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**Article**

## Productivity clustering and growth in Central and Eastern Europe

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# Productivity clustering and growth in Central and Eastern Europe

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## ABSTRACT

This article uses a non-linear time-varying model to test productivity convergence in 10 emerging countries within Central and Eastern Europe. The results show that the convergence algorithm has rejected the null hypothesis of convergence for all countries in most of the sectors. Also, we found evidence that the productivity clusters for total economy and other sectors are very different in terms of number and countries. Additionally, even if the productivity gaps in the region have been reduced, we still notice significant disparities between countries. The clustering algorithm shows countries which have a high productivity growth in some sectors and a low productivity growth in others. This reveals the prevalence of idiosyncratic factors in productivity determinants. Baltic countries are catching up, while other countries such as Bulgaria are underperformers.

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## 1. Introduction

An important objective of European Union (EU) is to sustain economic growth based on a competitive economic market, technological and scientific advances, and economic, social, and territorial cohesion between Member States. One of the main measures adopted by the European authorities stresses the importance of increasing the level of economic convergence between Member States, by promoting a common market together with an economic and monetary union. Moreover, the productivity growth and convergence within the EU are fundamentals of the Lisbon strategy (Denis, Mc Morrow, & Veugelers, 2005) and remain an important pillar of the Europe 2020 growth strategy (European Commission, 2010). The economic literature indicates the positive effects that an increased productivity can have on economic convergence and on reducing the development gaps (Ezcurra, Gil, Pascual, & Rapún, 2005; Gardiner, Martin, & Tyler, 2004; Inklaar & Timmer, 2009; López-Bazo, Vayá, & Artís, 2004). Together with this, Krugman (1994) states that productivity is highly important in the long run. All the studies mentioned above demonstrate that the interest in testing the productivity convergence hypothesis has significantly increased in the literature.

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However, the conceptual and methodological approaches employed in these studies are diverse. The pioneer literature focused on testing the productivity convergence hypothesis at the aggregate economy level. A detailed presentation of these articles can be found in Islam (2003) and Barro and Sala-i-Martin (2004). Following the reference work of Bernard and Jones (1996), a significant number of studies investigated productivity convergence at the main sector level. Other differences are related to the models used for testing the convergence hypothesis. Most of researchers have employed beta convergence, sigma convergence, unit root tests, and cointegration analysis. Beta convergence occurs when poor countries grow faster than the rich ones. Therefore, the coefficient of the output variable is less than zero. Sigma convergence refers to a reduction of the dispersion over time. Unit root tests and cointegration analysis are applied to test whether differences in productivity levels across countries are stationary or cointegrated. A detailed description of these methods can be found in Färe, Grosskopf, and Margaritis (2006). However, these previous approaches have several limitations. Beta and sigma convergence are criticized for generating weak and biased results (Bernard & Durlauf, 1996), while Quah (1996) argues that these models do not provide information on the behaviour of individual time series over the sample period or related to other series within the sample. Apergis, Christou, and Miller (2014) consider that unit root tests and cointegration analysis fail to identify convergence when multiple steady-state equilibria occur in the sample data, while Maddala (1999) claims that unit root tests do not succeed to solve the problem of growth convergence among countries. Although panel unit root tests with a stochastic trend are appropriate for testing convergence, they are very sensitive to data homogeneity. Consequently, Färe et al. (2006) recommend examining convergence using cluster analysis.

In this article, we use Phillips and Sul (2007, 2009) (hereafter PS) methodology to test the convergence of labour productivity per hour worked within Central and Eastern Europe (CEE), estimated as the ratio between the real value added and the number of total worked hours. We applied productivity clustering test for total economy, two main sectors, and other nine sub-sectors. We have chosen sample data from 1995 to 2014 for the total economy productivity, and data from 1995 to 2011 for the other sectors and sub-sectors. In general, productivity within CEE countries should converge towards Western European levels. However, even if the productivity gaps have been significantly reduced between CEE and Western Europe over the last decades, there are still major differences (i.e. the average of CEE labour productivity compared to the average of EU-15 labour productivity increased from 36% in 1995 to 55% in 2014). Given this, we cannot talk about a common convergence equilibrium point between CEE and Western Europe for the moment. Therefore, we choose to compare countries with similar patterns over the last two decades to get an image of their performance.

There are many studies that have focused on analysing the economic and productivity convergence. However, these studies have provided mixed results. Villaverde and Maza (2008) found a weak beta convergence process at the aggregate and sectoral levels for the European regions. These findings are in line with those obtained by Cuadrado-Roura, Mancha-Navarro, and Garrido-Yserte (2000) and López-Bazo et al. (2004) at the aggregate level. Also, the results of Le Gallo and Dall'erba (2008) indicated productivity convergence for the total economy and for services, but not for other sectors. Martino (2015) revealed convergence for the financial, real estate, and business-related activities,

and rejected convergence hypothesis for the other sectors and for the economy as a whole. As for the old EU Member States, Färe et al. (2006) found that they do not form a single convergence club, while Kutan and Yigit (2007) showed that convergence is relevant only in some countries. Sondermann's (2014) results did not show convergence at the aggregate level, but the hypothesis of convergence was accepted for some service sectors and manufacturing sub-industries. For the CEE countries, Bijsterbosch and Kolasa (2010) found a strong productivity convergence both at the country and at the industry level. A similar result for this region was obtained by Marelli (2007) at the aggregate level.

Notwithstanding its advantages, PS methodology has not been previously employed for testing convergence in labour productivity, although the model was extensively applied to analyse economic convergence. Fritsche and Kuzin (2011) investigated economic convergence, focusing on the price level, unit labour cost, income, and total factor productivity in EU-15 using PS methodology. Considering productivity convergence, they analysed total factor productivity for the total economy and the results revealed the existence of a small club including fast-growing countries and a club consisting of all other countries. Other studies also employed PS methodology to test real GDP and income per capita convergence (Bartkowska & Riedl, 2012; Borsi & Metiu, 2015; Fritsche & Kuzin, 2011; Monfort, Cuestas, & Ordonez, 2013) and price-level convergence (Fischer, 2012; Fritsche & Kuzin, 2011) within the EU.

Our study complements existing literature and adds important knowledge to this field. Firstly, PS clustering model has not been previously applied to test the productivity convergence for total economy and for other sectors within the CEE region. We have chosen this model due to its features that make it useful in practical work. Some of the most important advantages of this model are (Phillips & Sul, 2007): (i) it does not need particular assumptions on the trend stationarity or non-stationarity of the variables; (ii) it allows the estimation of long-run equilibrium in a heterogeneous panel, including the history of a country in transition dynamics; (iii) it enables illustration of the transition path for each country, more precisely the behaviour of a data series in relation to the panel average, which offers important information on individual behaviour in the panel.

