents a vector of n control variables, and $\varepsilon_{i,t}$ is the error term. The regression is estimated using a fixed-effects method for the panel data. The control variables in the regression equation allow us to capture the influence of business cycles and other factors on the

[3] There are two explanations. First, if a poor country grows faster than a rich country (β convergence) and exceeds the income level of a rich country, the differences between countries need not diminish (no σ convergence). Second, if GDP in a poor country is 1$ and in a rich country it is 1,000,000$ and the poor country grows at the rate of 50% and the rich country at the rate of 40% (β convergence), the new income levels are: 1.5$ and 1,400,000$, so the income differences are greater (no σ convergence).

[4] The number of years is actually $T + 1$ because of the inclusion of both first and last year in the analysis.

rate of economic growth.

In both of the cases, convergence occurs when $\alpha_1 < 0$, indicating that higher initial income level negatively affects the consequent growth rate. In such a case, we can calculate the value of β coefficient which exactly indicates the speed of convergence (for panel regressions $T=1$):[5]

$$\beta = -\frac{1}{T}\ln(1+\alpha_1 T). \tag{5}$$

The parameter β informs the distance from the steady-state the economy is converging during one year. For example, if $\beta = 0.02$, the economy converges at the annual rate of 2%.

3. Solow's Growth Model and Convergence

According to the standard neoclassical growth model of Solow (Solow, 1956), convergence occurs because of lower and diminishing returns to investment in more developed and capital-abundant countries and sectors. Capital investment spreads to new, less-capital abundant countries and sectors, where returns to investment are higher; likewise, labour migrates to the more developed countries where wages are higher. Nevertheless, capital accumulation merely cannot sustain growth in the long term, while growth in total factor productivity can.

The Solow model does not predict absolute convergence, but it does predict that per capita income in an economy converges to its steady-state value. It also predicts convergence in factor prices and the standard of living. In this case, convergence occurs not as a result of trade, but rather as a result of diminishing returns to investment in more developed economies and economic sectors and variation in the rate of economic growth across countries. Where the capital labour ratio is higher, additional capital inputs produce even-smaller returns on investment.

It is worth to emphasise that the neoclassical concept of conditional convergence has been rejected by many other models. Newer models of economic growth which belong to endogenous growth theory give completely different conclusions with regards to convergence. The most important difference between the neoclassical and endogenous growth theory is that the latter does not assume decreasing returns to scale, which is the main argument behind the catching-up process in the neoclassical models. All the endogenous models assume constant or increasing returns to factor inputs. This implies that these models do not confirm the existence of convergence even in conditional terms. For example, the Romer model of learning-by-doing (Romer, 1986) says that economic growth rate rises with income level, implying a divergence process. The same is argued by the Romer model with an expanding variety of products (Romer, 1990). The analysis of the transitional period in the two-sector Lucas model (Lucas, 1988) informs that less developed countries may grow faster or slower than more developed countries, depending on whether poorer economies have scarce physical capital or human

[5] Barro and Sala-i-Martin (2003, p. 467) analyse β convergence based on the neoclassical model. They derive the equation that relates the average economic growth rate with the initial income level:

$$(1/T)\log(y_{iT}/y_{i0}) = a - [(1-e^{-\beta T})/T]\log(y_{i0}) + w_{i0,T},$$

where y_{iT} and y_{i0} — GDP per capita in the country i in the final and the initial year, T — the length of the period, β — the coefficient of the speed of convergence, a — a constant term, $w_{i0,T}$ — an error term. The coefficient on initial income, i.e. $-[(1-e^{-\beta T})/T]$, is equal to the α_1 coefficient in equations (3) and (4). Thus, from $\alpha_1 = -[(1-e^{-\beta T})/T]$ we obtain the equation (5).

capital. The Aghion-Howitt model with an expanding quality of products (Aghion and Howitt, 1992) indicates no relationship between income level and growth rate.

We will analyse our results on convergence in Section III with reference to all these conflicting views.

4. Leading Experiences

Empirical research on economic growth has witnessed an enormous interest during the last 20 years. Empirical analyses on convergence began to appear in the economic literature from the beginning of the 1980s. One of these earlier studies was by Baumol (1986), who argued that homogenous groups of countries grow to converge towards a particular growth rate; while heterogeneous countries reveal rather divergence processes. Furthermore, empirical analyses on convergence were popularised by Barro (1989), Mankiw et al. (1992) and Barro and Sala-i-Martin (2003). Their analyses are mostly based on two methods. The first one is the Barro-regression method, where economic growth rate is regressed on the initial GDP level and other economic growth determinants. The second one is the Mankiw-Romer-Weil method, where economic growth rate is regressed on the initial income level and the variables which determine the steady-state of a given country according to the Solow model.

