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ABSTRACT

This article examines the real convergence hypothesis in some Central and East European countries (both towards the German and the US economies) by means of using time series techniques during the period 1950-2003. We do not find evidence of real convergence for the whole period. However, when we allow for structural breaks, we find evidence of a catch-up process during the nineties-2003 period for Poland, Czech Republic and Hungary towards Germany and only for Poland towards the US economy.

Keywords: Real convergence; Unit root tests; Central and Eastern Europe

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1. Introduction

There has been in recent years an emerging body of empirical literature on convergence in per capita output across different economies. The interest on this subject may be explained, at least in part, as a prediction test of the neoclassical growth model (Solow, 1956) as opposed to the "new" endogenous growth models (Romer, 1986; Lucas, 1988). As it is well known, the neoclassical model predicts (under some assumptions) that per capita output will converge to each country's steady-state (conditional convergence) or to a common steady-state (unconditional convergence), regardless of its initial per capita output level. On the contrary, in endogenous growth models there is no tendency for income levels to converge, since divergence can be generated by relaxing some of the neoclassical assumptions (e.g., incorporating non convexities in the production function).

Furthermore, the great differences observed in per capita output and in growth rates across countries justify a deeper study on convergence. However, among the great number of empirical paper which studies convergence, little attention has been paid to the Central and East Europe countries' experience.[1] For example, Estrin et al. (2001) analyze whether there has been convergence within the bloc or between the bloc as a group and the West over the period from 1970 to 1998. The results show little evidence of convergence within the bloc and with respect to the West. In other paper, Kocenda (2001) analizes the real and nominal convergence in Central and Eastern Europe for some macroeconomic variables such as real industrial output, monetary agregate (M1), producer and consumer prices and

[1] Although there are several papers which study the economic growth process in Central and Eastern European countries (see for example Estrin et al. 2001; Kocenda 2001; Dawson, 2004; Dritsakis, 2004; Janicki et al., 2004 or Kominek, 2004), little attention has been paid to the real convergence process in the post 1950 period.

nominal and real interest rates. The results show evidence of convergence in macroeconomic fundamentals over the period 1991:01-1998:12.

In this paper we use data of some Central and East European economies that cover the second half of the twentieth century. The past fifty years can be characterized as having higher disparity in productivity performance in Europe. Whereas both Eastern and Western Europe achieved rapid productivity growth during the period 1950-1973, West European growth rates have mostly been higher than in Eastern Europe. Between 1973 and 1989 both Eastern and Western Europe have experienced a productivity slowdown, and not much further convergence has taken place in any of the two regions. However, on the whole, the slowdown was bigger in Eastern Europe than in Western Europe so that divergence between the two regions increased further. The collapse of communism at the end of the 1980s created very diverse effects among East European countries, which explained the rapid rise in divergence within Eastern Europe. The collapse of productivity during the period 1989-1992 raised divergence between Eastern Europe and European Union, but since 1992 the recovery of productivity growth has led to a convergence path between the two regions. Since 1993-94, most Central and Eastern European countries have seen a recovery of growth. However, there has been substantial diversity across countries. Some countries (Czech Republic or Hungary) are now more or less back to the 1989 output level, while Poland has surpassed it. Other countries (including Bulgaria and Romania) also show recovery but at a much slower pace. For example, Czech Republic is now at per capita income levels between 60 and 70 percent of the EU – average, but others (Bulgaria and Romania) are only at 20 to 30 percent of the EU per capita income level.[2]

[2] See Van Ark (2000) and Barbone and Zalduendo (1996).

