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Real Convergence of EU Economies: Do Structural Breaks Matter?[1]

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Abstract

This study examines the real GDP convergence of EU Member States. It adds to the abundance of conditional convergence studies by utilizing a unit root test with up to two structural breaks, finding that the crisis has not stopped the long-run convergence within the EU. Differing from similar studies, we discriminate between up and down breaks in the convergence process, and apply the non-parametric Wilcoxon signed-rank test to identify variables that are coincidental with these shifts. Convergence accelerations are characterized by nominal exchange rate and unit labour cost changes, while slowdowns are followed by investment shocks. The importance of external trade is particularly emphasized during convergence accelerations. Several different robustness checks leave these findings quite intact.

Keywords: *output convergence, European integration, unit root test, structural break*

JEL Classification: C22, O47, O52, R12

Introduction

The issue of regional and national output convergence has been one of the focal points of macroeconomic research in recent years. Its relevance is particularly pronounced within the supranational political and economic associations such as the European Union (EU). Namely, reducing income and output disparities has been the key EU policy goal ever since its inception. The EU authorities have embedded the objective of reducing disparities and inequality in all of the essential EU documents, from the Treaty of Rome in 1957 to the recent *Europe 2020 Strategy*, a novel strategic agenda for the period of 2010 – 2020. With time,

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the EU has designed specific instruments for promoting convergence, competitiveness, well-being and reducing socio-economic disparities between EU regions. To reach these goals, the EU has set up the Cohesion Policy investment framework, ensuring EUR 351.8 billion (roughly a third of the EU budget) for the period 2014 – 2020.

It is therefore no surprise that the issue of economic convergence within the EU has drawn a lot of academic attention and stimulated a vast body of empirical literature. The observed variety of studies can be segregated into three methodological strands. The first, oldest and most popular literature branch builds upon the so-called β-convergence concept (Baumol, 1986; Barro and Sala-i-Martin, 1992; Workie, 2003; 2004), postulating a negative correlation between a country's initial real per capita output and its average growth rate.[2] The β-convergence approach, as initially introduced by Baumol (1996), uses cross-section regressions to test the predictions of the Solow (1956) neoclassical growth model. In particular, this approach examines how a particular country's average growth rate commoves with its initial output. This class of convergence testing has been very popular in the literature (see Barro and Sala-i-Martin, 1992, for an influential early effort, among many others; or Crespo Cuaresma, Ritzberger-Grünwald and Silgoner, 2008; and Cavenaile and Dubois, 2011, for a more recent examination). However, serious doubts have been raised about its validity. First, it is derived on the basis of the neoclassical growth model, but it fails to test the validity of the neoclassical model in comparison to any competing theoretical specification (see Bernard and Durlauf, 1996, or Durlauf and Quah, 1999, for a discussion). Second, some authors have emphasized that β-convergence concentrates solely on the behaviour of a 'representative' economy. In the set of examined economies, there might be one (or more) whose convergence process follows a vastly different law of motion than the others. Consequently, Quah (1993b) finds that a negative correlation between the average growth and initial output does not necessarily imply a decrease in the cross-sectional variance (completely contradicting the convergence hypothesis). The third vital criticism came from Islam (1995), who gave preference to panel estimation (not to cross-sectional regressions) in order to account for a limited number of observations (make use of both the cross-section and time dimension), resolve endogeneity issues and the omitted variable bias.

These three main criticisms have resulted in a series of methodological improvements. Concerning the groundless insisting on the behaviour of the 'representative' economy, researchers have changed the focus to unit root and

[2] Barro and Sala-i-Martin (1992) also introduce the notion of σ-convergence, referring to the reduction of output dispersion across cross-section units over time. That notion is, however, beyond the scope of this paper and will not be analyzed here.

co-integration analysis, which enable the examination of each economy individually (Ingnianni and Žďárek, 2009). On the other hand, Evans and Karras (1996), Kutan and Yigit (2005) and Reza and Zahra (2008) use panel unit root tests to account for small sample problems.

To examine the intra-distributional dynamics (not just the behaviour of a 'representative' economy, others have turned to the stochastic kernel and Markov chain methodology (Quah, 1993a, b; and Geppert and Stephan, 2008, among others). This approach is also not free of disapproval. For example, Bickenbach and Bode (2003) criticize the over-restrictive assumption that the data generating process is time-invariant and that it satisfies the Markov property. Bickenbach and Bode (2003) even empirically test the Markov property for the income distribution of 48 USA states over the period of as much as 70 years via a chi-square test. Their results firmly disapprove the Markov property.

To summarize, there is no consensus in the literature regarding the 'optimal' methodological route to measuring convergence. Each approach has its own flaws. This study tackles the issue of real GDP convergence among EU Member States by building upon the unit root testing procedure, but we make a serious effort to circumvent its most criticized flaw. Namely, a lot of attention has been drawn in the literature to the low power of univariate linear unit root tests such as the Augmented Dickey Fuller (ADF) test (see Reza and Zahra, 2008, for a discussion). Some researchers have responded to this criticism by applying panel unit root tests (Kutan and Yigit, 2005, or Reza and Zahra, 2008). However, the panel unit root tests employed in these studies are still linear, and fail to account for possible structural breaks in the observed series. Having in mind the evident trend breaks in the dataset examined here (see Appendix 1 for details), resorting to linear panel unit root tests to increase the low power of univariate specifications would be of little use. To counteract that, this study utilizes the 'Residual augmented least squares-Lagrange Multiplier' (RALS-LM) unit root test with allowance for two endogenously determined structural breaks (Lee, Strazicich and Meng, 2012; Meng, Lee and Payne, 2017). Apart from paying attention to the noticeable trend break(s) in the data series, this test has one more advantage that is important. Conventional nonlinear unit root tests assume a particular nonlinear function to account for breaks or smooth transition mechanisms, but they still preserve the assumption of error term normality. Lee, Meng and Lee (2011) find that these tests suffer from a significant loss of power in case of non-normal errors. The approach applied in this paper allows for non-normality and actually gains power in case of non-normal errors. To the best of the authors' knowledge, this paper is both the first that examines income convergence by a unit root test with trend breaks, and the first one to allow for error term non-normality.

Another reason for the growing interest on economic convergence within the EU is the recent European sovereign debt crisis, which raised questions of whether several Member States (Portugal, Ireland, Italy, Greece, and Spain – PIIGS in particular) were able to refinance their government debt, bail out their over-indebted banks and bring their economies back on the growth track. Since the existing studies of economic convergence within the EU uniformly focus on the period before the Great Recession of 2008, it is essential to provide a contribution in that sense and examine whether the crisis has affected the convergence process in any manner.[3] This study aims to fulfill that goal.

As a third empirical contribution to the literature, this paper utilizes the methodology of Jones and Olken (2008) to discriminate between up and down breaks in the data (implying intensifying and weakening of the catching-up process). The authors then examine a wide set of macroeconomic variables to inspect which of them coincide with upward and which with downward episodes. That way the authors add some understanding to the convergence puzzle and reveal some of the macro factors which are strongly interrelated to the catching up process of EU Member states. Finally, as it focuses on as much as 27 individual EU economies, this is (along with Cavenaile and Dubois, 2011) the most extensive convergence study of this sort.

The obtained results demonstrate strong evidence of conditional convergence, once the trend breaks in the examined GDP disparities are accounted for.

This paper is organized as follows. Section 1 offers a brief literature review, focusing on the most influential empirical studies of output catching-up within the EU. Section 2 explains the contribution of the newly developed LM unit root test with structural breaks, particularly in the context of output convergence in EU Member States. Section 3 presents the obtained empirical results and the relevant determinants of *up* and *down,* trend breaks in the examined catching-up process. The final section concludes the paper and proposes some promising extensions of the analysed model.

