European Integration, Productivity Growth

and Real Convergence

Taner M. Yigit[a]

Bilkent University

and

Ali M. Kutan[b]

Southern Illinois University, Edwardsville; ZEI, Bonn; and WDI, Michigan.

Abstract

This paper derives a stochastic endogenous growth model that investigates the impact of European Union integration on convergence and productivity growth. We deviate from the general strand of literature by not only deriving a theoretical model for the effects of integration on the rate of economic growth, but also by using more flexible estimation techniques. The outcome of a series of panel and structural break tests examining the accession process of five recent members to the Union generally show improved rates of productivity growth and convergence to EU standards. We then draw from the experience of these recent members to derive implications for the first-round EU candidate countries. Subsequent tests on the first-round candidate countries find a high level of heterogeneity in growth rates, and a fast-paced convergence to EU standards.

JEL Codes: F02, O47, O52, C22, C23
Keywords: Integration, Growth, European Union

---

[a]Corresponding author**:** Department of Economics, Bilkent University, Bilkent, 06800 Ankara-Turkey. Tel: +90 (312) 2901898, Fax: +90 (312) 2665140, E-mail: tyigit@bilkent.edu.tr

[b]Economics and Finance Department, School of Business, Southern Illinois University Edwardsville, IL 62026-1102, The Center for European Integration Studies (ZEI), Bonn, and The William Davidson Institute (WDI), Michigan. E-mail: akutan@siue.edu

1. Introduction♣

In an age where many former communist countries strive to become a member of the European Union (EU) and policy circles discuss how best to synchronize the policies so that the existing members "all" benefit, it is natural to ask whether the EU membership pays off and eliminates the divergence of EU's incumbents over time. To answer this question, we formulate and test a stochastic endogenous growth model that investigates the impact of EU integration on convergence and productivity growth. We achieve this by combining the ideas in Rivera-Batiz & Romer (hereafter, RB-R, 1991) and Lee, Pesaran & Smith (LPS, 1997), complemented later on by a battery of structural break and panel data tests.

This paper contributes to the literature in more than one way. First, we extend the stochastic neoclassical growth model of LPS by implementing the 'integration parameter' of RB-R to analyze the effects of accession into the Union. We assume that integration to a wider body of knowledge that comes with (prospective) membership into the EU leads to higher returns to scale by enhancing the effectiveness of capital, hence speeding up the convergence process. Second, we test the findings of our theoretical model by utilizing the methodology by LPS, which provides a sound framework regarding the variables that should be included in the estimation[1]. The use of this technique especially fits our analysis since it corrects for the false inference in convergence when technological progress or sufficient heterogeneity are not adequately accounted for. Third, we complement the LPS tests with a series of structural break tests to validate the implications of the theoretical model regarding changes in the parameters of the growth process. Finally, we apply our modified theoretical model to the case of real convergence of the candidate transition economies to gain insight on

♣ We thank Jesus Crespo-Cuaresma, Kostas Drakos, Balázs Egert, Lucjan T. Orlowski, Erinc Yeldan, the participants of the 7th International ERC, and the participants of the 49th East Jour Fixe for their valuable comments on the earlier versions of this paper.

[1] Earlier studies use rather *ad hoc* specifications with many control variables to test for convergence, developing models that have very little reliance on growth theory.

the prospects of their integration to the EU by drawing from the experience of recent EU members during pre- and post-membership periods. To our best knowledge, our work is the first research that brings theory *and* empirics together to analyze the impact of integration on convergence and productivity growth.