The empirical analyses on convergence of income for CEE countries began to appear in the late 1990s. The most recent works are: European Commission (2001), Wagner and Hlouskova (2002), EEAG (2004), Kaitila (2004), Kutan and Yigit (2004, 2005), Varblane and Vahter (2005), Próchniak (2008) and Vojinović and Oplotnik (2008). Although these analyses vary substantially on the period of coverage, the sample of countries, data, and the method, they all agree that the new EU countries grew during 1990s and 2000s in line with the neoclassical convergence hypothesis. The convergence occurred among the new EU member countries as well as between these countries and other EU members. Nevertheless, the pace of the catching-up process has been very slow.

Many studies on real per-capita income convergence have revealed an approximately 2% annual rate of convergence worldwide (see, for example, Barro and Sala-i-Martin, 2003 and Vojinović, 2005). Contrary to this, the studies focussed on the EU countries report a faster rate of convergence. Wagner and Hlouskova (2002) base their analysis on the historical convergence of the EU countries and then project it to the accession countries. With the exception of the higher income Slovenia and the Czech Republic, they estimate three to four decades for full convergence of per capita income of accession countries to the core EU countries. Kaitila (2004) reports the rate of income convergence of 3.4% per-annum for 7 CEE countries (excluding Slovenia) during 1995-2001.

Some studies have estimated both σ and β convergences. Varblane and Vahter (2005) confirm the existence of β convergence among 10 transition countries during 1993-2004, but they reject the existence of σ convergence among these countries during 1995-2005. Próchniak (2008) and Vojinović and Oplotnik (2008), however, confirm the existence of β and σ convergences among the CEE-8 countries as well as between CEE-8 and EU-15 countries. The speed of convergence is more rapid than annual 2% rate. According to some of the most recent research, that of Alsasua et al. (2007), Cornelisse and Goudswaard (2002), Corrado et al. (2003) and Vojinovic (2005), CEE-8 countries have converged to a common steady-state at the annual rate around 5% during 1993-2005, which could require about 14 years to reduce by a

half the distance to their common steady-state. The convergence to the European Union, however, was significantly slower, at the rate of 2.5% per annum.

III. *Findings*

1. σ Convergence

The results of σ convergence for EU-10 countries for the period 1992-2006 are presented in Table 2 and Figure 1.

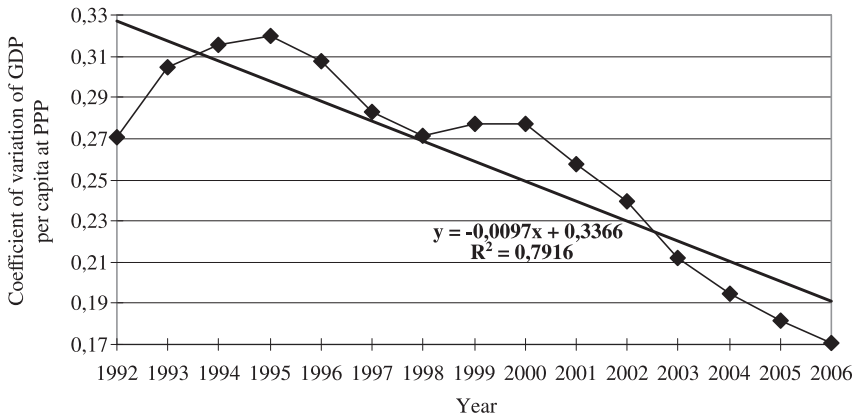
Table 2 presents the level of GDP per capita at PPP for the individual countries as well as the respective coefficient of variation. Figure 1 graphs the tendency of the coefficient of variation along with the trend line for the whole period 1992-2006.

The data show that the EU-10 countries revealed σ convergence during 1992-2006. The income differentiation between the economies decreased over time.

In some years, however, the EU-10 countries revealed σ-divergence. Income differentiation among these countries increased during 1992-1995 and 1998-1999. The σ-divergence in the first half of the 1990s was due to the recession, which in some countries, such as the Baltic States, lasted until the mid-1990s causing short-term σ-divergence.