1. Output Convergence in the European Union

This study focuses on real output convergence of 27 EU Member States.[3] Hitherto, authors have approached this topic mainly by cross section and panel regressions, or univariate and panel unit root tests. Among the recent β-convergence studies for the EU; it is worthwhile mentioning the study by Crespo

[3] The recent crisis is also an additional reason for allowing the error term non-normality. Empirical studies often recognize economic crisis as the source of outliers and extreme data points, which might induce non-normal error distributions.

Cuaresma, Ritzberger-Grünwald and Silgoner (2008). They analyse the EU-15 yearly real GDP per capita, spanning from 1960 to 1998. They find a significant negative β-coefficient in several panel model specifications, providing strong evidence in favour of the convergence hypothesis. In an attempt to shed some light on the determinants of GDP convergence, the authors find that (apart from macroeconomic fundamentals), the duration of EU membership plays a vital role in enhancing growth. Crespo Cuaresma, Ritzberger-Grünwald and Silgoner (2008) extend the model even further by a panel threshold technique, revealing that economies with a lower initial level of development comparatively benefit more from EU accession than the rich countries. With that in mind, it would be interesting to observe whether the New Member States (NMS) have gained more (in the context of GDP convergence to the EU average) from the EU accession than have the Old Member States (OMS). This study aims to provide an answer to that question.[4]

Cavenaile and Dubois (2011) also study β-convergence of the EU-27 countries, and similarly obtain a significant negative convergence coefficient. In addition, they find a considerably different convergence rate between 15 OMS countries and the 10 NMS from Central and Eastern Europe (CEE). These findings largely corroborate the conclusions of Crespo Cuaresma, Ritzberger-Grünwald and Silgoner (2008).

The most influential study within the unit root approach to convergence is done by Kutan and Yigit (2005). They examine (inter alia) the industrial production index as a proxy of overall activity and apply a battery of panel unit root tests to question the convergence of 10 NMS with regards to Germany and Greece. Although the results are somewhat sensitive to the utilized methodology, strong convergence is found with respect to both 'benchmark' countries. Reza and Zahra (2008) perform a rather similar study, exploiting three different panel unit root tests to examine the persistence of GDP disparities in 10 EU NMS. The obtained unit root test results go in line with the absolute convergence hypothesis.

Brada, Kutan and Zhou (2005) put a twist on the classic unit root approach to convergence, using rolling co-integration as an indicator of catching up between two groups of countries (4 OMS and 5 NMS) with respect to Germany and France as core EU economies. The authors find that real convergence (in terms

[4] It should be noted that regional income convergence is a topic beyond the scope of this paper. See, for instance, Magrini (1999) or Magrini (2004) for contributions of that kind. Although it is quite plausible to assume that regional and national convergence analysis might not lead to similar results (as empirically confirmed by Otoui and Titan, 2015), we opt for the latter approach for purely technical reasons. Namely, it is only the macro-level framework that enables us to perform an analysis in the vein of Jones and Olken (2008) and identify the macroeconomic variables that are relevant for explaining the up and down breaks in the convergence process. These variables are unfortunately not published at the regional level.

of real per capita GDP) is in total much weaker than the monetary convergence (in terms of monetary aggregates and inflation). More important, the real catching-up process is barely existing in the NMS (both with respect to Germany and France). This quite heavily contradicts the prevailing conclusions in other similar studies. The inconsistency can perhaps be explained by different methodological approaches, raising doubt on the robustness of the obtained results.

Ingnianni and Žďárek (2009) provide perhaps the most methodologically meticulous study of EU economies' real convergence. They focus on eight NMS from the fifth EU Enlargement, and their convergence with respect to the core EU-15 countries. The authors utilize the cross-section β-convergence approach, two different univariate unit root tests and co-integration tests. The obtained results show evidence of relatively strong β-convergence, while the ADF testing procedure point to rather diverse conclusions (depending on the observed model specification). The Johansen co-integration technique also provides strong evidence of convergence, just as the stochastic unit root test results.

2. Data and Methodology

Adding to the existing literature, the authors of this paper follow the route proposed by Meng, Payne and Lee (2013) in a similar study of energy consumption convergence. Therefore, output convergence is tested by calculating the logarithmic ratio of each Member States' real GDP per capita to the average of the same variable across all the examined EU countries (in each analysed time period):

$$y_{it} = ln\left(GDP_{it} \,/\, averageGDP_{t}\right) \tag{1}$$

Relation (1) implies that an equal percentage shock in all observed countries would leave the logarithmic ratio unchanged. In other words, a potentially observed structural break in the examined ratio would surely be country-specific. If the examined ratio for a particular country is stationary, a conclusion can be drawn that the country of interest does not diverge from the average EU GDP per capita time path. This paper focuses on 27 individual EU Member States.[5] The analysed variables are of monthly frequencies, obtained from Eurostat. The ratios obtained through equation (1) are seasonally adjusted using the ARIMA X12 method and then graphically depicted in Appendix A. The examined dataset essentially covers the period 2002 Q1 – 2016 Q1. Two countries differ in terms of sample ends. The data for Greece ends in 2014 Q4, while the Irish series ends in 2015 Q4. It is easily observable that the ratios of most examined countries are

[5] Romania is excluded from the analysis due to the unavailability of real GDP per capita data.

subject to up to two structural breaks. The recent global financial crisis is the central cause of the majority of identified breaks. Given that, standard (linear) unit root tests (such as the ADF test) should tend to under-reject the null hypothesis and produce biased results due to their inability to account for the evident break(s) in the examined series. To overcome that problem, this paper applies the relatively new RALS-LM unit root tests with allowance for two endogenously determined structural breaks (Lee, Strazicich and Meng, 2012; Meng, Lee and Payne, 2017). RATS software is used for estimation purposes.

The hereby-utilized unit root test with up to two structural breaks is based on the following unobserved component representation:

$$y_t = \delta' Z_t + e_t \tag{2}$$

where

y_t – the time series at hand,

Z_t – a set of regressors, and the error term follows an autoregressive process of first order ($e_t = \beta e_{t\text{-}1} + \varepsilon_t$).

Allowing for multiple structural breaks, let T_{Bi} be the time period of each particular break. Then let Z_t include the following exogenous variables:

$$Z_t = \left[1,\quad t,\quad D_{1t},\quad \ldots,\quad D_{Rt},\quad DT^*_{1t},\quad \ldots,\quad DT^*_{Rt}\right]' \tag{3}$$

where t is the trend term, while the break dummy variables are $D_{it} = 1$ for $t \geq T_{Bi} + 1,\quad i = 1,\ldots,R$ (level breaks), and zero otherwise; and $DT^*_{it} = t - T_{Bi}$ for $t \geq T_{Bi} + 1,\ i = 1,\ldots,R$, and zero otherwise (trend breaks).

Lee, Strazicich and Meng (2012) impose the restriction $\beta = 1$ and start the testing procedure from the following equation:

$$\Delta y_t = \delta' \Delta Z_t + u_t \tag{4}$$

where $\delta = [\delta_1,\quad \delta_2,\quad \delta'_{3i},\quad \delta'_{4i}]$, $i = 1,\ldots,R$. Then the de-trended series ($\tilde{S}_t$) is added to the equation:

$$\Delta y_t = \delta' \Delta Z_t + \varphi \tilde{S}_{t-1} + e_t \tag{5}$$

where $\tilde{S}_t$ is:

$$\tilde{S}_t = y_t - \tilde{\psi} - Z_t \tilde{\delta} \tag{6}$$

$\tilde{\delta}$ is the estimated coefficient from equation (4), and $\tilde{\psi} = y_1 - Z_1 \tilde{\delta}$. The unit root existence is thus tested through the null hypothesis $\varphi = 0$.