There are some related studies that complement ours. Henrekson, Thorstensson & Thorstensson (1997) examine the role of trade and institutional integration on economic growth, using a purely empirical approach on European Community (EC) and European Free Trade Area (EFTA) countries along with a sample of OECD countries. Using a cross-sectional and pooled OLS study, their study finds that joining the EU or EFTA enhances growth. Crespo-Cuaresma, Ritzberger-Grünwald, and Silgoner (2002) examine the impact of European integration on economic growth of current EU members, using a panel regression. They find that the length of EU membership has a significant and positive effect on growth, and it is higher for poorer countries, suggesting an asymmetric impact of EU membership. These studies solely focus on a regression analysis of the relation between membership and growth without providing an underlying theoretical framework or projections for the candidate economies. Martin and Velázquez (2001), Wagner and Hlouskova (2002) and Boldrin and Canova (2003) provide a descriptive analysis of how different experiences of convergence of the recent EU members affected economic growth after joining the EU and derive lessons from these countries' experience for the candidate countries. Employing different growth scenarios, they examine the beneficial effects of the EU membership and how long it would take for the candidate countries to fully complete the convergence process. They emphasize the importance of national policies to achieve a sustained period of significant growth above EU averages and hence real convergence towards the EU standards.

Our paper extends the analysis in these papers by providing not only an in depth theoretical foundation on the effects of integration, but also empirically testing for its implications on the specific aspects of growth, namely productivity and convergence. We also contribute to the literature by using a variety of estimation techniques that have less room for false inference due to impositions of homogeneity or neglecting of productivity growth. In addition, like in Martin and Velázquez (2001), Wagner and Hlouskova (2002) and Boldrin and Canova (2003), we provide lessons for the candidate economies by focusing the empirical evidence from the recent EU members. In this sense, we merge the two related but distinct literatures on integration and enlargement.

This paper is organized as follows. Section 2 sets up our theoretical model. We describe our estimation technique and data in Section 3, while Section 4 reports the empirical results. Section 5 discusses the importance of real convergence for the candidate countries and provides some preliminary estimates of convergence and productivity developments for these economies. The last section provides a summary of the key findings of the paper, along with its policy implications.

2. Theoretical framework

With developments in the econometrics field, 1990s have witnessed an abundance of studies on neoclassical growth theory and its implication of convergence. These empirical analyses of convergence fall into two categories. The first class of tests studies the cross-sectional correlation between initial per capita output levels ($y_{i,0}$) and the subsequent speed of growth ($y_{i,t} - y_{i,0}$).

$$T^{-1}\left(y_{i,t} - y_{i,0}\right) = \alpha + \beta y_{i,0} + \varepsilon_{i,t} \tag{1}$$

A negative correlation (or $\beta < 0$) is interpreted as convergence since it implies that countries with lower per capita output will grow faster (Dowrick & Nguyen, 1989; Barro, 1991; Barro and Sala-i-Martin, 1992). The second set of tests utilizes time series analysis to examine the long-run behavior of output per capita differences across countries (Quah, 1992; Bernard and Durlauf, 1995).

$$y_{i,t} - y_{j,t} = \kappa_{i,j} + \sum_{r=0}^{\infty} \pi_{i,j,r} \varepsilon_{i,j,t-r} \tag{2}$$

A zero mean-stationary difference in output levels of country *i* and *j* implies that long term forecasts of output differences between the two countries converge to zero. A later study by Bernard & Durlauf (1996) cautions the practitioners by showing that cross sectional tests could exhibit negative correlation even without the existence of convergence, while time series tests could give misleading results when applied to countries in transition, still far away from their long-run equilibrium.

Recent adoption of panel-data estimation techniques combines the dynamics in time series with cross sectional variation in analyses of convergence. One group of authors utilizes panel unit root techniques to check for the existence of a common stochastic trend as evidence of convergence across a panel of countries (e.g., Evans and Karras, 1996; Evans, 1998, Fleissig and Strauss, 2001). Recent applications of this technique (e.g., Kočenda, 2001) assume homogeneity in growth rates across panel countries studied. Kutan and Yigit (2004), however, show Kočenda's evidence for convergence is sensitive to the assumption of homogeneity in growth rates, and that further investigation, especially allowing for heterogeneity, is necessary. That is why we choose to employ dynamic panel data estimation techniques with the assumption of unobservable country-specific heterogeneity (Islam, 1995; Lee, Pesaran & Smith, 1997; Nerlove, 2000).