Higher and sustainable GDP per capita growth rates after 1995 have caused successively lower income dispersion, and thus a faster rate of σ convergence. Faster growth in poorer regions, of course, presumes that poorer nations are capable of learning and adopting new and more efficient technologies and production processes, along with a well-functioning legal, administrative and physical infrastructure, coupled with stable macroeconomic and political

FIG 1. σ CONVERGENCE OF GDP PER CAPITA AT PPP IN THE EU-10 COUNTRIES, 1992-2006



	Parameter	*t*-statistics	*p*-value
Intercept	0.3366	26.76	0.000
Slope	− 0.0097	− 7.03	0.000

TABLE 2. GDP PER CAPITA AT PURCHASING POWER PARITY (USD), 1992-2006

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Cyprus	11913	12047	12778	14016	14556	14912	15591	16334	17281	18172	18633	19135	20129	21232	22334
Czech Rep.	10432	10680	11139	12053	12821	12943	12963	13223	13968	14750	15266	16074	17220	18375	19478
Estonia	6157	5949	6279	6831	7384	8453	9010	9260	10258	11225	12300	13440	14926	16414	17802
Hungary	8434	8605	9069	9431	9774	10432	11104	11779	12725	13601	14395	15196	16336	17405	18492
Latvia	5002	4547	4820	5121	5484	6098	6522	6895	7600	8452	9226	10177	11396	12622	13784
Lithuania	7341	6244	5770	6172	6790	7440	8129	8164	8730	9559	10420	11713	12856	14158	15443
Malta	10947	11528	12214	13263	13948	14761	15354	16136	18017	18253	18667	18555	19100	19739	20365
Poland	5739	6105	6547	7128	7693	8346	8839	9340	9914	10384	10719	11359	12293	12994	13797
Slovak Rep.	7770	7629	8228	8870	9576	10165	10691	10985	11453	12161	12934	13775	14904	16041	17239
Slovenia	10255	10844	11665	12392	13082	13973	14686	15658	16604	17423	18317	19161	20574	21911	23250
St. deviation	2271	2562	2793	3047	3111	3045	3061	3267	3509	3449	3376	3151	3104	3099	3108
Mean	8399	8418	8851	9528	10111	10752	11289	11777	12655	13398	14088	14859	15973	17089	18198
Sigma convergence	0.27	0.30	0.32	0.32	0.31	0.28	0.27	0.28	0.28	0.26	0.24	0.21	0.19	0.18	0.17

Source: International Monetary Fund, *World Economic Outlook Database, September 2006*. Sigma convergence coefficients are authors' calculations.

environments.

2. β Convergence

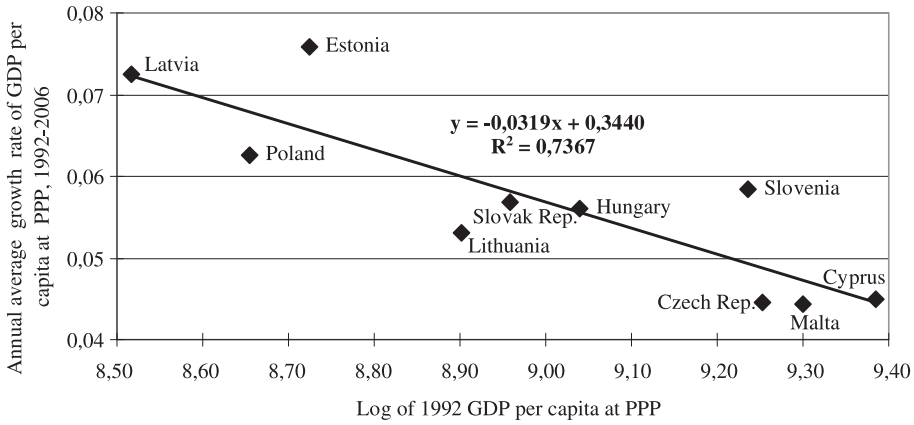
We analyse β convergence in the EU-10 countries for the full 1992-2006 period as well as three sub-periods: 1992-1997, 1995-2006, and 2002-2006. We made this subdivision of the whole period 1992-2006 into shorter ones in order to test the sensitivity of the results on convergence. The reason of this sub-division is that the first sub-period covers the years when the efforts linked with EU enlargement were not yet strongly pursued and several CEE countries suffered with the transition recession. The second subperiod does not include the years of transition recession. The third subperiod 2002-2006 includes the period while all the CEE countries were in EU.

The results for β convergence for the whole period as well as three distinguished sub-periods are presented in Figures 2-5 and Tables 3-6.

The figures show the results of testing the absolute convergence hypothesis based on cross-sectional data. The particular points marked on the chart represent the initial income level and the average annual growth rate over a given period. The figures also present the trend line and the regression equation. Below each figure, there are *t*-statistics, *p*-values, and the estimated β coefficients that measure the speed of convergence.