The differential behavior of the growth rates of these countries, their difficulties to converge to real per capita GDP levels of developed countries and the little research found in the literature regarding this group of countries motivates the analysis on real convergence made in this paper. In this paper we examine the real convergence hypothesis for some Central and East European economies towards leading economies, both within the European Union (such as Germany) or outside Europe (such as the US).[3]

Empirical testing of the convergence hypothesis provide several definitions of convergence and thus, different methodologies to test it. In a cross-section approach, a negative (partial) correlation between growth rates and initial income is interpreted as evidence of unconditional (conditional) beta-convergence. In this context, one of the most generally accepted results is that while there is no evidence of unconditional convergence among a broad sample of countries, the conditional convergence hypothesis holds when examining more homogenous groups of countries (or regions) or when conditioning on additional explanatory variables. Examples in this context are Baumol (1986), De Long (1988), Dowrick and Nguyen (1989), Grier and Tullock (1989), Barro (1991), Barro and Sala-i-Martin (1991, 1992, 1995), Mankiw, Romer and Weil (1992), etc. In a time series approach, stochastic convergence asks whether permanent movements in one country's per capita output are associated with permanent movements in another countries' output, that is, it examines, whether common stochastic elements matter, and how much persistent the differences among countries are. Thus, stochastic convergence implies that output differences among economies cannot contain unit roots. Empirical tests on this hypothesis have been carried out by Campbell and Mankiw (1989), Cogley (1990), Bernard (1991),

[3] We use as benchmark economies both Germany (as an economy representing the European Union standards) and the US economy (in a more global context, one of the leader international economies used as

Carlino and Mills (1993), Bernard and Durlauf (1995), Cunado et al. (2003), Beliu et al. (2004), and, in general, they do not find evidence of convergence. However, when the convergence tests take into account the possibility of structural breaks, the evidence of convergence is reinforced. Greasley and Oxley (1997) found evidence of bivariate convergence between Belgium and Netherlands, France and Italy, Australia and the UK, and Sweden and Denmark. St. Aubyn (1999) finds evidence of convergence between US and each of the UK, Australia and Japan, using the Kalman filter methodology. Cellini and Scorcu (2000) detect stochastic convergence only for the US and Canada, and the US and the UK when they allow for structural breaks. Strazicich, Lee and Day (2003) examine the differences in per capita incomes of fifteen OECD countries with the US economy over the period 1870-1994 allowing for two structural breaks and they reject the unit root null hypothesis in eleven of the fifteen countries, thus supporting the stochastic convergence hypothesis.

In this paper, we apply time series convergence tests allowing for structural breaks to the differences in per capita output for some Central and East European countries to the US and to Germany using data for the period 1950-2003. The outline of the paper is as follows. Section 2 describes the methodology employed in the article to test for convergence. Section 3 covers the empirical analysis and Section 4 offers some conclusions.

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benchmark in most of the analysis on real convergence).

2. Time Series Convergence Tests

In a time series testing framework, countries *i* and *j* convergence if their outputs are cointegrated with cointegrating vector [1,-1], that is, the difference $y_{i,t+k} - y_{j,t+k}$ must be a stationary I(0) process with no deterministic components (unconditional convergence), where y_i is the log real GDP per capita in country *i* and likewise y_j for country *j*.

Since most of the procedures for testing the unit root hypothesis include the cases of no regressors, an intercept, and an intercept and a linear trend, we can distinguish between long-run convergence (unconditional or conditional[4] depending on the significance of the intercept, α_0 in equation (1)) and convergence as a catch-up (if the log of relative output is trend stationary, α_1>0 in equation (1)). Although this last definition[5] may be open to criticism because the presence of a time trend allows for permanent per capita output differences, it might be appropiate in a context in which convergence is an on-going process (Bernard and Durlauf, 1995; Oxley and Greasly, 1995), as the one observed for less developed countries, such as the Central and East European countries analyzed in this paper. In this context, we will test for convergence analyzing the integration order of the relative incomes using the following equation:

$$\Delta RI_t = a_0 + a_1 t + bRI_{t-1} + \sum_{j=1}^{p} c_j \Delta RI_{t-j} + e_t \,, \qquad (1)$$

where $RI_t = \ln(y_t^{US}) - \ln(y_t^i)$ or $RI_t = \ln(y_t^{GERMANY}) - \ln(y_t^i)$, the p extra regressors, ΔRI_{t-j} are added to eliminate possible serial correlation in the error terms.