Lee, Strazicich and Meng (2012) prove that the unit root test statistic for this model depends on the break(s) location. This is a tremendous problem in empirical applications since it necessitates the calculation of novel critical values for each combination of the identified breakpoints. To overcome this issue, Lee, Strazicich and Meng (2012) introduce a simple transformation:

$$\tilde{S}_t^* = \begin{cases} \dfrac{T}{T_{B1}} \tilde{S}_t & \text{for } t \le T_{B1} \\ \dfrac{T}{T_{B2} - T_{B1}} \tilde{S}_t & \text{for } T_{B1} < t \le T_{B2} \\ \vdots & \\ \dfrac{T}{T - T_{BR}} \tilde{S}_t & \text{for } T_{BR} < t \le T \end{cases} \tag{7}$$

which removes the dependency on the nuisance parameters. Inserting transformation (7) into equation (5) yields the following test equation:

$$\Delta y_t = \delta' \Delta Z_t + \varphi \tilde{S}_{t-1}^* + \sum_{j=1}^{k} d_j \Delta \tilde{S}_{t-j} + e_t \tag{8}$$

where k is the lag order (added in the vein of the ADF test). The unit root test statistic (the *t*-statistic for the unit root hypothesis $\varphi = 0$, denoted by $\tilde{\tau}_{LM}^*$) does not depend on the location of the breaks, but only on their number (*R*).

The described unit root test is more powerful than the standard ADF procedure (Lee, Strazicich and Meng, 2012). However, further power improvement is acquired by allowing for non-normal errors. This is especially important in the context of the recent crisis, causing considerable outliers in the data and deviations from the presumed error term normality. To account for that, Meng, Lee and Payne (2017) adopt the RALS method, as elaborated by Meng and Lee (2012) and Im, Lee and Tieslau (2014). They augment regression (8) by the term $\hat{w}_t$:

$$\hat{w}_t = h(\hat{e}_t) - \hat{K} - \hat{e}_t \hat{D}_2 \tag{9}$$

where $\hat{K} = \frac{1}{T}\sum_{t=1}^{T} h(\hat{e}_t)$, $\hat{D}_2 = \frac{1}{T}\sum_{t=1}^{T} h'(\hat{e}_t)$, and $h(\hat{e}_t)$ captures the error term non--normality by the second and third moment of $\hat{e}_t$: $h(\hat{e}_t) = \left[\hat{e}_t^2, \hat{e}_t^3\right]'$. The test equation then becomes:

$$\Delta y_t = \delta' \Delta Z_t + \varphi \tilde{S}_{t-1}^* + \sum_{j=1}^{k} d_j \Delta \tilde{S}_{t-j} + \hat{w}_t' \gamma + u_t \tag{10}$$

The conventional least squares estimation of equation (10) leads to increased efficiency in case of non-normal errors. The empirical *t*-statistic for the null hypothesis $\varphi = 0$ is denoted by $\tau^{*}_{RALS-LM}$. The critical values are again not dependent on the location of the breaks and are tabulated in Meng, Lee and Payne (2017).

To summarize, the testing procedure is stepwise. In the first step, the maximum break number is set to R = 2 because Meng, Lee and Payne (2017) find a significant loss of test power when allowing for more than two breaks. Break locations are identified through the $max F$ -test, each break's significance is tested by a standard *t*-test, and the optimal lag order is set simultaneously. If the null hypothesis of no trend break[6] is not rejected or if the null is rejected, but one of the break dummy variables is not significant,[7] the first step is reiterated using R = 1. This step is repeated until R = 0 or all break dummy variables are significant. The second step is twofold. If R = 0, the no-break LM unit root test of Schmidt and Phillips (1992) is applied. If R = 1 or R = 2, the Amsler and Lee (1995) and Lee and Strazicich (2003) LM test is applied, determining the break location and significance as in the first step. The final, third step of the procedure involves the RALS methodology and obtaining the $\tau^{*}_{RALS-LM}$ test statistic. When comparing the efficiency of the two-step LM test (Amsler and Lee, 1995; Lee and Strazicich, 2003) and the three-step RALS-LM test (Meng, Lee and Payne, 2017), one should inspect the relative ratio of the error term variances from equation (10) and (8):

$$\rho^2 = \frac{E\left(u_t^2\right)}{E\left(e_t^2\right)} \tag{11}$$

3. Empirical Results

The starting point of the analysis is a standard ADF test, which strongly disapproves the convergence hypothesis by non-rejecting the null hypothesis for all countries except Luxembourg.[8] However, linear unit root test specifications (such

[6] Only trend breaks are considered here due to data characteristics (see graphical presentations in Appendix 1). This is also in line with previous empirical applications of this test (Meng, Payne and Lee, 2013; Meng, Lee and Payne (2017).

[7] 10% significance level is applied, in accordance with Meng, Payne and Lee (2013) and Meng, Lee and Payne (2017). Following the same authors, the maximum examined lag order k is set to eight. The optimal lag length is chosen through a general-to-specific modelling strategy. Starting from an 8 lags specification, in each iteration the *t*-statistic is examined for the *k*-th lag is examined. If it is not significant at the 10% level, the lag order is reduced by one. Finally, if the highest lag was not found to be significant for any *k*, the model is estimated with zero lags.

[8] The results are available upon request.

as the ADF test) are strongly biased in the presence of structural breaks (Perron, 1989). With that in mind, it seems crucial to employ the RALS-LM unit root test with up to two structural breaks. The obtained results are shown in Table 1.

Table 1

RALS-LM Unit Root Test Results

Country	$\tau^*_{RALS-LM}$	$\hat{\rho}^2$	$\hat{T}_B$		$\hat{k}$
Austria	–3.5448***	0.9708	2010:01	–	7
Belgium	–2.0183[a]	NA	NA	NA	NA
Bulgaria	–10.5669***	0.5116	2005:02	2009:02	8
Croatia	–5.8312***	0.7334	2004:03	2009:01	3
Cyprus	–4.9930***	0.8082	2010:02	2012:04	0
Czech Republic	–6.01517***	0.4424	2008:02	–	7
Denmark	–4.5002**	0.9384	2006:01	2010:02	6
Estonia	–4.8814**	0.7457	2007:03	2010:01	0
Finland	–5.7564***	0.7948	2008:03	2011:04	7
France	–6.1415***	0.9951	2008:02	2014:03	0
Germany	–4.9496***	0.8824	2007:01	2011:04	3
Greece	–3.9955**	0.7896	2009:03	–	6
Hungary	–6.1963***	0.6529	2005:01	2008:01	8
Ireland	–6.3145***	0.7843	2006:04	2011:02	0
Italy	–3.8609*	0.7296	2008:03	2014:02	3
Latvia	–1.1098[a]	NA	NA	NA	NA
Lithuania	–5.6993***	0.7733	2008:03	2010:04	3
Luxembourg	–5.7981***	0.7732	2006:02	2007:03	0
Malta	–5.2064***	0.9801	2007:01	2010:03	2
Netherlands	–5.8222***	0.9988	2006:04	2014:03	3
Poland	–5.8434***	0.9590	2008:03	2013:03	0
Portugal	–7.0225***	0.6918	2007:04	2013:03	7
Slovakia	–4.4372***	0.8863	2009:04	–	3
Slovenia	–3.4736*	0.8306	2008:02	–	7
Spain	–3.7320**	0.5203	2008:02	2009:01	8
Sweden	–4.1141**	0.6277	2009:04	2011:02	7
UK	–4.4807**	0.9915	2005:03	2011:01	7

Note: *(**, ***) denote significance at the 10 (5, 1) % significance level; NA – Non Available; [a] the Schmidt and Phillips (1992); τ test statistics is reported.