Secondly, in order to achieve a comprehensive picture of labour productivity patterns, we are interested in testing the convergence hypothesis at the level of activity sectors. We considered two main sectors, manufacturing and market services and other activity sectors, such as: construction, agriculture, trade, transport and storage, post and telecommunications, financial intermediation, renting and other business activities, public administration, education and health, and real estate activities.

Our results show that the convergence algorithm has rejected the null hypothesis of convergence in most sectors. We found evidence that the productivity clusters for total economy and other sectors are very different both in terms of number and countries, revealing discrepancy between CEE countries and significant gaps in productivity growth. The clustering algorithm indicated countries that have a high productivity growth in some sectors and a low productivity growth in others, emphasizing the prevalence of idiosyncratic factors in productivity determinants. Although the productivity gaps between the sample countries have been reduced, there are significant differences between the countries paths. The best-performing countries in the region are the Baltic economies, whereas Bulgaria is a clear laggard.

Also, the empirical findings display the divergence of CEE countries in terms of labour productivity, which has some relevant implications for the EU authorities. Although one of the most important EU goals is the economic and social cohesion between its Member States, European authorities do not seem to succeed in reducing regional disparities between member countries. Moreover, the recent global financial crisis and the sovereign debt crisis have intensified these discrepancies. In this context, our research could inform the decisions of policy-makers with regard to the labour productivity dynamics within the CEE region from the last two decades. In addition, this analysis will provide an overview of the catch-up process of less-developed countries towards the most developed within the examined sample.

The remainder of the article is organized as follows. Section 2 presents the methodology adopted in this study. Section 3 describes the data and variables. Section 4 reports and discusses the empirical results and, finally, the last section concludes.

## 2. Methodology

### 2.1. The non-linear factor model and convergence

The econometric approach suggested by PS uses a non-linear time-varying factor model and offers the framework for modelling the transitional dynamics as well as the long-run behaviour. Assume we have panel data for a variable  $X_{it}$ , where  $i = 1, \dots, N$  and  $t = 1, \dots, T$ , with  $N$  the number of units and  $T$  the time span of the sample. A simple linear factor model can be expressed as follows:

$$X_{it} = \delta_i \mu_t + \varepsilon_{it}, \quad (1)$$

where  $\mu_t$  is a single common steady-state trend function which may follow a non-stationary stochastic trend or a trend stationary process and  $\delta_i$  represents specific factor loadings which measures the economic distance between the common trend  $\mu_t$  and  $X_{it}$ .  $\varepsilon_{it}$  represents the unit-specific idiosyncratic components. PS reformulate Equation (1), allowing for time-variation in the loading coefficients as follows:

$$X_{it} = \delta_{it} \mu_t, \quad (2)$$

where  $\delta_{it}$  absorbs  $\varepsilon_{it}$ . Furthermore, PS model the factor loadings in a semi-parametric form as follows:

$$\delta_{it} = \delta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha}, \quad (3)$$

where  $\delta_i$  is fixed,  $\xi_{it}$  is *iid*(0,1) across  $i$  and weakly dependent over  $t$ ,  $L(t)$  is a slowly varying function (like  $\log(t+1)$ ) for which  $L(t) \rightarrow \infty$  as  $t \rightarrow \infty$ . This formulation certifies that  $\delta_{it}$  converges to  $\delta_i$  for all  $\alpha \geq 0$  and therefore becomes a null hypothesis of interest. If the null hypothesis holds and  $\delta_i = \delta_j$  for  $i \neq j$ , the model still allows for transitional periods in which  $\delta_{it} \neq \delta_{jt}$ . That is the model includes the possibility of transitional heterogeneity or even transitional divergence across  $i$ . As PS suggest, further heterogeneity may be introduced by allowing the decay rate  $\alpha$  and slowly varying function  $L(t)$  to be individual specific. To develop rigorous asymptotics for the regression, several regularity conditions on the idiosyncratic scale parameters  $\sigma_i$  and the random variables  $\xi_{it}$  are required.

The null hypothesis of convergence may be written as follows:

$$H_0: \delta_i = \delta \text{ and } \alpha \geq 0.$$

The alternative hypothesis is given by:

$$H_1: \{\delta_i = \delta \text{ for all } i \text{ with } \alpha < 0\} \text{ or } \{\delta_i \neq \delta \text{ for some } i \text{ with } \alpha \geq 0 \text{ or } \alpha < 0\}.$$

The alternative hypothesis includes divergence, but also allows the possibility of club convergence. The identification and estimation of  $\delta_{it}$  is not possible without imposing additional assumptions on the dynamic latent factor model. However, PS propose a suitable way to extract information about  $\delta_{it}$  by constructing the following relative transition paths:

$$h_{it} = \frac{X_{it}}{\frac{1}{N} \sum_{i=1}^N X_{it}} = \frac{\delta_{it}}{\frac{1}{N} \sum_{i=1}^N \delta_{it}}. \quad (4)$$

The relative transition parameter  $h_{it}$  captures  $\delta_{it}$  in relation to the panel average at time  $t$  and describes the transition path for country  $i$  compared to the panel average. Therefore,  $h_{it}$  measures country  $i$ 's relative departure from the common steady-state growth trend,  $\mu_t$ . If  $\delta_{it}$  converge to  $\delta$ , the relative transition paths  $h_{it}$  converge to unity, in which case the cross-sectional variance of  $h_{it}$  converges to zero asymptotically:

$$H_t = \frac{1}{N} \sum_{i=1}^N (h_{it} - 1)^2 \rightarrow 0 \text{ as } t \rightarrow \infty, \quad (5)$$

where  $H_t$  measures the distance for the panel from the common limit. Under convergence,  $H_t \rightarrow 0$  as  $t \rightarrow \infty$ . If convergence fails to hold, the distance remains positive as  $t$  goes to infinity. PS suggest different possibilities:  $H_t$  may converge to a non-zero constant, it may remain bounded above zero, but not converge, or it may diverge. For club convergence,  $H_t$  converges to a positive constant.

The log  $t$  regression to test the hypothesis of overall convergence, based on the asymptotic convergence property given in Equation (5), implies that the following ordinary least squared regression is performed:

$$\log \left( \frac{H_1}{H_t} \right) - 2 \log L(t) = \hat{a} + \hat{b} \log t + \hat{\mu}_t, \quad (6)$$

for  $t = [rT], [rT] + 1, \dots, T$  with some  $r > 0$ ;  $L(t) = \log(t + 1)$  and  $\hat{b} = 2\hat{\alpha}$ , where  $\hat{\alpha}$  is the estimate of  $\alpha$  in  $H_0$ .