We choose to follow the methodology employed in LPS because it stands out from the rest of the studies by including an explicit link, rather than an *ad hoc* stochastic specification, between economic theory and their econometric model. Their work also allows for the maximum amount of heterogeneity in growth rates across the panel. We expand their model to incorporate an endogenous growth suggestion by RB-R to analyze the impact of European

Union membership on the per capita GDP of recent entrants. The next section elaborates on this model.

2.1 Derivation of testable implications

Combination of the LPS suggested Cobb-Douglas production function with the integration parameter of RB-R yields

$$Y_{it} = K_{it}^{\alpha}\left(A_{it}L_{it}Z_{it}\right)^{1-\alpha} \text{ where } 0 < \alpha < 1 \tag{3}$$

where A is the labor (L) augmenting technology and Z, our contribution, is the capital (K) enhancing invention[2] that comes with improved dissemination of ideas and technologies through trade and foreign direct investment (FDI).

Assuming

$$\begin{aligned} K_{it} &= I_{i,t-1} + \left(1-\delta\right)K_{i,t-1} \\ I_{it} &= s_i Y_{it} \end{aligned} \tag{4}$$

the traditional evolution of capital formula gives us

$$\Delta\log\left(k_{it}\right) = -\Delta\log\left(A_{it}L_{it}Z_{it}\right) + \log\left(s_i k_{i,t-1}^{-(1-\alpha)} + 1 - \delta\right) \tag{5}$$

where s_i and δ are the savings and depreciation rates, respectively, and $k_{it} = K_{it} / A_{it}L_{it}Z_{it}$ (since capital enhancing inventions, Z, increases effectiveness of labor). Rather than following the normal deterministic path of solution to this growth problem, we follow the stochastic method by LPS with the assumptions

$$\log\left(A_{it}\right) = a_{0i} + g_i t + u_{ait} \tag{6}$$

$$u_{ait} = \rho_{ai}u_{ai,t-1} + \varepsilon_{ait} \text{ where } \left|\rho_{ai}\right| \le 1 \tag{7}$$

$$\log\left(L_{it}\right) = l_{0i} + n_i t + u_{bit} \tag{8}$$

[2] Derivation of this equation comes from the assumption that $K = \int_0^Z x\left(i\right)^{\alpha}\, di$ where i is the index of the most recently invented good.

and

$$u_{bit} = \rho_{bi} u_{bi,t-1} + \varepsilon_{bit} \text{ where } \left|\rho_{bi}\right| \leq 1 \tag{9}$$

where the technology shock, u_{ait}, summarizes factors that might shift total factor productivity (other than technological growth rate g_i), and the employment shock, u_{bit}, represents labor demand and supply effects other than population growth, n_i. We add the stochastic process for Z_{it}

$$\log\left(Z_{it}\right) = z_{i0} + \zeta_i t + u_{cit} \tag{10}$$

and assume the same autocorrelation as in the case of technological process only for notational simplicity.

Using the fact that expected change in capital is zero in the steady state and omitting the subscript i, we obtain

$$n + g + \zeta = E\left[\log\left(s k_\infty^{-(1-\alpha)} + 1 - \delta\right)\right] \tag{11}$$

Utilizing Jensen's inequality, this term equals

$$n + g + \zeta = \log\left(s e^{-(1-\alpha)\log(k_\infty)} + 1 - \delta\right) + h \tag{12}$$

Approximation of the nonlinear term in this equation around $E\left[\log\left(k_\infty\right)\right]$ yields

$$\log\left(s k_{t-1}^{-(1-\alpha)} + 1 - \delta\right) = \gamma - \left(1-\lambda\right)\log k_{t-1} + \xi_t \tag{13}$$

where ξ_t is the error of approximation and

$$1-\lambda = \frac{s\left(1-\alpha\right)e^{-(1-\alpha)E\left[\log(k_\infty)\right]}}{s e^{-(1-\alpha)E\left[\log(k_\infty)\right]} + 1 - \delta} > 0 \tag{14}$$

and

$$\gamma = \log\left(s e^{-(1-\alpha)\log(k_\infty)} + 1 - \delta\right) + \left(1-\lambda\right)E\left[\log(k_\infty)\right] \tag{15}$$