Source: Author's calculation.

The two-step LM unit root test results are not tabulated here for two reasons. First, the break locations obtained through the two-step estimator are the same as for the three-step RALS-LM test (since the first two steps of the procedure are exactly the same). Second, the $\hat{\rho}^2$ column reveals that RALS methodology increases efficiency in comparison to the two-step LM test in literally all examined countries. The improvement varies from more than double (in the case of Czech Republic) to only marginal (Netherlands).

Contradicting the ADF test results, Table 1 reveals strong signs of real convergence at conventional significance levels. The only two countries for which the null of non-stationarity (non-convergence) cannot be rejected are Belgium and Latvia. The finding of real convergence is in line with the conclusions of previous studies (Kutan and Yigit, 2005; Reza and Zahra, 2008; Ingnianni and Žďárek, 2009). It seems that the crisis has not shifted the integration process towards divergence.

As can be seen from Table 1, a total of 45 breaks is observed in the dataset. In accordance with the methodology of Jones and Olken (2008), this study discriminates between *up* and *down* breaks, depending on whether the average GDP disparity (defined by relation (1)) in the regime following the break is larger or smaller than the average GDP ratio prior to the break. Following this approach, a total of 25 *up* breaks and 20 *down* breaks are found. Shaded cells in Table 1 indicate *up* breaks, non-shaded cells point to *down* breaks.

Several macroeconomic variables are examined as potential determinants of *up* and *down* breaks. The variables of interest can be summarizes as follows. The group of fundamental macroeconomic aggregates include: real GDP per capita, government expenditures, household expenditures, and gross fixed capital formation. The next group of determinants comprise foreign trade variables: exports, imports, exports plus imports, and net exports, and terms of trade. The group of monetary variables include GDP deflator and the indices of nominal and real effective exchange rates. Lastly, unit labour cost index (as an indicator of a country' price competitiveness) and the Economic Sentiment Indicator (ESI) (quantifying the prevailing psychological sentiment in the national economy) are examined. A description of the examined dataset is presented in Appendix B.

The estimation strategy entails the following steps. The breaks identified in Table 1 are imposed on each of these variables, in each particular country. Subsequently, the average values of break determinants are calculated before and after the break occurrence. That way, for each of the 14 analysed macro determinants, 25 mean values before and 25 mean values after *up* breaks are obtained. In the same way, 20 averages before and after *down* breaks are gathered.[9] To inspect whether the mean values of the examined macro variables are equal across the breaks, we employ the non-parametric Wilcoxon signed-rank test instead of the standard t-test. This strategy is pursued because it solves two problems of the t-test. First, it successfully deals with non-normality of the data. Second, the convergence determinants at hand are mutually dependent (both time-wise and cross-sectionally, due to the fact that the EU States share a common market). The Wilcoxon signed-rank test is a non-parametric version of the dependent samples t-test, so it also resolves the dependence issue. This approach does not allow for specific causal interpretations, but merely identifies relevant variables whose changes coincide with breaks in the convergence process.

[9] ESI comprises 23 down breaks and 19 down breaks due to the fact that Ireland does not publish adequate ESI data, and Croatia has initiated the publication in as late as 2008:05, which annulled the *up* break in 2004:03.

The obtained results are summarized in Table 2. The presented mean differences quantify the discrepancies between the average values of the examined variables after the break (upward or downward) and before the break.

T a b l e 2

Determinants of *Up* and *Down* Breaks

Variable	UP BREAKS			DOWN BREAKS		
	Mean difference	p-value	Obs.	Mean difference	p-value	Obs.
GDP per capita	393.5796	0.0000	25	–110.555	0.2180	20
Government expenditures	–0.1077	0.6377	25	0.5879	0.0522	20
Household expenditures	–0.0775	0.6964	25	–0.1987	0.6813	20
Gross fixed capital formation	–1.2765	0.0230	25	–2.9827	0.0003	20
Exports	11.0911	0.0000	25	3.7240	0.0009	20
Imports	7.9863	0.0002	25	2.3340	0.0187	20
Exports + imports	19.0774	0.0000	25	6.0579	0.0017	20
Exports – imports	3.1048	0.0013	25	1.3901	0.0569	20
Terms of trade	0.0051	0.9036	25	–0.0014	0.7938	20
GDP deflator	13,6422	0.0000	25	8.3887	0.0001	20
NEER	2.7702	0.0370	25	0.9014	0.1913	20
REER	3.0908	0.1658	25	–1.3836	0.0859	20
Unit labour cost	7.1633	0.0000	25	0.8962	0.1790	20
ESI	–1.8512	0.6051	23	–3.0333	0.2954	19

Note: NEER – Nominal effective exchange rate; REER – Real effective exchange rate.

Source: Author's calculation.

Table 2 reveals several interesting asymmetries. Real GDP per capita is significantly different only across *up* breaks. This means that there is a considerable difference between the speed of convergence of rich and poor countries (on average). Path dependency seems to matter a lot. Government and household expenditures do not seems to possess any valuable information in that context, disapproving the classic Keynesian view that the aggregate demand is the main driving force of the economy. However, gross fixed capital formation is significantly lower in the periods after the *down* breaks. This can be traced back to the argument of Barry (2003), who states that the European integration process (financial integration in particular) is stimulating investments in the peripheral countries. A sharp investments decline has occurred in the recent crisis, coinciding with an obvious slowdown of the convergence process.

External trade variables (apart from the terms of trade) appears to be highly significant, in line with the arguments of Slaughter (1997). Looking at the observed positive mean differences of those variables, it is clear that EU Member States benefit from the EU common market, so the trade volumes (no matter how they are measured) exhibit continuous growth, regardless of the nature of the identified breaks (*up* or *down*). However, the external trade effects are always considerably stronger for the up breaks than for the down breaks. This once again firmly corroborates the strong link between external trade and economic convergence (Ben-David, 1993).

Moreover, the effect of external variables should be put in relation to the significance of both exchange rate variables (NEER and REER). *Up* breaks are characterized by appreciation pressures, while the opposite movement is present for *down* breaks. Another important aspect of the results from Table 2 is that a certain part of significant coincidental variables are internal and under direct influence of the economic policyholders. For instance, unit labour cost turns out significant only for the *up* breaks. In a sense, this contradicts the Kaldor's (1978) paradox. Recent studies have also made an effort to corroborate the link between unit labour cost and growth for EU countries (Felipe and Kumar, 2011). However, when put in the comparative context of real convergence, it seems that price competitiveness indeed does matter. A similar conclusion can also be drawn from the significance of exchange rate variables.

ESI seems to be non-significant for both types of breaks. This (surprisingly) contradicts both the theoretical framework of behavioural economics (Kindleberger and Aliber, 2011) and the empirical literature (Garner, 1991). Garner finds that the consumers' psychological sentiment is a significant predictor of households' expenditures in extreme events such as the Persian Gulf War recession in the USA. He also emphasizes a sharp and unexpected *down* break as necessary precondition for a psychologically driven recession. In that sense, it would be expected that ESI shifts are firmly related to *down* breaks. The found investments downfall in the presence of *down* breaks probably points to some kind of a psychological effect in the sense of Garner (1991). However, ESI seems not to be able to capture that effect accordingly. One should certainly raise the question of how much these results are robust to the choice of convergence benchmark. With that in mind, we perform four different robustness checks.