PS recommend starting the regression at some point  $t = [rT]$ , with some  $r > 0$ . Based on their simulations, PS suggest  $r = 0.30$ , when  $T$  is small or moderate (e.g.  $T \leq 50$ ) and  $r = 0.20$ , when  $T$  is large (e.g.  $T \geq 100$ ). By employing the conventional  $t$ -statistic  $t_b$ , the null hypothesis of convergence is rejected if  $t_b < -1.65$ . The rejection of full convergence does not imply the absence of convergence in the subgroups of the panel. Therefore, PS propose a club clustering algorithm to classify units in convergent clusters. The procedure is flexible, allowing all possible configurations: overall convergence, overall divergence, converging subgroups, and diverging units.

## 2.2. Clustering algorithm

The algorithm suggested by PS for sorting the panel units into converging subgroups, based on log  $t$  regressions, consists of four steps:

- (1) *Last observation ordering.* Order the  $N$  units in the panel according to the last observation  $X_{it}$ .
- (2) *Core group formation.* Select the  $k$  highest members in the panel to form the club  $C_k$  for some  $2 \leq k < N$ . Then run the log  $t$  regression and calculate the convergence  $t_b(k) = t_b(C_k)$ -statistic,  $t_b(k) = t_b(C_k)$ , for this club. The core club size is chosen by maximizing  $t_b(k)$  subject to  $\min t_b(k) > -1.65$ . If the condition  $\min t_b(k) > -1.65$  does not hold for  $k=2$ , then the highest members in  $C_k$  can be removed from each subgroup and new subgroups  $C_{2j} = \{2, \dots, j\}$  formed for  $3 \leq j \leq N$ . The step can be repeated with test statistics  $t_b(j) = t_b(C_{2j})$ .
- (3) *Sieve individuals for club membership.* After having formed the core group, each remaining unit is added separately to the core group and the log  $t$  is run. Include the new unit into the current subgroup if the associated  $t_b > c$ , with  $c$  being a critical value ( $c \geq 0$ ). The composition of the subgroup is followed by the log  $t$  test for the entire subgroup. If  $t_b > -1.65$ , the construction of the subgroup is completed, otherwise the critical value  $c$  is raised and the procedure needs to be repeated.
- (4) *Stopping rule.* Form a second group for all the units outside the convergence club. Run the log  $t$  regression for this set of units and if convergence is detected within this new cluster, a second club is built. If it does not converge, steps 1, 2, and 3 are repeated on the remaining units. If no subgroups can be found, then these units display a divergent behaviour.

## 3. Data

Ten emerging countries from CEE were included in the analysis: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. The convergence model was applied to test the productivity convergence for total economy, two main sectors (manufacturing and market services), and nine other sub-sectors (construction, agriculture, trade, transport and storage, post and telecommunications, financial intermediation, renting and other business activities, public administration, education and health, and real estate activities). We have chosen this classification because the drivers of productivity in all these activity sectors are different, and it may provide a comprehensive image of productivity patterns.

To study productivity convergence, we used labour productivity estimated as the ratio between the real value added and the number of total hours worked. To compare the level of productivity within CEE countries, the value added was transformed into a single currency unit taking into account price-level differences in the Euro area using purchasing power parities (PPPs). Current PPPs were chosen because they are more suitable for our data time interval (17–20 years) and because of long-run analysis drawbacks of constant PPPs (Sondermann, 2014).

The data needed for estimating productivity (i.e. real value added and number of total hours worked) have been extracted from Eurostat Database and World Input-Output



Database (WIOD). A detailed description of WIOD database can be found in Timmer (2012). Given the data availability, we have estimated productivity convergence for total economy over the period 1995–2014, while for the other sectors and sub-sectors the time frame is 1995–2011. Table 1 summarizes the descriptive statistics for labour productivity for the total economy and at the manufacturing and market services levels.

PS suggest employing the Hodrick–Prescott filter to extract the trend component from the series. In our estimations with annual data, the Hodrick–Prescott smoothing parameter is set to 100. As we mentioned earlier, in what concerns the  $r$  value, we use  $r = 0.3$ , given that most of the data series have fewer than 50 observations. All the estimations are run in OxEdit.

## 4. Results and discussion

### 4.1. Total economy productivity convergence

We have arranged total economy productivity according to the last time series observation, choosing Slovenia as a base country (see Table 2). We found a core group formed by Slovenia and Slovakia. Adding countries one by one to this group, the null hypothesis of convergence is also accepted ( $t_b > -1.65$ ) for the Czech Republic, Lithuania, Estonia, and Latvia. As a result, we have a first convergence cluster that includes Slovenia, Slovakia, the Czech Republic, Lithuania, Estonia, and Latvia. Given that the null hypothesis of convergence is accepted for the remaining countries ( $t_b = 0.229$ ), we have a second convergence cluster comprising Hungary, Poland, Romania, and Bulgaria. For both clubs, the speed of convergence shows only convergence in rates ( $\hat{b} = 0.386$  and,  $\hat{b} = 0.010$  respectively).

The transition paths (see Figure 1(a)) show that the first cluster equilibrium point is formed above the panel average. We noticed that Slovenia and the Czech Republic have downward-sloping curves, whereas the paths for the Baltic countries reveal an upward trend. The transition paths for the second cluster are quite different. Hungary had a clear downward-sloping curve that narrows towards the panel average, while the level of labour productivity in Poland reflects the sample average. Romania and Bulgaria, the countries with the lowest productivity levels, also exhibit different paths. For Romania, we noticed a clear upward trend, while Bulgaria has a downward curve until 2007 when it becomes steady. Although the dispersion between the countries paths has reduced over

**Table 1.** Descriptive statistics for labour productivity.

Country	Total economy				Manufacturing				Market Services			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Bulgaria	8.85	2.41	5.22	12.65	7.43	2.08	4.50	11.69	7.99	1.72	4.80	10.77
The Czech Republic	14.90	3.19	9.64	18.39	14.09	3.20	9.02	18.49	13.56	2.78	9.40	17.21
Estonia	12.79	4.43	5.44	18.78	9.38	3.09	4.68	14.08	11.99	4.37	5.10	17.64
Hungary	14.21	3.83	8.14	19.70	12.98	4.09	7.84	22.01	13.17	2.98	8.67	17.48
Latvia	10.03	3.94	4.64	16.77	6.91	2.36	4.56	13.70	9.34	2.87	4.63	15.14
Lithuania	12.30	4.85	4.37	18.94	11.97	5.40	4.44	22.53	12.26	4.61	4.64	18.54
Poland	14.33	4.34	7.46	20.66	12.48	3.40	7.64	19.10	17.97	4.29	10.37	23.96
Romania	9.02	3.29	4.64	13.95	9.52	4.19	5.02	17.96	10.38	2.75	7.74	16.11
Slovakia	17.27	5.48	8.45	24.76	15.98	4.85	9.33	22.67	14.75	3.62	8.82	19.67
Slovenia	18.48	3.91	10.79	22.53	16.73	3.88	9.43	21.97	18.42	3.50	12.19	23.04