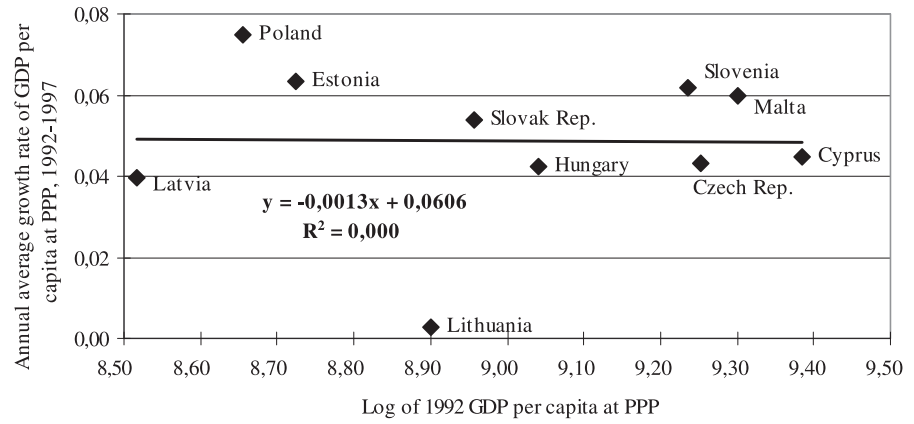
The tables present the results of testing the conditional convergence hypothesis based on panel data. In our research, we include five control variables: (a) gross fixed capital formation (% of GDP), (b) final consumption expenditure (% of GDP), (c) general government balance (% of GDP), (d) exports of goods and services (% of GDP), and (e) inflation rate (annual %). The control variables refer to the demand-side GDP equation according to which GDP is the sum of consumption, investment, government spending on goods and services, and exports net imports. Since annual GDP growth rates are influenced by the fluctuations of aggregate demand, we include the demand-side macroeconomic variables in the convergence equation to capture these effects.

FIG 2. ABSOLUTE β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON CROSS-SECTIONAL DATA, 1992-2006



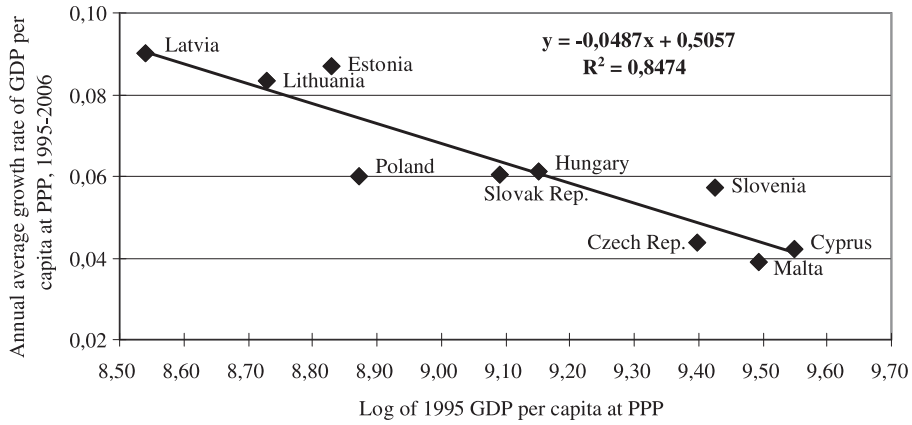
	Parameter	*t*-statistics	*p*-value	β coefficient
Intercept	0.3440	5.67	0.000	4.2%
Slope	− 0.0319	− 4.73	0.001	

FIG 3. ABSOLUTE β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON CROSS-SECTIONAL DATA, 1992-1997



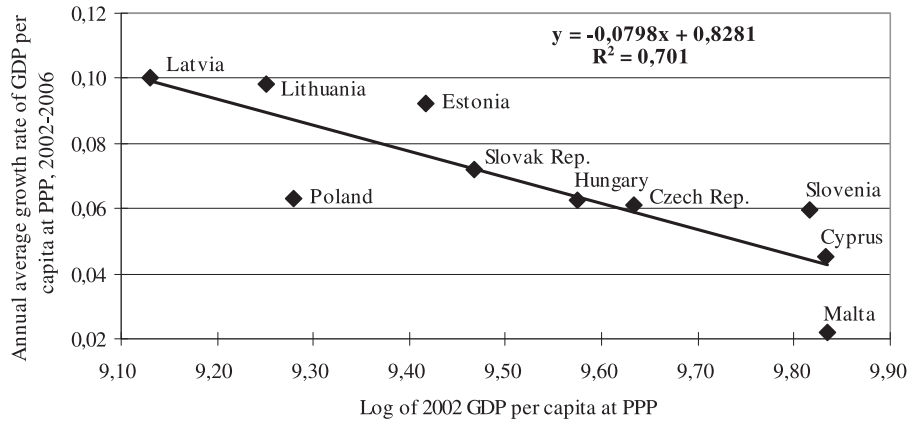
	Parameter	*t*-statistics	*p*-value	β coefficient
Intercept	0.0606	0.29	0.781	0.1%
Slope	− 0.0013	− 0.06	0.956	

FIG 4. ABSOLUTE β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON CROSS-SECTIONAL DATA, 1995-2006