The first one is performed by excluding Luxembourg from the analysis, since that is the only EU economy for which the ADF test results firmly rejected non-stationarity of GDP disparity (disapproving the convergence hypothesis). The following two robustness checks are performed for only OMS and NMS groups of countries (separately). Lastly, we augment the analysis by inspecting the convergence of individual Member States relative to Luxembourg as the most developed EU country (in terms of real GDP per capita). The purpose of the last robustness check is inspect not the convergence relative to the average development level (as in the previously developed models), but the convergence relative to the benchmark (Luxembourg, being the most developed country in the sample). The results of these four robustness checks (both the results of unit root tests and of break determinants analysis) are presented in Appendix C. The results obtained in Tables 1 and 2 are to an extremely large extent corroborated through the four alternative model specifications. Regarding the non-convergence hypothesis (non-stationarity of GDP disparities tested by the RALS-LM test), Table 1 rejects it only in the case of Belgium and Latvia. When Luxembourg is removed from the sample, these two countries are joined by Austria, Italy, Slovakia and Spain. When only the OMS are observed; Denmark, Portugal and the UK stand out as the diverging countries. In the NMS group, Latvia diverges again. Lastly, when Luxembourg is treated as the benchmark relative to which we measure convergence; France, Greece and Italy fail to show significant convergence. It is therefore obvious that (with minor differences in the results of alternative models), there are only minor signs of divergence within the EU national economies. The recent crisis obviously did not considerably destabilize the long-term economic convergence process in the EU.

Regarding the determinants of *up* and *down* breaks, all the above discussed results of Table 2 seem to stand unaltered. One of the rare exceptions in that sense is that negative ESI shocks are found to coincide with *down* breaks in the Luxembourg benchmarking model. This is a finding that was theoretically expected, but other hereby estimated models have failed to find evidence of it.

Conclusion

This paper tests the conditional real convergence hypothesis via unit root testing. It differs from previous studies of this sort by including the post-2008 period in the analysis. This has directly conditioned the utilized methodology. Having in mind the evident structural breaks in the GDP disparities of individual EU members, the authors were compelled to employ the RALS-LM unit root test with allowance for two endogenously determined structural breaks. That way, this paper ensures more power to the unit root test in comparison to the otherwise employed linear test specifications. The obtained results indicate strong support of real convergence among EU countries, despite the sharp economic downfall in the recent recession.

An additional contribution of this paper is the identification of relevant macroeconomic variables, which appear to be coincidental with *up* and *down* breaks in the convergence process. The results approve of the relevance of external trade variables in explaining structural breaks. Downward breaks are followed by significant declines in investments, while the growth of unit labour cost coincide with upward breaks. Effective exchange rate exhibits appreciation within *up* breaks, and depreciation for *down* breaks.

Future studies should certainly include the development of a panel unit root test with the allowance of several structural breaks. This way a more powerful test could be established both in terms of aggregating the cross-section and time dimensions of the dataset (panel specification), and in terms of accounting for the evident structural breaks (which conventional panel unit root tests neglect).

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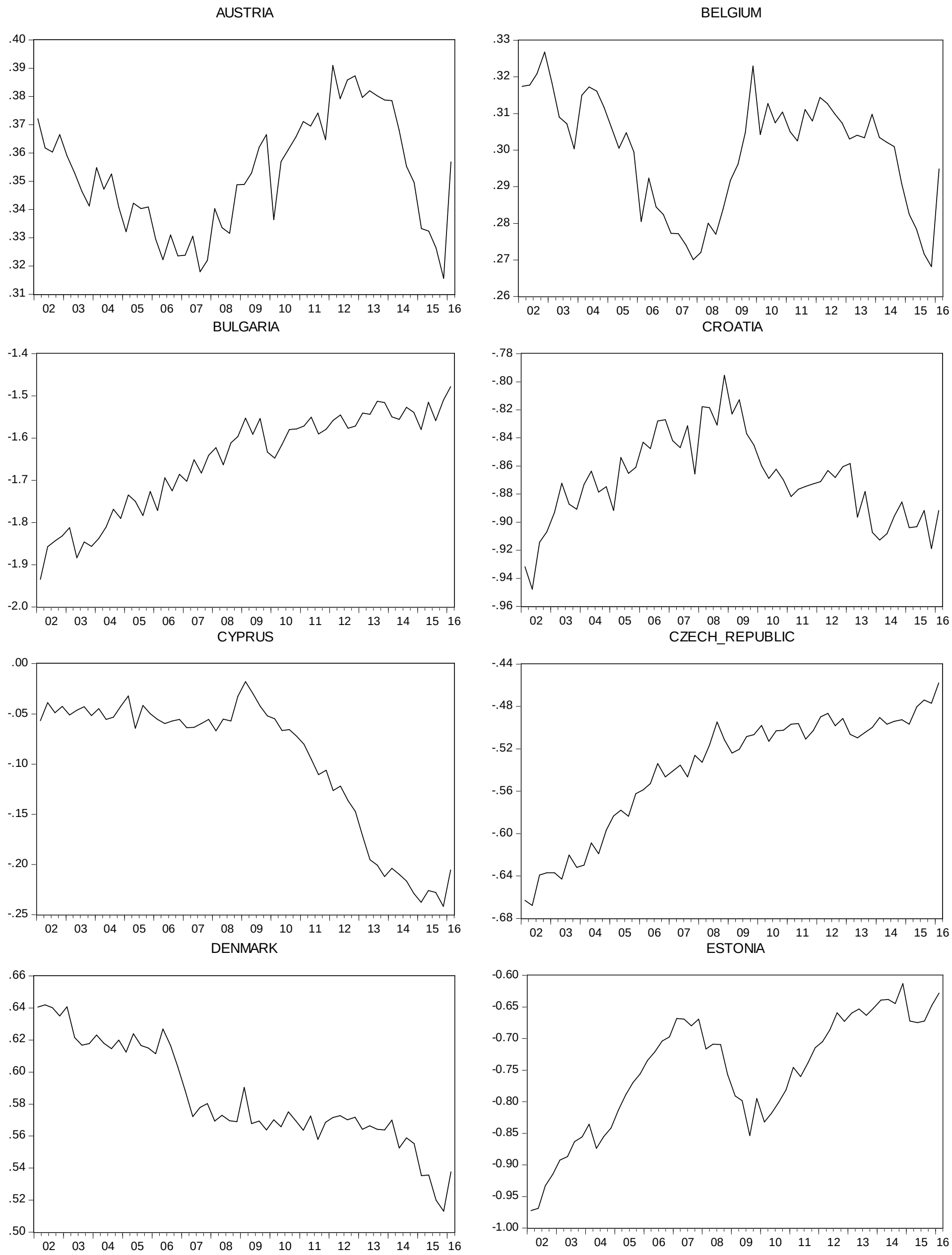
Appendices