[4] According to neoclassical models, unconditional or absolute convergence holds when per capita GDP of the different countries convergence to the same steady state. In contrast, conditional convergence applies when per capita GDP of each economy converge to its own steady state. In this last case, the constant α_0 measures the differences in the steady state of each of the economies.

[5] Carlino and Mills (1993), for example, use this methodology in order to allow initially low income countries to grow faster than higher income countries.

However, these type of unit root tests may fail to recognise convergence when structural breaks are present. For example, St. Aubyn (1999), Cellini and Scorcu (2000) show that the introduction of structural breaks makes the existence of convergence across countries more clear.

For the Central and East European case, we could think in the existence of one or more breaks in the convergence process during the period 1950-2003. As Perron (1989) pointed out, these tests perform poorly when there is a break in the constant or deterministic trend function. However, Perron's method has been criticized on the grounds that the break point is chosen exogenously. Several authors, such as Christiano (1992), Perron and Vogelsang (1992) or Zivot and Andrews (1992) have developed methods to endogenously search for a break point and test for the presence of a unit root when the process has a broken constant or trend and have demonstrated that their test are robust and more powerful than the augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests[6]. However, these last procedures have also been critized in the literature (Nunes, Newbold and Kuan, 1997; Lee and Strazicich, 2001, 2003), since these type of tests derive their critical values assuming no breaks under the null, so that, in the presence of a unit root with break, these tests will tend to reject the null hypothesis suggesting that the time series is stationary around a break when it is nonstationary with a break. In order to solve this problem, we will use the endogenous two-break[7] LM unit root test proposed by Lee and Strazicich (2003) which is unaffected by breaks under the null. Following these authors, a unit root test statistic can be obtained by estimating the following model:

[6] Recent empirical application of these tests can be found in Leybourne et al. (2003), Atkins et al. (2004), Sen (2004), Hacker et al. (2005) or Narayan (2005a,b), Sen (2004), Atkins et al. (2004) or Narayan (2005a, b) among others.

$$\Delta y_t = d'\Delta Z_t + f\tilde{S}_{t-1} + \sum_{i=1}^{p} g\Delta\tilde{S}_{t-i} + e_t, \qquad (2)$$

where Z_t reflects the deterministic components, $\tilde{S}_t = y_t - \tilde{y}_x - Z_t\tilde{d}$, t=2,3,…,T. $\tilde{d}$ is a vector of coefficients in the regression of Δy_t on ΔZ_t and $\tilde{y}_x = y_1 - Z_1\tilde{d}$, where y_1 and Z_1 denote the first observations of y_t and Z_t, respectively. e_t is the contemporaneous error term and is assumed independent and identically distributed with zero mean and finite variance. ΔS_{t-i} are added to eliminate possible serial correlation. When $Z_t = \{1, t\}$, we have the statistic proposed in Schmidt and Phillips (1992). If we want to account for some structural breaks, we can extend the models A (which allows for a one-time change in level) and C[8] (which allows for a change in both the level and trend) considered by Perron (1989) and define Z_t in the following ways: $Z_t = \{1, t, D_1, D_2\}'$ for model A and $Z_t = \{1, t, D_1, D_2, DT_1, DT_2\}'$ for model C, where D_j=1 for t $\geq T_{Bj}+1$ and zero otherwise, DT_j=t for t $\geq T_{Bj}+1$ and zero otherwise, and T_{Bj} are the date of the breaks.