For small values of $n,\ g,\ \zeta,\ \delta,$ and h, they simplify to

$$1-\lambda \approx \left(1-\alpha\right)\left(n + g + \delta + \zeta - h\right) \tag{16}$$

and

$$\gamma \approx (n+g+\zeta-h)+(n+g+\zeta+\delta-h)\left[\log s-\log(n+g+\zeta+\delta-h)\right] \tag{17}$$

In the deterministic version the linearization is done around the steady state k and u's are assumed to be zero. For h equaling zero, the term $(1-\lambda)$ is the measure of beta convergence. Defining output per capita as

$$\frac{Y}{L}=x_t=a_t+z_t+\alpha\log(k_t) \tag{18}$$

where a is log(A) and z is log(Z) and $k_t=\dfrac{K_t}{A_tL_tZ_t}$, it is easy to see that

$$\Delta x_t=\Delta a_t+\Delta z_t+\alpha\left[-(n+g+\zeta)-\Delta u_t+\gamma-(1-\lambda)\frac{x_{t-1}-a_0-z_0-(g+\zeta)(t-1)-u_a-u_c}{\alpha}\right] \tag{19}$$

Using equations from (6) to (10), we can rewrite this as

$$x_t=\mu+(1-\lambda)(g+\zeta)t+\lambda x_{t-1}+e_t \tag{20}$$

where

$$\mu=\lambda(g+\zeta)-\alpha(n+g+\zeta)+\alpha\gamma+(1-\lambda)(a_0+z_0) \tag{21}$$

and

$$\begin{aligned} e_t &= \Delta u_{at}+\Delta u_{ct}-\alpha\Delta u_t+(1-\lambda)(u_{at}+u_{ct}) \\ \Delta u_t &= \Delta u_{at}+\Delta u_{bt}+\Delta u_{ct} \end{aligned} \tag{22}$$

In the context of the Solow growth model ($0<\alpha<1$), output will have a unit root only if e_t has a unit root. LPS show that the unit root in e only depends on the unit root in the technology error, u_a. Therefore, assuming $\rho_b=1$ (and $\rho_a=\rho$), as they do, and eliminating the autocorrelation in u_a, we get

$$x_t=\left[(1-\rho)\mu+(1-\lambda)(g+\zeta)\rho\right]+(1-\lambda)(1-\rho)(g+\zeta)t+(\lambda+\rho)x_{t-1}-\lambda\rho x_{t-1}+(1-\psi L)\varepsilon_t \tag{23}$$

where ε_t is a composite error term from equations (7) and (9) and ψ is a nonlinear function of variances/covariances of technology, employment, innovations, and the other parameters of the model.

The important implications of this model mentioned in LPS are the different speed of convergence due to the existence of *h*, and the difficulty of using Augmented Dickey-Fuller (ADF) type estimation techniques to evaluate convergence. This is because the autoregressive coefficient tested is the product of many variables like $\rho, \alpha, g, n, \delta, h$, and ζ with our addition, and that the unit root in output not necessarily being evidence against the neoclassical model, but also being caused by a unit root in the technology process ($\rho = 1$). What *we* illustrate with our contribution in this paper is that there is a positive impact of integration on *a*) the rate of growth via increasing the steady state value, the first term on the right hand side of Equation (23), *b*) the previously mentioned convergence rate in Equation (16), and *c*) the productivity growth, the coefficient of the deterministic trend again in Equation (23).

As in the LPS methodology, our estimation part is based on the assumptions that the convergence rate and the autocorrelation in technology approximately equal the moving average coefficient ($1-\lambda \approx 1-\rho \approx 1-\psi$), which transforms the system into

$$x_t = \mu + (1-\lambda)(g+\zeta)t + \lambda x_{t-1} + \varepsilon_t \tag{24}$$

where

$$\mu = \lambda(g+\zeta) - \alpha h + (1-\lambda)\left\{a_0 + \frac{\alpha}{1-\alpha}\left[\log s - \log(n+g+\zeta+\delta-h)\right]\right\} \tag{25}$$