	Parameter	*t*-statistics	*p*-value	β coefficient
Intercept	0.5057	7.60	0.000	7.0%
Slope	− 0.0487	− 6.66	0.000	

FIG 5. ABSOLUTE β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON CROSS-SECTIONAL DATA, 2002-2006



	Parameter	*t*-statistics	*p*-value	β coefficient
Intercept	0.8281	4.72	0.001	9.6%
Slope	− 0.0798	− 4.34	0.002	

TABLE 3. CONDITIONAL β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON PANEL DATA, 1992-2006

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.7306 4.35 0.000	0.4838 4.33 0.000	0.3406 3.25 0.002	0.3476 3.44 0.001	0.0080 0.09 0.928	−0.2669 −2.31 0.022
Log of GDP per capita at PPP from the previous year	−0.0629 −4.59 0.000	−0.0546 −4.13 0.000	−0.0315 −2.85 0.005	−0.0282 −2.66 0.009	0.0062 0.66 0.508	0.0347 2.81 0.006
Gross fixed capital formation (% of GDP)	0.0017 2.34 0.021	0.0021 3.00 0.003	0.0016 2.26 0.026			
Final consumption expenditure (% of GDP)	−0.0019 −1.95 0.054					
General government balance (% of GDP)	0.0021 3.23 0.002	0.0023 3.50 0.001	0.0024 3.54 0.001	0.0023 3.45 0.001		
Exports of goods and services (% of GDP)	0.0009 2.65 0.009	0.0010 2.97 0.004				
Inflation rate (annual %)	−0.0019 −7.77 0.000	−0.0017 −7.50 0.000	−0.0015 −6.65 0.000	−0.0016 −7.55 0.000	−0.0007 −10.72 0.000	
F statistics (*p*-value)	15.23 (0.000)	17.04 (0.000)	17.76 (0.000)	22.61 (0.000)	64.91 (0.000)	7.89 (0.006)
Number of obs.	117	117	117	124	140	140
Number of groups	10	10	10	10	10	10
Obs. per group: min/avg/max	5/11.7/14	5/11.7/14	5/11.7/14	12/12.4/14	14/14/14	14/14/14
R-square: - within	0.4750	0.4552	0.4081	0.3793	0.5035	0.0576
- between	0.2001	0.2226	0.6301	0.6309	0.1781	0.5502
- overall	0.2982	0.3011	0.4528	0.4263	0.3688	0.0000
β coefficient	6.5%	5.6%	3.2%	2.9%	x	x

Dependent variable: The growth rate of GDP per capita at PPP. Method: Fixed-effects panel data regression.

For each period, six convergence equations are estimated. Model 1 includes all the five control variables. Models 2-5 are derived from model 1 by a gradual elimination of a least significant variable (based on the results for the period 1992-2006). Model 6 does not include any control variable (meaning that absolute convergence based on panel data is tested). At the bottom of the table, there are regression characteristics as well as the estimated values of β coefficient.

We calculate β coefficients from the regressions based on both cross-sectional and panel data. However, we have to emphasise that the β coefficients are more accurate when they are based on cross-sectional data. Here, β measures the absolute convergence. In the case of conditional convergence, however, the values of β may be overestimated. This is because in such regressions there are many explanatory variables and the coefficient on initial income level may have spuriously too high negative value. Even if this strong negative relationship is not spurious, the interpretation of β coefficient in terms of the convergence of income has only a theoretical importance because the income differences between economies do not necessarily

TABLE 4. CONDITIONAL β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON PANEL DATA, 1992-1997

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	2.0773 4.73 0.000	1.9794 4.18 0.001	1.7479 3.59 0.002	1.5533 3.34 0.003	−0.4468 −0.81 0.422	0.0202 0.02 0.981
Log of GDP per capita at PPP from the previous year	−0.1979 −3.83 0.001	−0.2200 −4.00 0.001	−0.1868 −3.37 0.003	−0.1593 −3.11 0.005	0.0570 0.94 0.355	0.0031 0.03 0.973
Gross fixed capital formation (% of GDP)	0.0018 1.04 0.312	0.0016 0.88 0.391	0.0023 1.22 0.237			
Final consumption expenditure (% of GDP)	−0.0030 −2.11 0.050					
General government balance (% of GDP)	0.0020 3.44 0.003	0.0024 3.81 0.001	0.0025 3.76 0.001	0.0023 3.55 0.002		
Exports of goods and services (% of GDP)	0.0006 0.62 0.541	0.0018 1.90 0.073				
Inflation rate (annual %)	−0.0026 −8.74 0.000	−0.0026 −7.95 0.000	−0.0021 −9.83 0.000	−0.0022 −10.14 0.000	−0.0007 −7.33 0.000	
F statistics (*p*-value)	27.15 (0.000)	26.84 (0.000)	28.87 (0.000)	37.14 (0.000)	26.88 (0.000)	0.00 (0.973)
Number of obs.	34	34	34	34	50	50
Number of groups	10	10	10	10	10	10
Obs. per group: min/avg/max	3/3.4/5	3/3.4/5	3/3.4/5	3/3.4/5	5/5/5	5/5/5
R-square: - within	0.9005	0.8760	0.8524	0.8414	0.5859	0.0000
- between	0.1775	0.2177	0.2422	0.2062	0.2859	0.0381
- overall	0.4137	0.3124	0.3812	0.4027	0.4134	0.0051
β coefficient	22.1%	24.8%	20.7%	17.4%	x	x