The unit root null hypothesis is described by ϕ=0 and the LM test t-statistic is defined by:

$$\tilde{t} = \text{t-statistic for the null hypothesis } \phi=0. \qquad (3)$$

To implement the test, the number of augmentation terms $\Delta\tilde{S}_{t-i}, i = 1,\ldots,k$ that correct for serial correlation in equation (2) must be determined. At each combination of break points, k is determined by following the general to specific procedure suggested by Perron (1989). The procedure begins with a maximum number of lagged first-differenced

[7] We use this two-break LM unit root test and not the one-break LM test because an examination of the empirical results reveals that the two structural breaks included in the model were significant in all the five analyzed countries for the period 1950-2003.

terms (k=8) and examines the last term to see if it is significantly different from zero at the 10% level. If it is insignificant, the maximum lagged term is dropped and the model is reestimated with k=7 terms and so on, until either the maximum term is found or k=0. After determining the "optimal" number of k, the unit root test statistic is estimated using equation (3). The process is repeated for each λ, to determine the LM test statistic with the minimum t-value.[9]

3. Empirical Analysis

The data used in this section are annual log real GDP per capita in 1990 Geary-Khamis PPP-adjusted dollars. The series runs from 1950 to 2003 for five Central and East European countries (Bulgaria, Czech Republic, Hungary, Poland, Romania) plus the US and Germany. All the variables have been obtained from Maddison (2001).[10]. As convergence measure, we define the differences of each of the log real per capita GDP series with respect to Germany and the US.[11]

The results from the augmented Dickey Fuller (ADF) tests are reported in Tables 1 and 2. We are unable to reject the unit root hypothesis in favor of unconditional convergence for any of the Central and Eastern European countries neither when relative incomes are measured with respect to the US or Germany.

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[8] In the empirical analysis, and as in Lee and Strazicich (2003), we consider Model C which allows for two changes in level and trend.

[9] See Lee and Strazicich (2003) for a more detailed description of the test. The computation of the LM unit root test statistic has been carried out using the Gauss codes provided by Junsoo Lee and available on the web site http://www.cba.ua.edu/~jlee/gauss.

[10] We have applied the same unit root tests to an alternative dataset obtained from the Penn World Table, version 6.1 (Heston, Summers and Aten, 2002). The analyzed variables are real per capita GDP adjusted for PPP and the sample periods range from 1991 to 2000 for Bulgaria, 1990-2000 for Czech Republic, 1970-2000 for Hungary, 1979-2000 for Poland, 1960-2000 for Romania and 1970-2000 for Germany. The results, which are consitent with those obtained with the Maddison dataset, are presented in the Appendix.

(Insert Tables 1 and 2 about here)

When we include an intercept and a time trend in the model, we can only reject the unit root hypothesis in favor of conditional convergence towards the German economy for the case of Czech Republic. However, in this case, trend stationarity is a necessary but not sufficient condition for converge or catch-up (Carlino and Mills, 1993), since it is also needed that countries with a per capita output level below the average must have grown more than the average. In order to test for this hypothesis, we follow Tomljanovich and Vogelsang (2002) and run the following regression for this case in which we found trend stationarity:

$$RI_t = m + bt + u_t \,, \qquad (4)$$

where the relative per capita output is regressed on a constant and a linear time trend, and ų follows a stationary process. β represents the average growth of RI_t over time and μ represents the initial level of RI_t. For convergence, μ and β must be of opposite sign. When convergence is measured with respect to Germany or the US, β must be positive, since the initial per capita output of the Central and Eastern European countries are lower than those of the US and Germany.

The little evidence of convergence or catch-up among this group of countries could be due to the existence of different convergence speeds in the convergence process or the case in which countries pass through convergence to nonconvergence processes (or viceversa), two possibilities which will be studied while allowing for structural breaks

[11] We have carried out our empirical analysis for these five economies since Maddison (2001) data base has data only for five Central and Eastern European economies begining in 1950.

when applying the miminum Lagranger Multiplier statistic suggested by Lee and Strazicich (2003). In Tables 3 and 4 we report the minimum LM statistic and the date of the breaks.[12]

(Insert Tables 3 and 4 about here)