This system is a modified version of the typically adopted method of convergence testing with the addition of increases in the steady state term and the productivity growth. For estimation of λ and $(g+\zeta)$ separately, LPS suggests rewriting the equation

$$\begin{aligned} x_{it} &= c_i + (g_i + \zeta_i)t + u_{it} \\ u_{it} &= \lambda_i u_{i,t-1} + \eta_{it} \end{aligned} \tag{26}$$

Separating λ and $(g+\zeta)$ prevents any false inferences about convergence that could have resulted from a unit root in productivity growth. After the estimation of these equations, one could use these estimates to derive μ_i by noting that

$$\mu_i = (1-\lambda_i)c_i + \lambda_i(g_i + \zeta_i) \tag{27}$$

It is apparent that one cannot identify both g and ζ from these estimations, but a sudden change in the integration process could generate a structural shift in the GDP per capita. Results for the tests for these structural breaks are reported in Section 5.

Prior to estimation of the system in Equation (26), LPS suggests demeaning (across i) to remove the cross-correlation between countries caused by the common time component. Therefore, the estimated system becomes

$$\begin{aligned} x_{it} - \overline{x}_t &= (c_i - \overline{c}) + (g_i + \zeta_i - \overline{g} - \overline{\zeta})t + (u_{it} - \overline{u}_t) \\ (u_{it} - \overline{u}_t) &= \lambda_i(u_{i,t-1} - \overline{u}_{t-1}) + (\eta_{it} - \overline{\eta}_t) \end{aligned} \tag{28}$$

where the common component coefficients are obtained from a similar regression

$$\begin{aligned} \overline{x}_t &= \overline{c} + (\overline{g} + \overline{\zeta})t + \overline{u} \\ \overline{u}_t &= \lambda \overline{u}_{t-1} + \overline{\eta}_t \end{aligned} \tag{29}$$

Finally, coefficient values in Equation (26) are obtained by adding the estimates of Equation (28) to those of Equation (29).

There are important differences in our modified LPS model from all of studies that test for conditional convergence. The first one is that we have an explicit constant term μ_i, representing differences in steady states rather than arbitrarily attaching a set of variables to control for differences in steady states. Despite the benefits of control variables in general, unnecessarily increasing the number of explanatory variables in dynamic panel studies is likely to increase the cross-correlation between sample countries, leading to size problems in the final estimation. The second difference is the fact that we allow for heterogeneity in technological growth rates across panel countries. LPS show that failure to account for this possible variation will bias the convergence rates, resulting in slower convergence findings. Third and more importantly, we apply the same methodology to a different idea to illustrate that exposure to a wider knowledge base results in increased rates of productivity growth and convergence as shown in equations (16) and (24). We do this by measuring the most recent members' convergence rates and productivity growth before and after joining the EU. We complement the outcome of these tests with the results from a series of structural break tests to find that integration does generally create the intended difference. Finally we expand our results to comment on an important question: are the first-group EU candidate countries following a similar path as the recent members, and will they and the EU benefit from a union?

3. Data and empirical methodology

3.1. Data

Our data set consists of quarterly GDP per capita from 13 countries; the earlier five members[3], for the first stage estimations, and eight EU candidates[4] for the latter stage of the estimations. The sample period for the member countries is from 1980 to 2002, while the candidate country data range is chosen to be between 1993 and 2002.[5] We exclude Slovenia and Cyprus in the estimations due to data limitations. We construct real GDP per capita data based on purchasing power parity (PPP) values. Finally, since the classical definition of convergence refers to the log of real GDP per capita, we take the natural logarithm of all the series.

[3] Spain, Portugal, Austria, Finland, and Sweden
[4] The Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, and the Slovak Republic
[5] Pre-93 period is highly unstable, reflecting the shock effects of the early 1990 reforms.

3.2 An overview of the estimation technique

We test Equation (26) for pre- and post-membership periods of the 5 recent members using Least Squares with Dummy Variables (LSDV) methodology. We choose this method over more complicated techniques such as the Exact Maximum Likelihood used in the LPS (1997) paper, as well as GMM or 3SLS, due to small number of cross sectional units and a much larger quantity of time series observations[6]. The fact that our sample countries are not randomly drawn from a large population and arguments by Baltagi (1995) lead us to the choice of fixed effects estimation over random effects.