Dependent variable: The growth rate of GDP per capita at PPP. Method: Fixed-effects panel data regression.

diminish. Thus, when interpreting the values of β coefficients, we will focus on cross-sectional regressions.

Figure 2 indicates that the EU-10 countries have developed in line with the β convergence hypothesis during the whole period analysed — 1992-2006. In average, the less developed countries grew faster than more developed ones. The highest growth rates (greater than 7%) were recorded in Estonia and Latvia, i.e. the countries relatively poor in 1992. Poland, which was another poor country, also recorded a high growth rate of more than 6%. On the other hand, Czech Rep., Malta, and Cyprus, i.e. the rich economies in 1992, revealed relatively slow economic growth — less than 5% during 1992-2006.

The regression equation further reinforced by very good statistical properties is the evidence of the convergence of the EU-10 countries' per capita income during 1992-2006. The coefficient of initial income is highly significant (p-value = 0.001) and R-square of the regression is also high (74%). The regression equation shows that individual countries reveal very good trend of convergence as evident from statistically significant values of β coefficient.

TABLE 5. CONDITIONAL β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON PANEL DATA, 1995-2006

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.6290 3.90 0.000	0.2028 1.73 0.087	0.0738 0.59 0.554	0.0987 0.84 0.405	0.0345 0.31 0.757	0.0087 0.11 0.916
Log of GDP per capita at PPP from the previous year	−0.0423 −3.28 0.001	−0.0292 −2.22 0.029	−0.0042 −0.32 0.750	−0.0030 −0.24 0.808	0.0032 0.27 0.787	0.0058 0.67 0.507
Gross fixed capital formation (% of GDP)	0.0012 1.92 0.058	0.0021 3.36 0.001	0.0015 2.20 0.030			
Final consumption expenditure (% of GDP)	−0.0035 −3.63 0.000					
General government balance (% of GDP)	0.0009 1.07 0.288	0.0013 1.47 0.145	0.0014 1.46 0.148	0.0014 1.57 0.119		
Exports of goods and services (% of GDP)	0.0014 4.44 0.000	0.0015 4.49 0.000				
Inflation rate (annual %)	−0.0001 −0.37 0.714	−0.0001 −0.31 0.755	−0.0002 −0.46 0.647	−0.0003 −0.73 0.467	−0.0001 −0.34 0.732	
F statistics (*p*-value)	7.60 (0.000)	5.76 (0.000)	1.81 (0.134)	1.01 (0.391)	0.28 (0.757)	0.44 (0.507)
Number of obs.	113	113	113	120	120	120
Number of groups	10	10	10	10	10	10
Obs. per group: min/avg/max	5/11.3/12	5/11.3/12	5/11.3/12	12/12/12	12/12/12	12/12/12
R-square: - within	0.3197	0.2272	0.0680	0.0276	0.0051	0.0040
- between	0.0119	0.0344	0.3843	0.5911	0.7355	0.7664
- overall	0.0301	0.0400	0.1667	0.1848	0.0764	0.1507
β coefficient	4.3%	3.0%	0.4%	0.3%	x	x

Dependent variable: The growth rate of GDP per capita at PPP. Method: Fixed-effects panel data regression.

The slope of the regression line implies that the estimated β coefficient for the whole period equals 4.2%. This means that the countries of the enlarged EU reduce the distance towards the common hypothetical steady-state by 4.2% annually. Thus, it is not a rapid catching-up process but slightly faster than a 2% speed of convergence observed worldwide.

Based on the panel data, countries exhibited conditional convergence (Table 3) implying that the annual GDP growth rates bear negative relationship with the GDP per capita of the preceding years provided that other variables are controlled. The conditional convergence is confirmed by model 1 with all the five control variables (investments, consumption, government balance, exports, and inflation) as well as by models 2, 3, and 4 that include fewer control variables. The convergence based on panel data has only a conditional form because model 6 indicates that the catching-up process did not occur in absolute terms as revealed by the positive relationship between the annual GDP growth rate and the income level of the previous year.