The main results presented in these tables may be summarized as follows: First, a broad examination of the significance of the dummy variables indicate that the convergence processes of the different East European countries have experienced structural changes which should be taken into account when analyzing the order of integration of relative incomes. Second, we can reject the unit root null hypothesis in all the cases. Following Tomljanovich and Vogelsang (2002) and Nieswiadomy and Strazicich (2004), we must study if there has been a catch-up process in per capita output after the structural break for all these cases, so that we run the following regression:

$$RI_t = m_1 + m_2 + m_3 + b_1 t_1 + b_2 t_2 + b_3 t + u_t , \qquad (5)$$

where μ_1 and β_1 are the intercept and the slope before the first break, μ_2 and β_2 the intercept and the slope after the first break and μ_3 and β_3 the intercept and the slope after the second break. Testing for converge for the last period is equivalent to testing whether the parameters μ_3 and β_3 are different from zero and negatively related. The last columns in Tables 3 and 4 summarize the results found in this analysis. In this case, and following Tomljanovich and Vogelsang (2002) and Nieswiadomy and Strazicich (2004), C denotes catch-up (those cases in which the unit root hypothesis was rejected in favor of stationarity around different time trends and satisfy the β-convergence hypothesis in equation (5), c denotes catch-up (with only one coefficient, μ_3 or β_3, statistically significant at 10%), D

[12] In all the cases, the dummy variables which account for the structural breaks were significant.

denotes divergence (stationarity around different time trends which do not satisfy the above β-convergence condition), d denotes divergence (with only one coefficient statistically significant at 10%), and U denotes unit root (we did not find evidence to reject the unit root null hypothesis). We find evidence of a catch-up process after the second break towards Germany for Czech Repubic, Hungary and Poland, but only for Poland towards the US economy. Third, while the break point varies from country to country, most of them occur in the late sixties-early seventies and in late eighties. This means that the relative performance of these Eastern European countries is characterized by a first period of rapid divergence from 1950 to late-sixties-early seventies, a second period of ralentization of this divergence process with the general productivity slowdown since 1973, and a third episode of convergence since late eighties-nineties as a result of the recovery after the transition in 1989. However, even though the direction of the trends is more or less uniform in the five countries, the results suggest that these economies show different behaviors (see Van Ark, 2000). For example, while Czech Republic, Poland and Hungary have diminished their per capita GDP differences with Germany, this is not the case for Bulgaria and Romania. Furthermore, Poland is the only country which has also diminished its per capita GDP differences with the US. According to some papers such as Janicki et al. (2003) or Dawson et al. (2004), a relevant variable which explain the different behaviour of these countries is their trade openness.

Finally, we apply the same methodology to real per capita GDP adjusted for PPP data obtained from the Penn World Table for a more recent period (1991-2000 for Bulgaria; 1990-2000 for Czech Republic, 1970-2000 for Hungary; 1979-2000 for Poland and 1970-

2000 for Romania) and the results, which are presented in the Appendix, are consistent with those obtained with Maddison data.

4. Concluding Remarks

In this article we have examined the real convergence process of some Central and Easter European countries by means of using time-series tests over the period 1950-2003. In particular, we have analyzed the convergence process of some East European countries towards the German per capita GDP and the US economy, first based on ADF unit root tests and then allowing for structural breaks.

Using the first tests, we find no evidence of unconditional convergence (stationarity of the differences in per capita GDP levels with no deterministic terms) for any of the Central and East European countries analyzed neither with respect to the German economy or the US. When we include an intercept and a time trend, we can only reject the unit root null hypothesis for the Czech Republic towards Germany. However, the inspection of the coefficients on the intercept and the time trend suggests that there have been an increase in the per capita GDP differences between these two economies, and thus, a divergence process, when the whole period is considered.