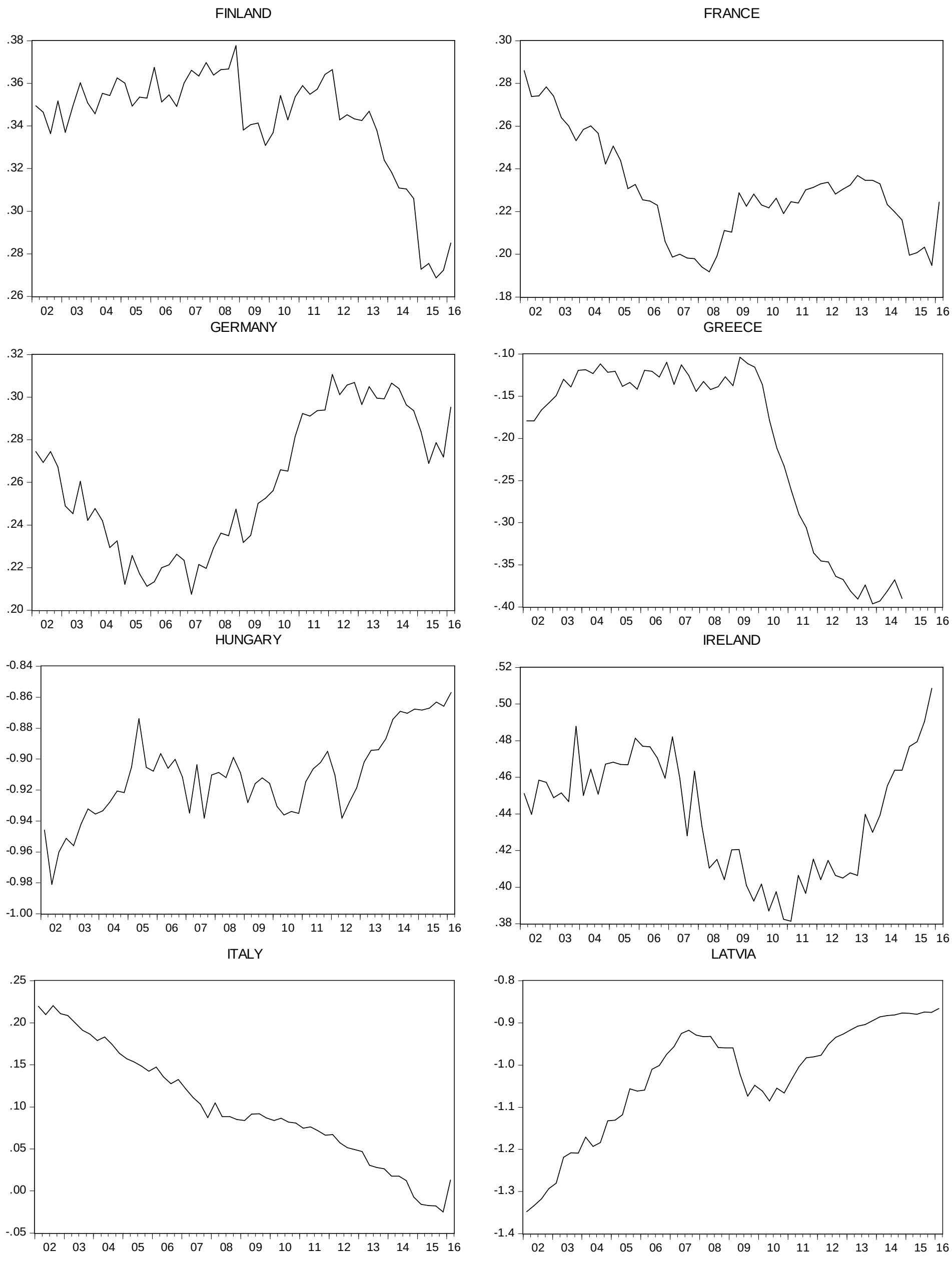
Appendix A

Graphical Presentations of GDP Disparities



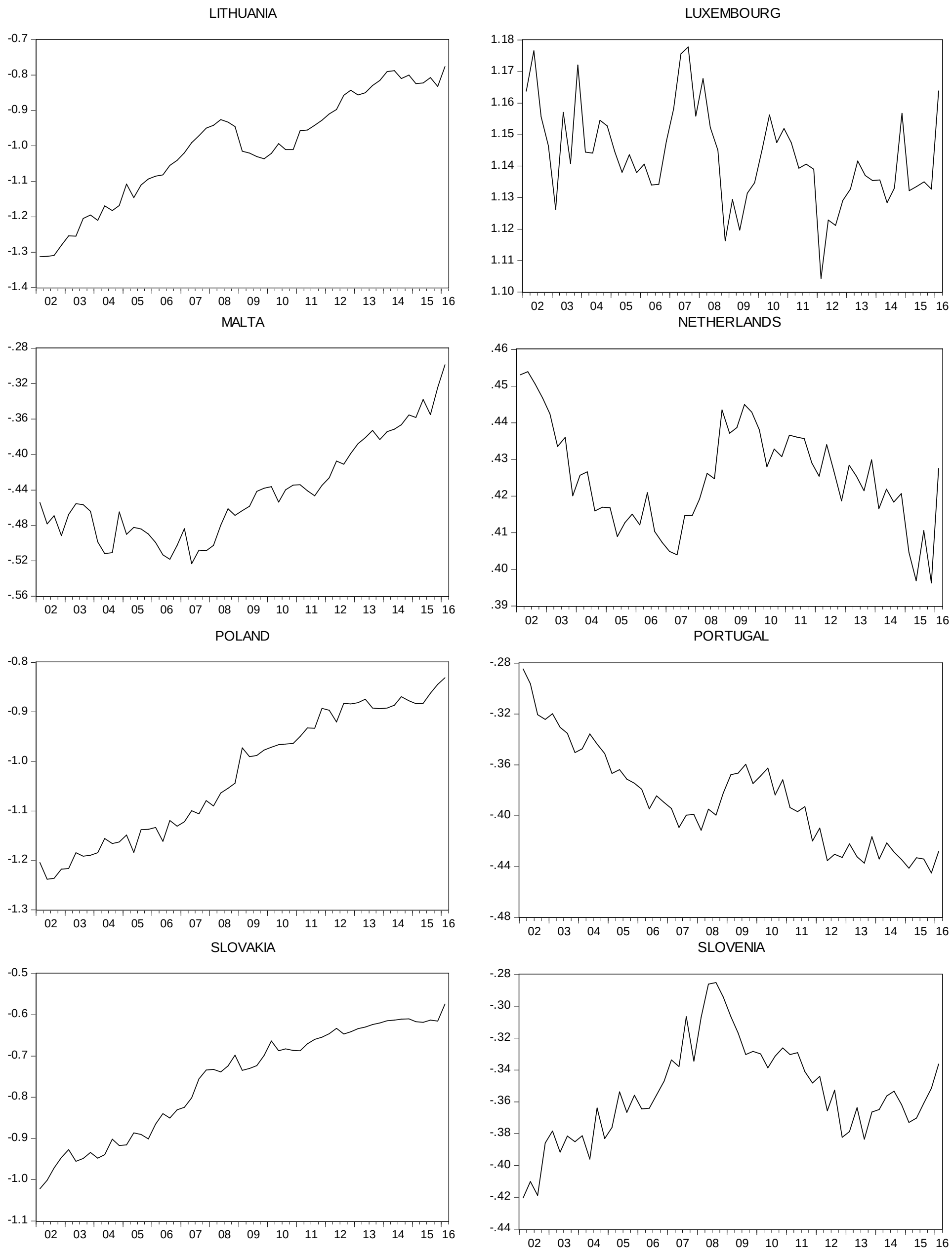
A p p e n d i x A

Graphical Presentations of GDP Disparities (continued)