We demean each series with French GDP/capita as the proxy for convergence to EU standards[7]. Then, using the reduced form coefficients from Equation (28) and the French coefficients[8] from Equation (29), we obtain the structural parameters of Equation (26). Utilizing these coefficients, we next check the assumption of heterogeneity versus common efficiency growth (g), common convergence rate ($1-\lambda$), and finally common g and common ($1-\lambda$). Likelihood ratio tests are used to establish the best fitting model among the four options. When the LR tests are not sufficient in providing a model of choice, we refer to the Akaike criterion to make a final determination. Results for Spain and Portugal (members since 1986) are displayed in Table 1 while the results for Austria, Finland, and Sweden (members since 1995) can be found in Table 2.

Next, not being able to identify the shift parameter, ζ, caused by the integration process in Equation (26), we resort to two structural break tests, to examine the validity of our theory. Structural break tests are important for our paper not only because the theory section can't

[6] The bias associated with dynamic panel datasets is going to be negligible with such a high T and a low N (Judson and Owen, 1999; Nickell, 1981).
[7] Unit root is rejected using Im-Pesaran-Shin (2003) test for each panel, which enables us to refer to ($1-\lambda$) as the *convergence rate*. Also *convergence* can also be verified from the opposite signs on the intercept and slope parameters of the trend model in Tables 1-7. Tomljanovic & Vogelsang (2002) indicate that a converging country with an initial per-capita income lower than the French average must exhibit a positive growth trend.
[8] We use OLS to derive the estimates for these coefficients.

separate the impact of integration from the previous values of the parameters, namely the identification problem, but also the break tests are the direct tests of our theory displayed in Equation (26). The first test we use is the stochastic multiple-break test developed by Bai & Perron (1998) and the other one is a single break test by Banerjee *et al.* (1992) (later extended by Sen, 2003). We apply these tests on the recent five EU member countries to examine the impact of integration on the growth and convergence processes. We abstain from any PPP adjustment in this section to measure structural changes more accurately[9].

The Bai-Perron (henceforth BP) methodology considers the following multiple structural break model, with *m* breaks (*m*+1 regimes)

$$y_t = x_t'\beta + z_t'\delta_j + u_t \tag{30}$$

for $t = T_{j-1}+1,.....,T_j$ and $j = 1,....,m+1$. y_t is the observed dependent variable at time *t*; x_t (*p* x 1) and z_t (*q* x 1) are the vector of covariates, β and δ_j are the corresponding vectors of coefficients, and *u* is the disturbance term at time *t*. The break points (*T*) are treated as unknown, and are estimated together with the unknown coefficients when T observations are available. In the terminology of BP, this is a partial structural change model, in the sense that β does not change, and is effectively estimated over the entire sample. If $p = 0$, this becomes a pure structural change model where all coefficients are subject to change.

The procedure for detecting structural breaks, suggested by Bai and Perron, is the following. First, calculate the UDMAX and WDMAX[10] statistics. These are double maximum tests, where the null hypothesis of no structural breaks is tested against the alternative of an unknown number of breaks. These tests are used to determine if at least one structural break is present. In addition, the SupF(0|*l*) is a series of Wald tests for the hypothesis of 0 breaks vs. *l* breaks. In this paper, the maximum number of breaks (*l*) is chosen to be 3. If these tests show

[9] GDP per capita in real terms is used in the estimations.
[10] UDMAX stands for equally weighted double maximum test while WDMAX refers to the weighted version.

evidence of at least one structural break, then the number of breaks can be determined by the sequential SupF(l+1|l). If this test is significant at the 5 percent level, then l+1 breaks are chosen. Finally, we choose the number of breaks by the Bayesian Information Criteria (BIC).