However, when we analyze the possibility of structural breaks, we find significant evidence of two structural breaks in the convergence process of these countries, with the breaks occurring in all the cases in early seventies and late eighties. We interpret this result indicating that the relative performance of these Eastern European countries is characterized by a first period of divergence process from 1950 to late-sixties-early seventies, a second period of ralentization of this divergence process with the general productivity slowdown since 1973, and a third episode of convergence since late eighties-nineties as a result of the recovery after the transition in 1989. When we apply unit root tests allowing for these two structural breaks, we find evidence of a catch-up process during the last period, the nineties-2003 for three of the countries (Poland, Czech Republic and Hungary) towards the German economy, and only for Poland towards the US economy.

Appendix

In the appendix, we show the results obtained when we apply the same methodology to data from the Penn World Table, version 6.1. As in the text, the results from the ADF tests are reported in Tables A1 and A2. Tables A3 and A4 report the one-break minimum LM statistic and the date of the break.[13] As above, the results also suggest the existence of a structural break in the convergence processes of these countries occurred in late eighties-early nineties. For the period after this structural break, the results also show evidence of a catch-up process for Poland and Hungary towards Germany and for Poland towards the US economy.

(Insert Tables A1, A2, A3 and A4 about here)

[13] The one-break LM minimum statistic has not been applied in the cases of Bulgaria and Czech Republic because the sample period in these countries range from 1990/1 to 2000. For the rest of the countries we have only allowed for one-break since the sample period range from 1970/9-2000.

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TABLE 1. ADF unit root tests

Testing the integration order of the differences of log real per capita GDP series with Germany				
	With no regressors	With intercept	With intercept and time trend	Converging?
Bulgaria	0.56	-1.44	-1.47	U
Czech Republic	0.40	-2.16	-3.29*	D
Hungary	0.45	-2.36	-2.47	U
Poland	0.12	-2.41	-2.26	U
Romania	0.35	-1.47	-2.07	U

The 10%, 5% and 1% critical values are: Model with no regressors: -1.61, -1.95, -2.61. Model with an intercept:-2.60, -2.92, -3.57. Model with an intercept and a linear time trend: -3.18, -3.50, -4.16.
*, ** and *** indicate significant at the 10%, 5% and 1% levels respectively. U and D denote unit root, and divergence, respectively.

TABLE 2. ADF unit root tests

Testing the integration order of the differences of log real per capita GDP series with the US				
	With no regressors	With intercept	With intercept and time trend	Converging?
Bulgaria	-0.30	-1.10	-1.36	U
Czech Republic	-0.07	-1.24	-2.32	U
Hungary	-0.20	-1.26	-1.88	U
Poland	-0.35	-1.54	-1.89	U
Romania	-0.17	-1.32	-1.87	U

The 10%, 5% and 1% critical values are: Model with no regressors: -1.61, -1.95, -2.61. Model with an intercept:-2.60, -2.92, -3.57. Model with an intercept and a linear time trend: -3.18, -3.50, -4.16.
*, ** and *** indicate significant at the 10%, 5% and 1% levels respectively. U denotes unit root.

TABLE 3. LM unit root tests

Testing the integration order of the differences of log real per capita GDP series with Germany			
	LM stat (Model C)	T_B	Converging?
Bulgaria	-5.58***	1972, 1988	d
Czech Republic	-8.29***	1965, 1989	C
Hungary	-6.64***	1965, 1988	C
Poland	-4.67**	1966, 1988	C
Romania	-6.13***	1972, 1988	d

The 10%, 5% and 1% asymptotic critical values have been obtained from Lee and Strazicich (2003). *, ** and *** indicate significant at the 10%, 5% and 1% levels, respectively. C denotes catch-up (with both μ_2 and β_2 are significant) and d denotes divergence (with only one coefficient statistically significant at 10%).