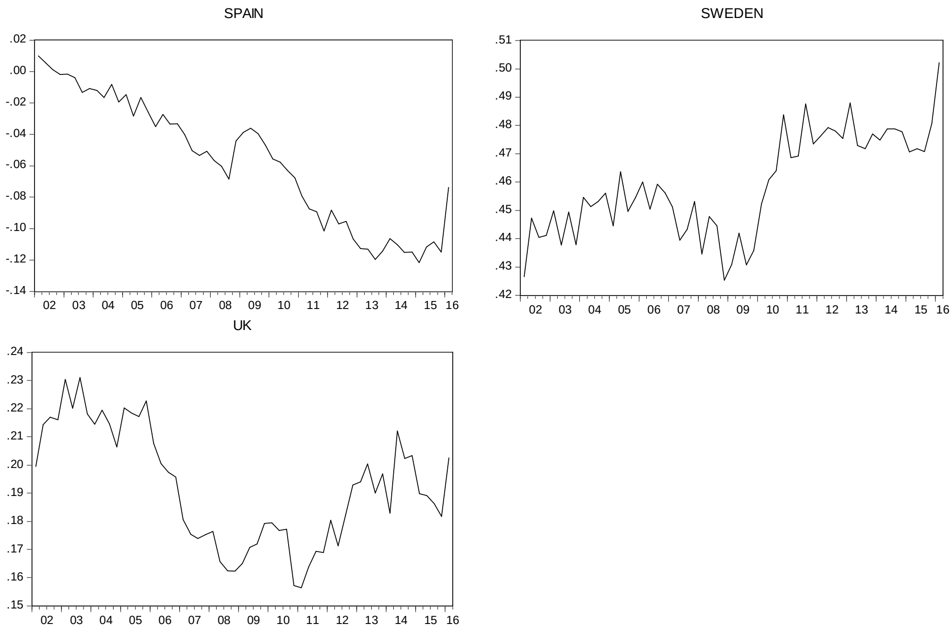
A p p e n d i x A

Graphical Presentations of GDP Disparities (continued)



A p p e n d i x A

Graphical Presentations of GDP Disparities (continued)



Source: Author's calculation.

A p p e n d i x B

Data Description

<table>
<tr><th>Variable</th><th>Description</th><th>Source</th></tr>
<tr><td>GDP per capita</td><td>In Euros</td><td rowspan="7">Eurostat</td></tr>
<tr><td>Government expenditures
Household expenditures
Gross fixed capital formation
Exports
Imports
Exports + imports
Exports – imports</td><td>GDP shares</td></tr>
<tr><td>Terms of trade</td><td>Ratio of a country's exports prices to imports prices</td></tr>
<tr><td>GDP deflator</td><td>Index (2005 = 100)</td></tr>
<tr><td>NEER</td><td>(2005 = 100, 42 trading partners included), increase = currency appreciation</td></tr>
<tr><td>REER</td><td>(2005 = 100, 42 trading partners included), increase = currency appreciation</td></tr>
<tr><td>Unit labour cost</td><td>Index (2010 = 100)</td></tr>
<tr><td>ESI</td><td>See European Commission (2016) for methodological details</td><td>European Commission</td></tr>
</table>

Note: All variables are seasonally adjusted using the ARIMA X12 method.

Source: Author's calculation.

A p p e n d i x C

Robustness Checks

C1. RALS-LM Unit Root Test Results (Luxembourg omitted)

Country	$\tau^{*}_{RALS-LM}$	$\hat{\rho}^2$	$\hat{T}_B$		$\hat{k}$
Austria	–2.3293[a]	NA	NA	NA	NA
Belgium	–2.2864[a]	NA	NA	NA	NA
Bulgaria	–10.8706***	0.5047	2005:02	2009:02	8
Croatia	–5.1384***	0.9838	2004:03	2009:01	3
Cyprus	–4.5227**	0.7754	2010:02	2012:04	0
Czech Republic	–5.2789***	0.8432	2008:02	–	0
Denmark	–3.5516[a]**	NA	NA	NA	NA
Estonia	–4.9932**	0.7382	2007:03	2010:01	0
Finland	–4.8532**	0.9175	2008:03	2011:04	6
France	–6.6250***	0.9140	2008:02	2014:03	0
Germany	–3.9608*	0.9482	2007:01	2014:01	3
Greece	–4.1260**	0.7572	2009:03	–	6
Hungary	–4.9290***	0.9372	2007:01	2008:01	4
Ireland	–6.6139***	0.7721	2006:04	2011:04	0
Italy	–2.5227[a]	NA	NA	NA	NA
Latvia	–1.1004[a]	NA	NA	NA	NA
Lithuania	–5.2354***	0.9268	2008:03	2010:04	3
Malta	–5.6304***	0.9542	2007:01	2010:04	2
Netherlands	–6.7459***	0.8952	2007:01	2014:03	7
Poland	–6.9487***	0.8462	2006:01	2008:04	7
Portugal	–7.1454***	0.6936	2008:02	2013:03	7
Slovakia	–4.7204***	0.7938	2009:04	–	3
Slovenia	–1.5851[a]	NA	NA	NA	NA
Spain	–1.8194[a]	NA	NA	NA	NA
Sweden	–4.4032**	0.7036	2009:04	2011:02	7
UK	–5.1748***	0.9420	2005:03	2009:01	7

Note: *(**, ***) denote significance at the 10% (5%, 1%) significance level; [a] the Schmidt and Phillips (1992); τ -test statistics is reported.

Source: Author's calculation.

C2. Determinants of *Up* and *Down* Breaks (Luxembourg omitted)

Variable	UP BREAKS			DOWN BREAKS		
	Mean difference	**p-value**	**Obs.**	**Mean difference**	**p-value**	**Obs.**
GDP per capita	340.1273	0.0001	21	–50.2070	0.8261	14
Government expenditures	–0.0906	0.8757	21	0.6433	0.1240	14
Household expenditures	–1.7674	0.0005	21	1.3227	0.0355	14
Gross fixed capital formation	–1.0272	0.1060	21	–3.2089	0.0019	14
Exports	10.6921	0.0001	21	3.4952	0.0157	14
Imports	7.6776	0.0013	21	2.0990	0.0555	14
Exports + imports	18.3697	0.0001	21	5.5942	0.0009	14
Exports – imports	3.0145	0.0057	21	1.3962	0.1578	14
Terms of trade	0.0090	0.5901	21	–0.0041	0.6378	14
GDP deflator	13.7639	0.0001	21	7.9206	0.0015	14
NEER	3.6251	0.1305	21	0.0331	0.0132	14
REER	3.8698	0.1305	21	–2.1374	0.0132	14
Unit labour cost	7.4687	0.0001	21	1.4095	0.0736	14
ESI	–1.9142	0.6009	19	–2.2558	0.4216	13

Note: NEER – Nominal effective exchange rate; REER – Real effective exchange rate.

Source: Author's calculation.

C3. RALS-LM Unit Root Test Results (OMS)

Country	$\tau^*_{RALS-LM}$	$\hat{\rho}^2$	$\hat{T}_B$		$\hat{k}$
Austria	–3.8851**	0.9838	2010:01	–	7
Belgium	–4.8446***	0.8430	2007:04	2014:03	0
Cyprus	–5.2777***	0.9295	2009:03	2012:03	0
Denmark	–2.7226	NA	NA	NA	NA
Finland	–5.0315***	0.5287	2008:03	2009:02	7
France	–5.5057***	0.9458	2008:01	2014:03	0
Germany	–4.7849**	0.9882	2005:03	2014:03	0
Greece	–4.5845***	0.6965	2009:03	–	6
Ireland	–6.4729***	0.8609	2006:04	2010:03	0
Italy	–4.8224***	0.8404	2007:03	2014:03	0
Luxembourg	–5.0810***	0.9095	2005:01	2014:03	2
Malta	–5.1724***	0.9673	2007:01	2010:01	2
Netherlands	–4.8408***	0.9128	2014:03	–	0
Portugal	–2.2183	NA	NA	NA	NA
Spain	–4.2780*	0.9775	2008:02	2009:04	4
Sweden	–5.3388**	0.6469	2008:01	–	7
UK	–2.1272	NA	NA	NA	NA

Note: *(**, ***) denote significance at the 10% (5%, 1%) significance level; [a] the Schmidt and Phillips (1992); τ -test statistics is reported.