**Table 2.** Convergence club classification for total economy productivity.

Last $T$ order	Name	Club 1		Results
		Step 1	Step 2	
1	Slovenia	Base	Core	1
2	Slovakia	6.854	Core	1
3	The Czech Republic	0.7823	0.7823	1
4	Lithuania	5.036	5.424	1
5	Hungary	-1.708	-26.771	2
6	Estonia		1.810	1
7	Poland		-4.475	2
8	Latvia		5.176	1
9	Romania		-2.027	2
10	Bulgaria		-15.484	2
Test club	-2.158	0.386 [5.324]		
Test rest		0.010 [0.229]		

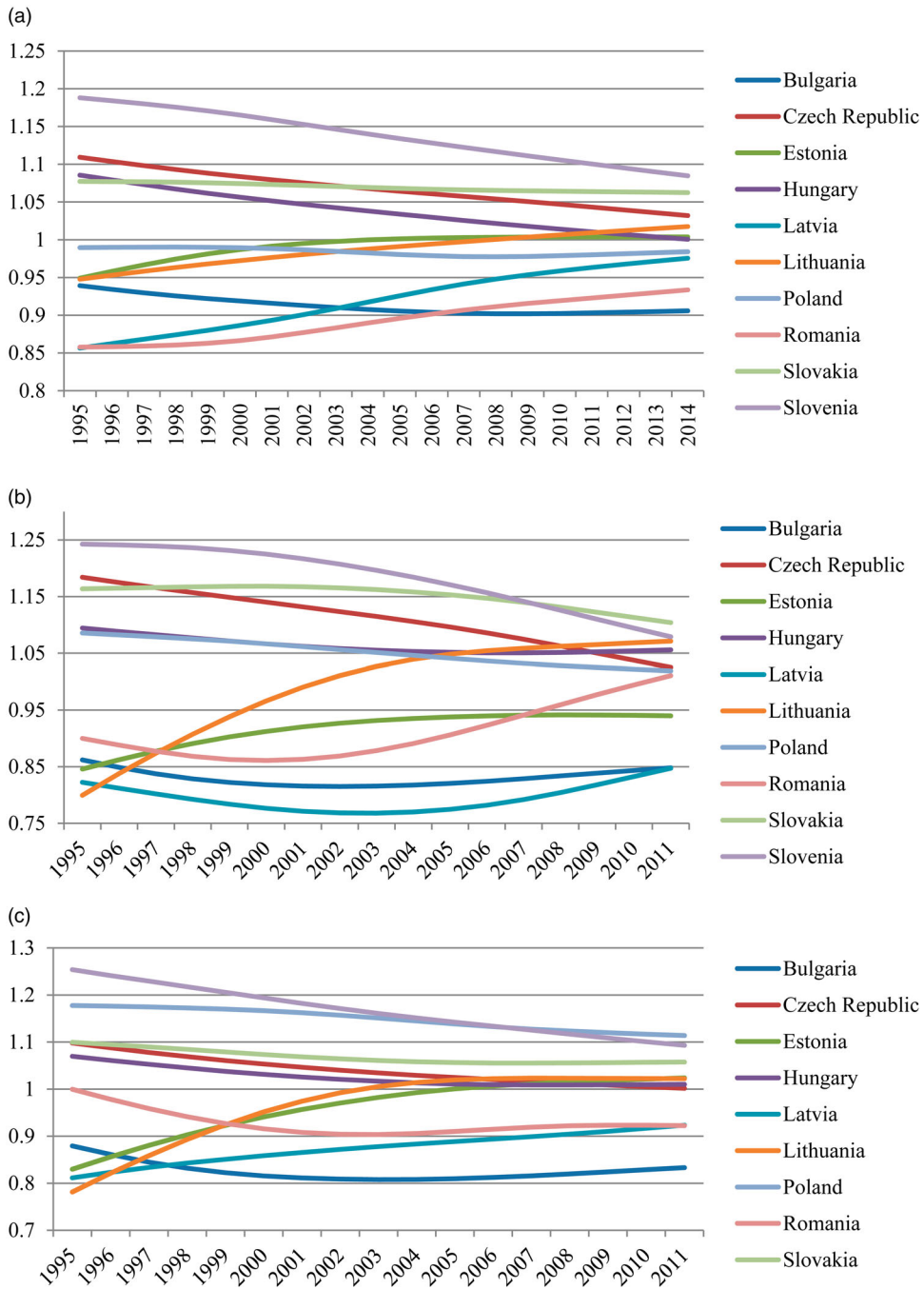
Notes: We report  $t_b$  statistics [in brackets] and  $\hat{b}$  values.

The null hypothesis of convergence is rejected at the 5% level if  $t_b < -1.65$ .

the sample period, there still are disparities. These differences can be explained by the initial conditions of transition towards market economy, which were more favourable in some countries. For instance, EBRD Transition Report (1999) reported that the highest values for the initial conditions index were in the Czech Republic, Hungary, Slovenia, and Slovakia, while the lowest were reported in the Baltic countries.

In order to get a comprehensive picture of the productivity patterns within CEE countries, we tested the convergence of productivity index. The results are listed in the Appendix. We noticed that Baltic countries and Romania had the highest productivity growth in the region compared to the regional average (see Figure A1(a)). Thus, they managed to reduce the productivity gaps, but the catch-up effect is stronger for the Baltic countries. This implies a high productivity growth in the Baltic countries which outperforms the other countries and reveals clear regional linkages. The rapid productivity growth allowed these countries to significantly reduce the productivity gaps compared to the best performers in the region. However, this growth is due to a very low base at the beginning of the sample period. Romania has also shown a catch-up effect and high productivity growth, especially after 2000. It is important to mention that Slovakia has a stable productivity growth above the panel average over the entire sample period. For Slovenia, the Czech Republic, Hungary, and Bulgaria we noticed lower productivity growth compared to the panel average. For Slovenia, the Czech Republic, and Hungary, the sluggish productivity growth is due to a high base at the beginning of the time frame.