TABLE 4. LM unit root tests

Testing the integration order of the differences of log real per capita GDP series with US			
	LM stat (Model C)	T_B	Converging during last period?
Bulgaria	-6.30***	1973, 1993	d
Czech Republic	-7.11***	1972, 1989	d
Hungary	-6.99***	1973, 1989	d
Poland	-7.67***	1972, 1988	C
Romania	-6.90***	1972, 1988	D

The 10%, 5% and 1% asymptotic critical values have been obtained from Lee and Strazicich (2003). *, ** and *** indicate significant at the 10%, 5% and 1% levels, respectively. C denotes catch-up (with both μ_2 and β_2 are significant), c denotes catch-up (with only one coefficient statistically significant at 10%), D denotes divergence (stationarity around two time breaks which do not satisfy the above β-convergence condition) and d denotes divergence (with only one coefficient statistically significant at 10%).

TABLE A1. ADF unit root tests (PWT data)

Testing the integration order of the differences of log real per capita GDP series with Germany				
	With no regressors	With intercept	With intercept and time trend	Converging?
Bulgaria, 1991-2000	0.25	-1.59	-3.27	U
Czech Republic, 1990-2000	0.62	-2.06	-1.43	U
Hungary, 1970-2000	-0.40	-1.66	-2.51	U
Poland, 1979-2000	-0.13	-1.12	3.92	U
Romania, 1970-2000	-0.44	-2.34	-2.55	U

The 10%, 5% and 1% critical values are: Model with no regressors: -1.61, -1.95, -2.61. Model with an intercept:-2.60, -2.92, -3.57. Model with an intercept and a linear time trend: -3.18, -3.50, -4.16.
*, ** and *** indicate significant at the 10%, 5% and 1% levels respectively. U denotes unit root.

TABLE A2. ADF unit root tests (PWT data)

Testing the integration order of the differences of log real per capita GDP series with the US				
	With no regressors	With intercept	With intercept and time trend	Converging?
Bulgaria, 1991-2000	1.07	-1.69	-2.76	U
Czech Republic, 1990-2000	2.06	-2.17	-1.85	U
Hungary, 1970-2000	0.16	-0.70	-2.46	U
Poland, 1979-2000	0.01	-3.34*	3.19	D
Romania, 1970-2000	-0.80	-2.10	-1.44	U

The 10%, 5% and 1% critical values are: Model with no regressors: -1.61, -1.95, -2.61. Model with an intercept:-2.60, -2.92, -3.57. Model with an intercept and a linear time trend: -3.18, -3.50, -4.16.
*, ** and *** indicate significant at the 10%, 5% and 1% levels respectively. U and D denote unit root and divergence, respectively.

TABLE A3. LM unit root tests (PWT data)

Testing the integration order of the differences of log real per capita GDP series with Germany			
	LM stat (Model C)	T_B	Converging?
Bulgaria, 1991-2000	n.a.	n.a.	n.a.
Czech Republic, 1990-2000	n.a.	n.a.	n.a.
Hungary, 1970-2000	-6.42***	1989	C
Poland, 1979-2000	-29.32***	1993	C
Romania, 1970-2000	-6.30***	1987	d

The 10%, 5% and 1% asymptotic critical values have been obtained from Lee and Strazicich (2001). *, ** and *** indicate significant at the 10%, 5% and 1% levels, respectively. C denotes catch-up (with both μ_2 and β_2 are significant) and d denotes divergence (with only one coefficient statistically significant at 10%).

TABLE A4. LM unit root tests (PWT data)

Testing the integration order of the differences of log real per capita GDP series with US			
	LM stat (Model C)	T_B	Converging during last period?
Bulgaria	n.a.	n.a.	n.a.
Czech Republic	n.a.	n.a.	n.a.
Hungary	-5.46***	1988	d
Poland	-17.99***	1990	C
Romania	-6.30***	1987	D

The 10%, 5% and 1% asymptotic critical values have been obtained from Lee and Strazicich (2001). *, ** and *** indicate significant at the 10%, 5% and 1% levels, respectively. C denotes catch-up (with both μ_2 and β_2 are significant), D denotes divergence (stationarity around two time breaks which do not satisfy the above β-convergence condition) and d denotes divergence (with only one coefficient statistically significant at 10%).