The detailed analysis indicates that β convergence — based on cross-sectional data —

TABLE 6. CONDITIONAL β CONVERGENCE IN THE EU-10 COUNTRIES BASED ON PANEL DATA, 2002-2006

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.6840 1.77 0.086	0.3435 1.02 0.317	0.0319 0.15 0.881	0.1500 0.88 0.384	−0.1494 −0.88 0.384	−0.1388 −0.85 0.403
Log of GDP per capita at PPP from the previous year	−0.0377 −0.92 0.364	−0.0320 −0.76 0.451	0.0088 0.37 0.716	−0.0070 −0.40 0.695	0.0225 1.26 0.214	0.0213 1.24 0.221
Gross fixed capital formation (% of GDP)	−0.0003 −0.18 0.861	−0.0003 −0.18 0.856	−0.0014 −1.07 0.292			
Final consumption expenditure (% of GDP)	−0.0032 −1.68 0.103					
General government balance (% of GDP)	0.0036 2.55 0.016	0.0038 2.69 0.011	0.0037 2.56 0.015	0.0043 3.58 0.001		
Exports of goods and services (% of GDP)	0.0002 0.30 0.764	0.0008 1.18 0.246				
Inflation rate (annual %)	−0.0008 −0.68 0.503	−0.0007 −0.60 0.556	−0.0008 −0.70 0.487	−0.0012 −1.14 0.262	−0.0004 −0.30 0.765	
F statistics (*p*-value)	2.83 (0.027)	2.67 (0.041)	2.95 (0.035)	4.98 (0.005)	0.80 (0.457)	1.54 (0.221)
Number of obs.	45	45	45	50	50	50
Number of groups	9	9	9	10	10	10
Obs. per group: min/avg/max	5/5/5	5/5/5	5/5/5	5/5/5	5/5/5	5/5/5
R-square: - within	0.3612	0.3009	0.2694	0.2876	0.0404	0.0381
- between	0.4068	0.2281	0.0443	0.4717	0.6339	0.6104
- overall	0.3972	0.2386	0.0796	0.4340	0.3921	0.3725
β coefficient	3.8%	3.3%	x	0.7%	x	x

Dependent variable: The growth rate of GDP per capita at PPP. Method: Fixed-effects panel data regression.

accelerated over time.

Countries exhibited no convergence during 1992-1997 (Figure 3). The coefficient on initial income close to zero and *p*-value of 0.956 indicate no significance of the explanatory variable. However, for the period 1995-2006, the convergence was apparent (Figure 4). The regression is characterised by a very high *R*-square value (85%) and a significant negative slope coefficient (*p*-value = 0.000). It implies a relatively fast income-level convergence (β coefficient 7.0%). This is much faster catching-up process than in the whole period 1992-2006.

Moreover, if we focus on the very end of the period analysed — 2002-2006, the convergence becomes even more rapid (Figure 5). The β coefficient for this period equals 9.6% indicating a very fast income-level convergence. The two poorest countries in 2002 (Table 1), Latvia and Lithuania, revealed very high GDP growth rate of about 10%. Also Estonia, which was the fourth poorest country, recorded a fast economic growth of about 9%. On the other hand, the richest country, Malta, recorded an extremely slow annual economic growth of 2%. These facts confirm a rapid tendency towards the common hypothetical steady-state. The high

TABLE 7. TESTING THE HYPOTHESIS ON THE EQUALITY OF CONVERGENCE COEFFICIENTS

	β = 4.2% (1992-2006)	β = 0.1% (1992-1997)	β = 7.0% (1995-2006)	β = 9.6% (2002-2006)
β = 4.2% (1992-2006)	x	$F(1,16) = 2.38$ p-value = 0.143	$F(1,16) = 1.90$ p-value = 0.187	$F(1,16) = 3.31$ p-value = 0.088
β = 0.1% (1992-1997)	$F(1,16) = 2.38$ p-value = 0.143	x	$F(1,16) = 5.81$ p-value = 0.028	$F(1,16) = 6.99$ p-value = 0.018
β = 7.0% (1995-2006)	$F(1,16) = 1.90$ p-value = 0.187	$F(1,16) = 5.81$ p-value = 0.028	x	$F(1,16) = 0.72$ p-value = 0.409
β = 9.6% (2002-2006)	$F(1,16) = 3.31$ p-value = 0.088	$F(1,16) = 6.99$ p-value = 0.018	$F(1,16) = 0.72$ p-value = 0.409	x

Each test is a non-linear F test. Null hypothesis assumes the equality between β coefficients from two regression equations. Shadowed cells indicate the rejection of null hypothesis implying that β coefficients are statistically different.

R-square coefficient (70%) reinforces this fact.