The results of productivity convergence within CEE region reveal the disparity between its countries and significant gaps in their productivity growth. These findings are related to macroeconomic differences between CEE countries and to inconsistency of labour productivity determinants. The reforms adopted by these countries for designing a market economy have been implemented at different paces as shown by transition reports of the European Bank for Reconstruction and Development (EBRD). For example, the Baltic countries have managed to reduce the productivity gaps faster due to steady reforms implemented in the transition periods, while the speed of reforms had a slower pace in Romania and Bulgaria. Estonia has implemented the fastest privatization process. By 1995, more than 50% of Estonian state-owned enterprises were privatized, compared to



**Figure 1.** Relative transition curves in CEE countries. (a) Total economy productivity. (b) Manufacturing productivity. (c) Market services productivity

approximately 25% in Lithuania and only isolated cases in Latvia. In the same year, all small companies in Baltic countries were completely privatized (EBRD Transition Report, 1995). The rapid privatization in Estonia was also influenced by a lower percentage of all-union

enterprises (20%), compared to 40% in Lithuania and Latvia (Arkadie & Karlsson, 1992). Estonia had also taken constant measures to promote enterprise restructuring, in contrast with moderate actions implemented in Latvia and Lithuania. The process of privatization was fast and, by 1998, all three countries had a GDP private sector share above 60%. Romania and Bulgaria had lower privatization and enterprise restructuring performances than Baltic countries. The privatization of state-owned companies and enterprise restructuring determined the shape of labour market institutions in post-socialist countries (Pilc, 2015).

Baltic countries have also successfully implemented different reforms in order to promote financial stabilization. In 1992, all three countries established independent currencies. While Estonia has adopted a pegged exchange rate, Latvia and Lithuania followed a floating exchange rate regime. Even though both Estonia and Latvia had managed to stop high inflation, Sachs (1996) claimed that the costs were higher for Latvia, considering their much deeper and prolonged economic recession. The costs of stabilization under floating rates appeared to be higher than in the pegged-exchange-rate regime. However, Latvia and Lithuania also adopted a pegged exchange rate and currency-board arrangements in 1994. The Baltic States were the first countries in the CEE region to meet IMF Article VIII requirements on currency convertibility (EBRD Transition Report, 2000) which facilitates foreign trade liberalization. Romania and Bulgaria were the last countries to implement this standard.

Compared to the other countries in our sample, Romania and Bulgaria had a slow reform process. Fiscal and monetary policies remained lax, while triple digit inflation persisted. Therefore, Romania and Bulgaria were the last countries in the CEE region in terms of macro-stabilization (Roaf, Atoyan, Joshi, & Krogulski, 2014). The costs of delayed reforms triggered significant consequences in 1997. Bulgaria witnessed a banking and currency crisis which led to a 14% GDP reduction. In Romania, triple digit inflation reoccurred and the national economy underwent significant currency depreciations, followed by three years of deep recession (Roaf et al., 2014). In both countries, the GDP has steadily gained significant increase since 2000, with a more pronounced trend for Romania. Also, EU accession negotiations started during the same year.

The pace of labour markets reform was different across our sample countries, leading to direct impact on productivity. Kovtun, Cirkel, Murgasova, Smith, and Tambunlertchai (2014) and Roaf et al. (2014) emphasize cross-country differences in labour markets in terms of redundancy costs, minimum wage and unemployment benefits (percentage of average wages), social assistance spending (percentage of GDP), active working age labour force (percentage of working age population), and unit labour costs within CEE countries. Most of the countries benefited from EU accession (e.g. capital and labour flows, trade integration, EU funding, institutional development, etc.) and agreements with other institutions (i.e. International Monetary Fund, EBRD, European Investment Bank, and World Bank). However, some countries managed to satisfy integration criteria sooner than others. The Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia became members of the EU in 2004, while Bulgaria and Romania in 2007.

Other factors that could explain cross-country productivity gaps are also mentioned in the literature: human capital, education, regulation, investments in research and development (Arazmuradov, Martini, & Scotti, 2014; Barro, 2001; Coe, Helpman, & Hoffmaister, 1997; Kutan & Yigit, 2009; Nicoletti, Scarpetta, & Boylaud, 1999; Romer, 1990; Seck, 2012;

Stengos & Yazgan, 2014; Van Ark & Inklaar, 2005). Other authors have showed that knowledge, innovation, and the ability of countries to successfully adopt foreign technology could also explain the differences in productivity (Capello & Lenzi, 2013; Cuadros & Alguacil, 2014; Dettori, Marrocu, & Paci, 2012; Easterly & Levine, 2001; Paci & Marrocu, 2013).

#### 4.2. Sectoral productivity convergence

Table 3 displays the productivity convergence in the manufacturing sector. We started our algorithm with Lithuania as a base country (see Table 3). The resulting core group was formed by Lithuania and Slovakia together with five other countries which were added to this convergence club (Hungary, Slovenia, Poland, Romania, and the Czech Republic). A second cluster comprised Latvia and Bulgaria. Furthermore, we decided that Estonia was suitable for the initial convergence club. The values of  $\hat{b}$  indicate only relative convergence in terms of convergence speed.

Figure 1(b) displays transition paths for productivity in the manufacturing sector. The first convergence cluster is formed above the panel average. The paths for the countries included in this cluster indicate clear signs of convergence due to the continuous narrowing of dispersion between them. The second convergence club is built below the panel average. It is important to note that country slopes for the manufacturing sector, with some exceptions, are quite similar with those obtained for total economy. For Lithuania we observe a clear upward slope over the sample period, while for Latvia, Romania, and Bulgaria the slope becomes positive after 2000. For Estonia, the trend is upward until 2004 when it stabilizes. The other countries present downward-sloping curves. The results obtained for convergence growth confirm patterns of productivity growth (Table A1 and Figure A1(b)).

For productivity in market services, we started the algorithm with Poland as a base country and we obtained a first group of core countries formed by Poland, Slovenia, Slovakia, and Lithuania (see Table 4). While adding these countries to the group, Estonia and Hungary were also included in the first convergence cluster. We continued the clustering algorithm because the null hypothesis of convergence was rejected for the remaining countries ( $t_b = -5.518$ ). Starting with the Czech Republic as a base country, we noticed

**Table 3.** Convergence club classification for manufacturing productivity.

Last $T$ order	Name	Club 1		Club 2		Results
		Step 1	Step 2	Step 1	Step 2	
1	Lithuania	Base	Core			1
2	Slovakia	7.688	Core			1
3	Hungary	5.411	5.411			1
4	Slovenia	5.845	7.482			1
5	Poland	4.377	2.030			1
6	Romania	3.736	3.1069			1
7	The Czech Republic	3.906	25.456			1
8	Estonia	2.881	-9.143	Core	-2.915	Rest/1
9	Latvia	-0.508	-4.803	-2.197	Core	2
10	Bulgaria	-1.913	-9.305	1.745	Core	2
Test club	-1.913	0.693 [3.906]		0.597 [1.745]		
Test rest		-2.915				

Notes: We report  $t_b$  statistics [in brackets] and  $\hat{b}$  values.

The null hypothesis of convergence is rejected at the 5% level if  $t_b < -1.65$ .