Source: Author's calculation.

C4. Determinants of *Up* and *Down* Breaks (OMS)

Variable	UP BREAKS			DOWN BREAKS		
	Mean difference	**p-value**	**Obs.**	**Mean difference**	**p-value**	**Obs.**
GDP per capita	696.0829	0.0033	11	–64.8138	0.6002	13
Government expenditures	1.1644	0.0619	11	0.3285	0.2787	13
Household expenditures	–2.7611	0.0329	11	0.8625	0.2787	13
Gross fixed capital formation	–0.3946	0.8589	11	–3.3637	0.0019	13
Exports	9.6968	0.0262	11	6.0140	0.0107	13
Imports	8.0675	0.0329	11	4.2328	0.0464	13
Exports + imports	17.7642	0.0329	11	10.2468	0.0159	13
Exports – imports	1.6293	0.2860	11	1.7812	0.0392	13
Terms of trade	–0.0080	0.2132	11	–0.0078	0.3454	13
GDP deflator	10.8994	0.0044	11	7.5035	0.0019	13
NEER	1.8099	0.1549	11	0.8867	0.6002	13
REER	–1.3004	0.5337	11	–1.2201	0.3109	13
Unit labour cost	2.8009	0.0128	11	1.3920	0.1520	13
ESI	–3.0241	0.4446	10	–0.1020	0.8139	12

Note: NEER – Nominal effective exchange rate; REER – Real effective exchange rate.

Source: Author's calculation.

C5. RALS-LM Unit Root Test Results (NMS)

Country	$\tau^*_{RALS-LM}$	$\hat{\rho}^2$	$\hat{T}_B$		$\hat{k}$
Bulgaria	–3.5326*	0.8078	2005:02	–	8
Croatia	–5.4057***	0.8316	2007:03	2009:03	0
Czech Republic	–6.7597***	0.5429	2006:02	2007:04	7
Estonia	–4.0866*	0.9000	2007:03	2010:01	0
Hungary	–5.4638***	0.9161	2005:01	2007:04	8
Latvia	–1.4969[a]	NA	NA	NA	NA
Lithuania	–3.2489*	0.7294	2014:01	–	3
Poland	–4.2909**	0.7768	2008:03	2009:02	1
Slovakia	–3.6510**	0.7979	2007:03	–	4
Slovenia	–4.9231**	0.9504	2007:01	2011:01	7

Note: *(**, ***) denote significance at the 10% (5%, 1%) significance level; [a] the Schmidt and Phillips (1992); τ -test statistics is reported.

Source: Author's calculation.

C6. Determinants of *Up* and *Down* Breaks (NMS)

Variable	**UP BREAKS**			**DOWN BREAKS**		
	Mean difference	**p-value**	**Obs.**	**Mean difference**	**p-value**	**Obs.**
GDP per capita	413.0613	0.0180	7	178.9618	0.0663	9
Government expenditures	–0.7895	0.1282	7	0.2978	0.6784	9
Household expenditures	–1.3193	0.0630	7	–0.5948	0.2604	9
Gross fixed capital formation	–0.7610	0.6121	7	–2.5787	0.0506	9
Exports	13.3442	0.0180	7	7.8024	0.0109	9
Imports	9.9134	0.0180	7	3.8126	0.0858	9
Exports + imports	23.2576	0.0180	7	11.6147	0.0209	9
Exports – imports	3.4308	0.0180	7	3.9902	0.0077	9
Terms of trade	0.0145	1.0000	7	0.0015	0.9528	9
GDP deflator	17.2668	0.0180	7	13.4168	0.0077	9
NEER	7.9032	0.0630	7	2.6953	0.2604	9
REER	9.5241	0.0630	7	4.6560	0.0506	9
Unit labour cost	13.2368	0.0180	7	4.7779	0.0382	9
ESI	–0.6395	0.8658	7	–5.8058	0.2076	8

Note: NEER – Nominal effective exchange rate; REER – Real effective exchange rate.

Source: Author's calculation.

C7. RALS-LM Unit Root Test Results (Luxembourg as benchmark)

Country	$\tau^*_{RALS-LM}$	$\hat{\rho}^2$	$\hat{T}_B$		$\hat{k}$
Austria	–5.2972***	0.9754	2007:02	2011:04	7
Belgium	–7.0008***	0.6739	2007:02	2011:04	7
Bulgaria	–6.0904***	0.6745	2006:01	2013:03	3
Croatia	–6.4335***	0.7240	2007:03	2009:01	2
Cyprus	–4.8121***	0.8096	2007:04	2009:01	0
Czech Republic	–2.8201[a]*	NA	NA	NA	NA
Denmark	–3.9230[a]**	0.9439	2011:03	–	0
Estonia	–5.2542***	0.6978	2006:02	2011:04	2
Finland	–6.3782**	0.6614	2008:03	2011:04	6
France	–2.1045[a]	NA	NA	NA	NA
Germany	–4.1154***	0.8223	2007:04	2011:04	3
Greece	–1.0632[a]	NA	NA	NA	NA
Hungary	–4.3771***	0.8797	2006:02	2007:04	0
Ireland	–5.4517***	0.9202	2006:04	2011:02	8
Italy	–2.7385[a]	NA	NA	NA	NA
Latvia	–6.3619***	0.6584	2008:04	2011:04	7
Lithuania	–6.1112***	0.9673	2008:03	2013:03	8
Malta	–4.3112***	0.5861	2010:01	–	7
Netherlands	–4.9590***	0.8245	2007:02	2011:03	7
Poland	–7.7098***	0.6761	2007:04	2011:04	7
Portugal	–8.8651***	0.4676	2007:04	2011:04	7
Slovakia	–6.2186***	0.5739	2008:03	2011:02	6
Slovenia	–6.2401***	0.8090	2009:04	–	3
Spain	–4.1751**	0.8348	2008:02	2009:01	0
Sweden	–6.6750***	0.9764	2007:01	2011:04	7
UK	–4.6180**	0.9961	2005:03	2011:03	4

Note: *(**, ***) denote significance at the 10% (5%, 1%) significance level; [a] the Schmidt and Phillips (1992); τ -test statistics is reported.

Source: Author's calculation.

C8. Determinants of *Up* and *Down* Breaks (Luxembourg as benchmark)

Variable	**UP BREAKS**			**DOWN BREAKS**		
	Mean difference	**p-value**	**Obs.**	**Mean difference**	**p-value**	**Obs.**
GDP per capita	325.3362	0.0000	29	–70.1222	0.4328	12
Government expenditures	0.0678	0.6266	29	0.9256	0.0229	12
Household expenditures	–0.9495	0.0125	29	0.7932	0.0844	12
Gross fixed capital formation	–1.0258	0.1908	29	–3.7937	0.0037	12
Exports	8.4013	0.0000	29	4.5987	0.0060	12
Imports	6.0927	0.0000	29	2.3251	0.1579	12
Exports + imports	14.4940	0.0000	29	6.9238	0.0186	12
Exports – imports	2.3085	0.0036	29	2.2735	0.0995	12
Terms of trade	0.0018	0.6420	29	–0.0047	0.4328	12
GDP deflator	13.7094	0.0000	29	7.5397	0.0022	12
NEER	2.6836	0.0225	29	0.0071	0.9375	12
REER	2.5621	0.5235	29	–1.7184	0.3078	12
Unit labour cost	6.7151	0.0000	29	2.4769	0.0150	12
ESI	–1.7040	0.3871	27	–4.4271	0.0619	11

Note: NEER – Nominal effective exchange rate; REER – Real effective exchange rate.

Source: Author's calculation.