Unfortunately, detecting multiple structural changes in the existence of trending terms or possible unit roots, as in our model specification, is quite difficult. For instance, the restrictions that BP mention on the application of their methodology are that *a*) one should not allow for a unit root, and that *b*) when a lagged dependent variable is used, autocorrelation in the error term cannot be allowed. Despite their claim of being able to include trending terms in the regression, estimating a pure structural break model, in which all the coefficients could change, generated non-convergence in our estimations (especially for the trend variable)[11]. Therefore, it is almost impossible to simultaneously derive structural breaks in the mean, AR parameter, and the trend term using the BP methodology. We tried to bypass this problem by estimating two versions of the system: first, a de-trended version to measure the breaks in the convergence rate (under the assumption of constant trend), and the second on the differenced version where the constant term represents the trend coefficient (and the mean break is undetectable). Results for these tests are displayed in Tables 3 and 4.

We also apply another strand of the literature that allows for only a 'single break', but permits for unit roots in the existence of trend and mean breaks, namely an extension of Banerjee *et al.* (1992) by Sen (2003). We utilize the sequential F-test to test for three types of model originally suggested by Perron (1989): the crash model allowing for a break in the intercept, the changing growth model allowing for a break in the trend, and finally the mixed model that allows for breaks in both the intercept and the slope (AR parameter is assumed as constant) . The general model we use is

$$y_t = \mu_0 + \mu_1 DU_t\left(T_b^c\right) + \mu_2 DT_t\left(T_b^c\right) + \mu_3 t + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \qquad (31)$$

[11] There are working papers at early draft stages addressing this problem of the methodology.

where $DU_t(T_b^c)$ is the indicator function that equals 1 after the break date T_b^c, $DT_t(T_b^c)$ equals $(t - T_b^c)$ if $t > T_b^c$. Also in Equation (31), μ_0 and μ_2 are the mean and trend before possible breaks, and α is the autoregression parameter. We add k additional regressors, $\sum_{j=1}^{k} c_j \Delta y_{t-j}$, to the model for possible serial correlation in the disturbance term. Lag length is chosen using the methodology suggested by Ng & Perron (1995).

Sequential maximum F-test statistics presented in Sen (2003) is:

$$F_t(T_b) = \left(R\theta(T_b) - r\right)' \left[R\left(\sum_{t=1}^{T} X_t(T_b) X_t(T_b)'\right)^{-1} R' \right]^{-1} \left(R\theta(T_b) - r\right) \Big/ q\sigma^2(T_b) \qquad (32)$$

where $X_t(T_b) = (1, DU_t(T_b), t, DT_t(T_b), y_{t-1}, \Delta y_{t-1}, ..., \Delta y_{t-k})'$, r is the restriction matrix, q is the number of restrictions, $\sigma^2(T_b)$ equals $(T - 5 - k)^{-1} \sum_{t=1}^{T} \left(y_t - x_t(T_b)' \theta(T_b) \right)^2$, and $\theta(T_b)$ is the OLS estimator of $\theta = (\mu_0, \mu_1, \mu_2, \mu_3, \alpha, c_1, ..., c_k)'$ in Equation (31). For instance, if we want to allow for a unit root in case of trend and mean break, i.e. test for $H_0: \alpha = 1, \mu_1 = 0, \mu_3 = 0$, we use the restriction matrix $r = (0,0,1)'$ with the appropriate R. The results for Sen (2003) test are reported in Table 5. Please note that in our study, we restrict our tests to cases where trend does not coexist with a unit root since there is no economic rationale for that to happen in the case of real GDP/capita data.

Finally, we apply the LPS methodology to 8 first-group candidate countries. We run two versions of this test first after demeaning with French GDP/capita as above, and then using the group mean to test for conditional convergence "within" these specific groups to examine their economic integration and strength of their ties. We again use LR-tests and AIC criterion to pick the level of heterogeneity allowed. The results are displayed in Tables 6 and 7.