**Table 4.** Convergence club classification for market services productivity.

Last $T$ order	Name	Club 1		Club 2		Results
		Step 1	Step 2	Step 1	Step 2	
1	Poland	Base	Core			1
2	Slovenia	0.633	Core			1
3	Slovakia	1.163	Core			1
4	Lithuania	9.654	Core			1
5	Estonia	8.887	8.887			1
6	Hungary	5.399	1.231			1
7	The Czech Republic	3.483	-3.530	Base	Core	2
8	Latvia	-1.914	-2.424	2.276	Core	2
9	Romania		-3.063	1.954	1.954	2
10	Bulgaria		-11.337	-5.518	-5.643	Div.
Test club	-7.736	0.249 [5.399]		0.184 [1.954]		
Test rest		-5.518				

Notes: We report  $t_b$  statistics [in brackets] and values.

The null hypothesis of convergence is rejected at the 5% level if  $t_b < -1.65$ .

that a core group was formed alongside Latvia. In the following step, we found that Romania could be added to the second club. Also, we observed that Bulgaria was divergent. The speed of convergence for both clubs showed convergence in rates.

Figure 1(c) displays the transition curves for productivity convergence in the market services sector. The clear performers of the sample are Baltic countries. Lithuania, Estonia, and Latvia have significant upward sloping curves and the highest productivity growth (see Figure A1(c)), managing to reduce the productivity gaps in the service sector. The dispersion between the countries paths has narrowed over the analysed period. However, the patterns of the slopes in the service sector are also similar with the findings for the total economy.

We continued with the productivity convergence in other important sectors. The results reflect significant heterogeneity (Table 5). The clusters had a low speed of convergence, emphasizing only relative convergence, except for public administration, education, and health sectors, for which the tests revealed the overall convergence. However, the overall convergence for this sector should be interpreted with caution, as the output for some services (i.e. public administration, education) is often un-priced.

The cluster analysis of productivity in the construction industry showed the presence of one weak convergence club, with two diverging countries. Bulgaria, the Czech Republic, Estonia, Latvia, Poland, Slovenia, Romania, and Lithuania formed a convergence cluster, while Hungary and Slovakia diverged. In agriculture, the clustering algorithm indicated the formation of two clubs: the Czech Republic, Estonia, Slovakia, and Latvia were included in the first convergence club; Bulgaria, Lithuania, Slovenia, and Poland were incorporated in the second cluster, while Hungary and Romania diverge.

We continued our analysis with the sectors that form the market services. The productivity convergence in trade revealed the formation of three convergence clubs. The first cluster included Lithuania, Slovenia, and Poland. The second cluster was comprised of Slovakia and Estonia, while Hungary and Latvia were included in the third convergence club. Bulgaria, the Czech Republic, and Romania diverged. The analysis for the transport and storage sector revealed the formation of a single convergence club and a diverging country. The convergence cluster included Hungary, the Czech Republic, Slovenia, Latvia, Romania, Slovakia, Bulgaria, Estonia, and Poland, while Lithuania diverged. An

**Table 5.** Convergence club classification for other sectors.

Club	Countries	$t_b$	$\hat{b}$
<b>Sample: Construction</b>			
Club 1	Bulgaria, the Czech Republic, Estonia, Latvia, Poland, Slovenia, Romania, Lithuania	-0.026	-0.001
Diverging	Hungary, Slovakia		
<b>Sample: Agriculture, hunting, forestry, and fishing</b>			
Club 1	The Czech Republic, Estonia, Slovakia, Latvia	-1.099	-0.051
Club 2	Bulgaria, Lithuania, Slovenia, Poland	0.702	0.077
Diverging	Hungary, Romania		
<i>Testing convergence between clubs</i>			
Club 1 + Club 2		-95.827	-0.791
<b>Sample: Trade</b>			
Club 1	Lithuania, Slovenia, Poland	5.044	0.161
Club 2	Slovakia, Estonia	1.604	0.278
Club 3	Hungary, Latvia	-0.814	-0.049
Diverging	Bulgaria, the Czech Republic, Romania		
<i>Testing convergence between clubs</i>			
Club 1 + Club 2		2.321	0.025
Club 2 + Club 3		-72.602	-0.663
<b>Sample: Transport and storage</b>			
Club 1	Hungary, the Czech Republic, Slovenia, Latvia, Romania, Slovakia, Bulgaria, Estonia, Poland	4.016	0.224
Diverging	Lithuania		
<b>Sample: Financial intermediation</b>			
Club 1	Bulgaria, Slovakia, Estonia, the Czech Republic, Slovenia, Hungary	3.200	0.179
Club 2	Poland, Lithuania	6.147	0.503
Club 3	Latvia, Romania	0.333	0.456
<i>Testing convergence between clubs</i>			
Club 1 + Club 2		-3.535	-0.293
Club 2 + Club 3		-19.820	-1.174
<b>Sample: Post and telecommunications</b>			
Club 1	Lithuania, Slovakia, Slovenia, Estonia	3.876	0.753
Club 2	Hungary, Latvia, Poland, Romania	3.880	0.704
Diverging	Bulgaria, the Czech Republic		
<i>Testing convergence between clubs</i>			
Club 1 + Club 2		-108.293	-1.091
<b>Sample: Renting and other business activities</b>			
Club 1	Hungary, Lithuania, Romania, Slovakia, Poland, Bulgaria, Estonia	3.720	0.219
Club 2	The Czech Republic, Latvia, Slovenia	-1.256	-0.118
<i>Testing convergence between clubs</i>			
Club 1 + Club 2		-9.099	-0.217
<b>Sample: Public administration, education, and health</b>			
Club 1	Overall convergence	2.416	0.140
<b>Sample: Real estate activities</b>			
Club 1	Estonia, Romania, Slovenia, Hungary	0.633	0.043
Club 2	The Czech Republic, Latvia	3.399	0.285
Diverging	Bulgaria, Lithuania, Poland, Slovakia		
<i>Testing convergence between clubs</i>			
Club 1 + Club 2		-4.351	-0.223

Note: The null hypothesis of convergence is rejected at the 5% level if  $t_b < -1.65$ .

increased heterogeneity was noticed for the financial intermediation sector. The clustering algorithm revealed the formation of three clusters. Bulgaria, Slovakia, Estonia, the Czech Republic, Slovenia, and Hungary were included in the first cluster; Poland and Lithuania formed the second cluster, while Latvia and Romania were grouped in the third convergence cluster.

Concerning the productivity in post and telecommunications, we noticed the formation of two clubs, comprising on the one hand Lithuania, Slovakia, Slovenia, and Estonia and on the other hand Hungary, Latvia, Poland, and Romania. Bulgaria and the Czech Republic



diverged. The clustering algorithm for the productivity convergence in renting and other business activities revealed the formation of two clubs: the first one comprised Hungary, Lithuania, Romania, Slovakia, Poland, Bulgaria, and the second one comprised Estonia, the Czech Republic, Latvia, and Slovenia.