Tables 4-6 show the existence of conditional convergence based on panel data for the sub-periods. If we control the economic growth determinants, the initial income level is negatively correlated with the subsequent growth rate. However, similar to the whole period (1992-2006), panel data analysis does not confirm the existence of absolute convergence (models 6 of each regression have positive coefficients on initial income level) for sub-periods also.

The analysis based on cross-sectional data shows that the convergence accelerated over time: β coefficient for the whole period was 4.2%; for the sub-periods 1992-1997, 1995-2006, and 2002-2006 it equalled 0.1% (no convergence), 7.0%, and 9.6% respectively. Moreover, the statistical tests regarding the significance of these differences are presented in Table 7. This table presents, for each pair of coefficients, F-statistic and p-value for testing the hypothesis on the equality of β coefficients.[6] The cells indicating the high significance level of coefficients are shadowed.

Data included in Table 7 indicate that the null hypothesis of the equality in coefficients is rejected in most of the cases. Only in two cases, β=7.0% and β=9.6%, we can confirm that the differences are statistically insignificant. This slightly changes our previous results that indicated a systematic increase in the speed of convergence. Now we see that the convergence during 2002-2006 was not significantly faster than during the years 1995-2006. Nevertheless, the catching-up process in both of these sub-periods was faster than during the years 1992-1997 — the period of no convergence — and than during the whole period analysed — 1992-2006.

Let us give some explanations of our results. The results for the period 1992-1997 reject the existence of β convergence. This is in line with the earlier results of σ convergence, where we observed that income differentiation between the countries rather increased during 1992-1995. The convergence did not occur for several reasons. Firstly, the transformation process passed through recession in almost all the countries (except Poland, Slovenia, Malta and

[6] β coefficients are calculated based on the regression coefficients using a logarithmic (i.e. nonlinear) transformation, according to equation (5). The statistical tests are performed on β coefficients, not on the regression coefficients. Thus, in order to verify the null hypothesis the *nonlinear* test was used.

Cyprus) during this period. Convergence could not occur during the recession, when the output declines. Secondly, the CEE countries did not have well developed market systems at the beginning of the transition and the real output was significantly lower than the potential output. Thirdly, at the beginning of the 1990s, the EU policy of reducing income disparities of the accession countries was not very pronounced.

In successive years, when the EU enlargement proceeded, the convergence became much more evident. The acceleration of the convergence process was partly caused by further trade liberalisation, including significant tariff cuts. EU-10 countries also adapted better to EU technical standards, which contributed to more trade integration with EU. Moreover, the FDI inflows to the CEE countries peaked-up during this period.

There are many other reasons behind these convergences. First, following the neoclassical explanation, marginal productivity of factor inputs are decreasing in high income countries; therefore, capital flows from more developed to less developed economies within EU-10 countries are apparent that raised the economic growth rates among the low-income EU-10 countries. Second, structural and institutional reforms, policy co-ordination, as well as EU funds helped developing poorer countries grow faster.

IV. *Conclusion*

This paper estimates and analyses σ and β convergences for per capita income among the 10 European countries that accessed the European Union in 2004. Our results confirm the existence of both types of convergence. The poorer new EU member states grew generally faster in the transition period than richer new EU member states. As a result, the income gap between these countries has narrowed, although it still remains quite large. Our analysis reveals that the convergence took place in the second half of the 1990s and the 2000s; whereas in the first half of the 1990s the countries did not converge. The convergence occurred at the rate of 4.2% during the whole period 1992-2006.

More specifically, the speed of convergence accelerated over time. During 1992-1997, the GDP growth rate did not correlate with the initial income level. During 1995-2006 and 2002-2006, convergence occurred at the rate of 7.0% and 9.6%, respectively. Thus, the rate of convergence is becoming faster over the successive sub-periods. This implies effective integration going on among the new member states. Furthermore, it will help the integration of the EU-15 and EU-10 countries as well.

Our estimation of σ and β convergences of per capita GDP among the EU-10 countries led us to a robust conclusion that central and eastern European countries diverged to some extent during 1992-97, but converged afterwards. The reasons of the short-term divergence in per capita GDP were recessions during early 1990s in some transition economies, the lack of well developed market systems among them, and the lack of EU policy in reducing income disparity among the member countries at the beginning of the 1990s. However, after the economic recovery, promotion of the market systems and effective EU policy in reducing disparities among the EU countries not only helped in substantially reducing the per capita GDP divergence, but it also helped convergence among the new member states. σ convergence among the EU-10 countries after 1995 has two implications. In the first place, there is the tendency of long-term convergence of per capita GDP so long as the current EU policies

prolong. In the second place, low-income EU-10 countries reveal the further prospect of capital inflow from developed EU countries.

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