With respect to real estate activities, the clustering analysis indicated the presence of two clubs: the first one comprised Estonia, Romania, Slovenia, and Hungary, and the second one comprised the Czech Republic and Latvia, along with four diverging countries: Bulgaria, Lithuania, Poland, and Slovakia.

The results show that productivity paths are very diverse across sectors and between countries. These findings correspond with those obtained by Inklaar and Timmer (2009) who showed that the patterns of convergence are highly industry-specific and that there is no dominant convergence trend in sectoral productivity growth in OECD countries. Bijsterbosch and Kolasa (2010) have also highlighted important productivity differences at the country and industry level, while Kuusk, Staehr, and Varblane (2016) have emphasized different labour productivity growth across different sectors and different courses within CEE countries.

Several factors can explain sectoral cross-country productivity differences. Kancs (2007) emphasized sectoral specialization in CEE countries. The author showed that the sectoral specialization level became heterogeneous within CEE, as countries have become specialized according to their comparative advantages. Considering similar regional specialization and sectoral concentration patterns, the author identifies three groups of countries: the Czech Republic, Hungary, Poland, and Slovakia; Bulgaria and Romania; and Estonia, Latvia, and Lithuania. Productivity was influenced by the share of foreign direct investments and other forms of financial support that each sector had attracted. Moreover, according to WIOD data, the share of each sector in GDP ranged significantly from one country to another. For example, manufacturing percentage in GDP ranges from 9.9% in Latvia to 25.8% in the Czech Republic, while services share ranges from 7.7% in Romania to 15.3% in Slovenia in 2011. Furthermore, cross-country differences were present in the share of total hours worked by high-, medium-, and low-skilled employees (e.g. the high-skilled employee share ranged from 10.4% in Romania to 38.2% in Estonia in 2009). Therefore, we conclude that sectoral different paths are caused by idiosyncratic factors.

The clustering procedure and the transition curves for productivity convergence within the CEE countries provide some important findings. Firstly, the performance of the Baltic countries should be highlighted. For most of the analysed sectors, the productivity growth has significantly accelerated in Lithuania, Estonia, and Latvia compared to other countries within CEE. Therefore, these countries have reduced productivity gaps compared to the countries with the highest levels of productivity in the region (i.e. Slovenia, Slovakia). Productivity patterns in Slovakia and Poland have been, with minor exceptions, above or around the panel average. Productivity in Slovenia, the Czech Republic, and Hungary follows a similar pattern. The downward curves for these countries can be explained through the catch-up process that other countries, especially Baltic countries, have experienced. The productivity pattern in Bulgaria is well below the sample average, while in Romania, especially after 2000, we noticed a catch-up process with more visible results in the manufacturing industry. However, Romania, alongside Bulgaria, still has the lowest productivity levels in this region. These findings are strengthened by the



productivity growth analysis (see the Appendix). Secondly, the regional proximity explains the formation of some clubs, mainly for clusters that include Lithuania, Estonia, and Latvia. Thirdly, the detected clusters display only relative convergence, with some minor exceptions. The dynamics of growth transition paths exhibit a pronounced degree of heterogeneity, implying divergent paths for productivity growth in these countries. Conversely, the dispersion between the productivity level curves has reduced over the sample period.

## 5. Conclusions

This article studied the productivity convergence in the emerging countries from CEE –the most recent EU Member States. Productivity convergence was tested for the total economy and for the most important sectors. Given the competition to which countries are exposed to after integration in the European single market, we believe that it is essential to identify productivity growth patterns and to test convergence hypotheses. Therefore, in order to avoid potential economic losses, productivity convergence is required. To achieve our objectives, we applied a non-linear single-factor model.

The results revealed important aspects. The convergence hypothesis for productivity convergence within CEE was rejected for all countries in most sectors. The main advantage of the employed model is that it enables the formation of convergence clubs in which diverse countries converge to different steady-state equilibria. The formed convergence clubs are very different both in terms of number and countries. We notice that the gaps in the region have reduced over the sample period, mainly due to higher productivity growth rates for some countries. However, there are still significant disparities between CEE countries in terms of labour productivity. Also, the values of convergence speed are very low for most of the clusters, revealing only convergence in rates. The divergent productivity patterns could lead to a lower output, particularly for those countries that have a productivity growth below the sample average.

Clustering tests reveal productivity divergence within the CEE region. The best performers in the region are unequivocally Baltic countries which have a strong catch-up process. In our opinion, these countries have managed to reduce productivity gaps faster than others due to steady reforms implemented in the transition period. All Baltic countries have adopted shock therapy reform processes. Consequently, the GDP has dropped considerably during 1991–1993, and after 1995 the output growth rates have become robust. The performance of Slovakia and Poland (with some exceptions) is noteworthy. Productivity in Bulgaria has the lowest growth in our sample, while in Romania we can observe a catch-up process, especially after 2000. A possible explanation is the incremental reform process in Romania and Bulgaria and stabilized GDP growth rates since 2000. The sectoral productivity exhibited countries that recorded a high productivity growth in some sectors and a low productivity growth in others, revealing the prevalence of idiosyncratic factors in productivity determinants within CEE.

Our findings have important implications for both policy-makers and investors. The productivity divergence in the analysed sectors implies significant structural and institutional differences between countries. Therefore, the authorities should adopt more robust measures to stimulate productivity growth among CEE countries and increase convergence. For instance, public authorities should adopt reforms to improve competitiveness

in some sectors. Also, structural and cohesion funds should be oriented towards sectors where productivity has downward-sloping curves. For investors, the information provided by the convergence analysis can be extremely useful. Foreign companies could direct their investments towards those countries where the productivity growth is higher, taking into account that a higher productivity leads to a higher return.

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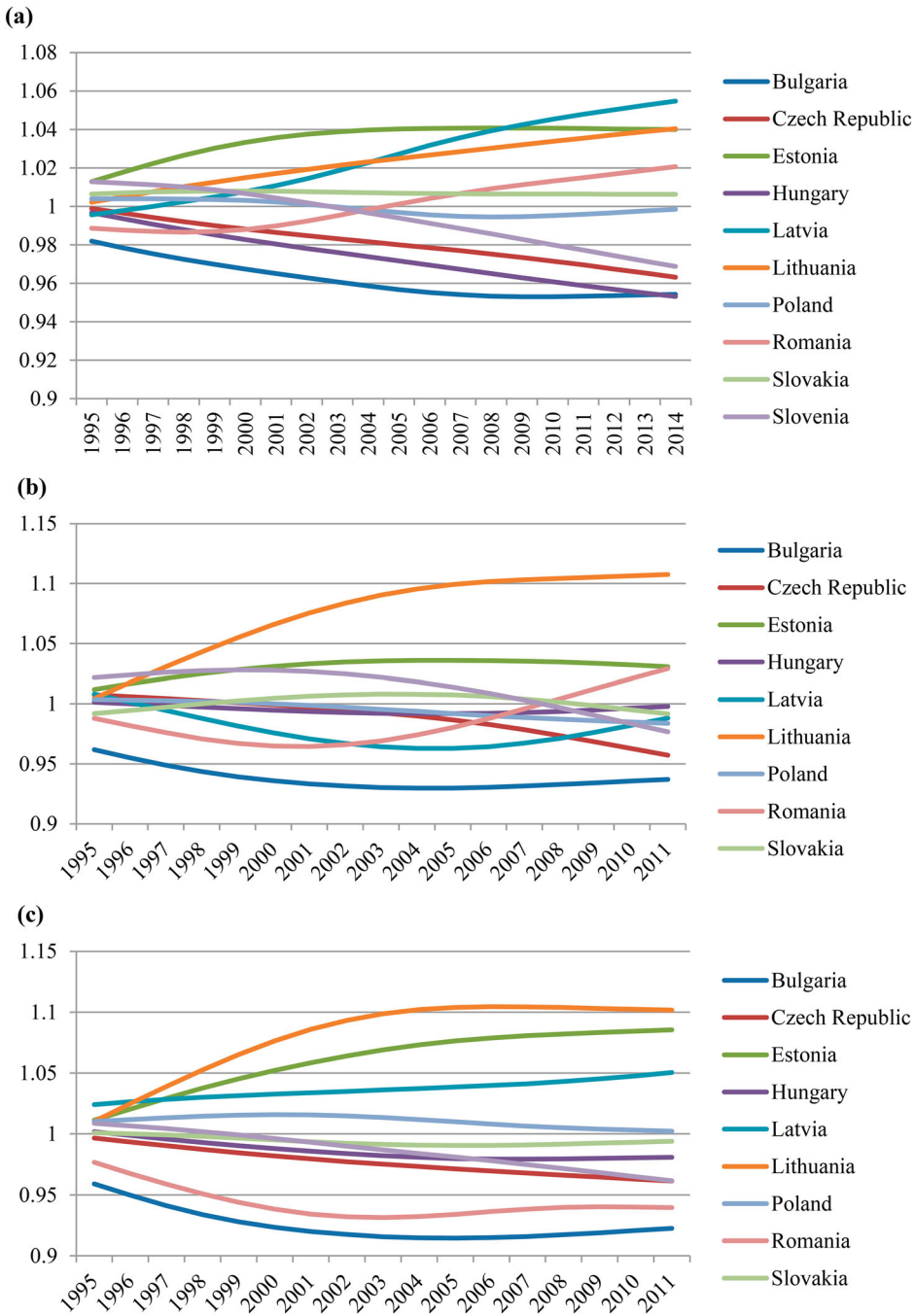
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## Appendix

**Table A1.** Convergence club classification for labour productivity indices.

Club	Countries	$t_b$	$\hat{b}$
<b>Sample: Total economy productivity</b>			
Club 1	Latvia, Estonia, Lithuania	10.152	0.404
Club 2	Romania, Slovakia	-0.168	-0.464
Club 3	Slovenia, the Czech Republic, Bulgaria, Hungary	2.305	0.254
Diverging	Poland		
<b>Sample: Manufacturing productivity</b>			
Club 1	Lithuania, Romania, Estonia, Latvia, Hungary, Poland, Slovenia, Slovakia	-1.316	-0.097
Club 2	The Czech Republic, Bulgaria	1.749	0.369
<b>Sample: Market services productivity</b>			
Club 1	Lithuania, Estonia	0.370	0.050
Club 2	Poland, Slovakia	2.766	0.528
Club 3	Hungary, the Czech Republic, Slovenia, Bulgaria, Romania	3.731	0.571
Diverging	Latvia		
<b>Sample: Construction</b>			
Club 1	Latvia, Bulgaria, Poland, Romania, the Czech Republic	-1.367	-0.358
Club 2	Estonia, Slovenia	-1.119	-2.094
Diverging	Slovakia, Lithuania, Hungary		
<b>Sample: Agriculture, hunting, forestry, and fishing</b>			
Club 1	Latvia, Slovakia, Estonia	5.414	3.331
Club 2	Lithuania, Poland, Slovenia	0.264	0.039
Club 3	Romania, Bulgaria	1.277	3.444
Diverging	Hungary, the Czech Republic		
<b>Sample: Trade</b>			
Club 1	Poland, Slovakia, Slovenia, the Czech Republic, Hungary	2.357	0.384
Diverging	Lithuania, Latvia, Estonia, Romania, Bulgaria		
<b>Sample: Transport and storage</b>			
Club 1	Latvia, Estonia	1.120	2.221
Club 2	Hungary, Poland	0.837	1.405
Club 3	Bulgaria, Romania	0.836	1.847
Club 4	The Czech Republic, Slovakia	3.781	3.218
Diverging	Lithuania, Slovenia		
<b>Sample: Financial intermediation</b>			
Club 1	Poland, the Czech Republic, Hungary	2.494	0.481
Club 2	Latvia, Slovakia	2.560	0.383
Diverging	Lithuania, Estonia, Slovenia, Bulgaria, Romania		
<b>Sample: Post and telecommunications</b>			
Club 1	Estonia, Slovakia, Romania	2.155	1.005
Club 2	Bulgaria, Poland, the Czech Republic, Hungary	2.690	0.432
Diverging	Lithuania, Latvia, Slovenia		
<b>Sample: Renting and other business activities</b>			
Club 1	Slovakia, Estonia, Romania	3.183	0.935
Club 2	Latvia, Poland, Slovenia, the Czech Republic	2.099	0.304
Diverging	Lithuania, Hungary, Bulgaria		
<b>Sample: Public administration, education, and health</b>			
Club 1	Estonia, Lithuania, Bulgaria, Romania, Latvia	3.461	0.421
Club 2	Poland, Slovenia	1.807	2.063
Diverging	Slovakia, Hungary, the Czech Republic		
<b>Sample: Real estate activities</b>			
Club 1	Estonia, Slovakia, Lithuania	2.831	1.210
Club 2	Poland, Hungary	-0.010	-0.002
Club 3	Romania, the Czech Republic, Bulgaria	-1.442	-0.334
Diverging	Latvia, Slovenia		

Notes: The null hypothesis of convergence is rejected at the 5% level if  $t_b < -1.65$ . The null hypothesis of convergence between clubs was rejected in all cases.



**Figure A1.** Relative transition curves in CEE countries. (a) Total economy productivity index. (b) Manufacturing productivity index. (c) Market services productivity index.