4. Empirical evidence

4.1. Convergence

The critical question we try to answer is whether membership to the EU leads to faster convergence and higher productivity rates. The answer to this question is not only important for EU policymakers, but also the candidate countries planning to join soon. Higher level of convergence and productivity would indicate less adjustment, smaller fiscal costs and hence less stabilization funds. To shed some light on these issues, we focus on the experience of the recent EU members by studying their performances before and after the membership, initially using the LPS methodology described above. Results for the LSDV tests are reported in Table 1 for Spain and Portugal (members since 1986) and for Austria, Finland, and Sweden (members since 1995) in Table 2. These are followed by the results of the structural change tests in Tables 3 to 5.

Findings in Tables 1 and 2 provide an interesting picture of the effects of integration to the Union. Our theoretical model's implication was that all of the parameters in the equation, $\mu, g+\zeta$, and λ, should increase with membership into the Union. The most recent EU members comply more with the theoretical implications than the older ones. This finding suggests that the older members already enjoyed the benefits of economic and trade liberalization within the region before they formally became EU members and the benefits of integration hence occur within a few years after joining, so it is a relatively fast process. This finding is consistent with evidence in Ben-David (1996) who shows that the prospect of an EU membership exerts a positive impact on potential entrants' economic performance prior to their entry. This finding is encouraging for the candidate economies because it suggests that they would acquire the benefits of EU membership relatively quickly once they join in.

Before interpreting the results in Tables 1 to 2 (also 6 and 7 later on) further, the reader should note that different blocks in the rows of these tables display differing levels of heterogeneity in the parameters of the model, g, μ, and (1-λ), representing productivity growth rate, the steady state level, and the convergence rate, respectively. Prior to commenting, we first pick the specification that likelihood-ratio tests reveal and then move on to the interpretation of those results. For instance, looking at the results for Spain and Portugal in Table 1, we note that the model of choice is common convergence rate option before becoming a member, and common productivity growth and convergence (by Akaike criterion) after membership. In these specifications, the only increase occurs in the estimates of the steady states. This switch in the model specification shows an increase in homogeneity after joining the EU indicating a strong integration into the common standards.

In Table 2, there also is a switch in the specification, though not very strong. The preferred model (by AIC) in pre-membership is the common productivity growth, switching to common convergence rate afterwards. In these options, we see not only the implications of the theory section (increase in all coefficients) generally holding with a few exceptions, but also a higher degree of harmonization, namely in the convergence rate. Finland stands out from the rest of the group by having experienced a significant benefit in their productivity after membership. There also is a very healthy increase in the convergence rate of the group compared to the EU standards.

4.2 Structural change tests

Next, we apply the stochastic structural break tests by Bai & Perron (1998) and Sen (2003) on individual country real GDP per capita data to investigate whether integration leads to any changes in the coefficients of Equation (26). For the Bai & Perron test, we use two modifications on the original data, namely the de-trended and the differenced versions. The difficulty of analyzing pure structural break models in the existence of time trends and possible nonstationarity compel us to de-trend the data to focus on the convergence rate and difference it to examine the productivity growth (trend coefficient). We interpret the results, as mentioned above, by first looking at the results of the double maximum tests to determine whether there is ‘any break’, and then focusing on the sequential test for the consecutive breaks. Along with reporting these statistics and their significance levels, the tables also report the dates and the direction of the structural changes in the parameters of interest after the breaks.

The results of beak tests, especially the BP multiple break test can be affected by several factors, e.g., the degree of international technology spillovers, given by the amount of FDI and imports, developments in the Exchange Rate Mechanism (ERM), and business cycles. The differences in macroeconomic policies pursued as well as progress in structural reforms and institutional developments can also cause structural breaks in data. Given significant diversity across countries with respect to above factors, it is difficult to identify the exact factors that might cause every structural break. For our purposes, however, the critical point is whether there is a significant break around the time of EU accession.

The results of Table 3, which report the breaks in the convergence rates, confirm increased convergence rates in Austria, Spain and Sweden coinciding with their membership dates (within the confidence interval of the reported dates). Austria shows another break at around 1988, most likely due to one of the above factors. Finland’s break in the end of 1990 could be the result of a finding of the ERM recovery since post-1992 is in the confidence interval of this break. Finally Sweden shows two other breaks; first one in early 1980s, and the other one coinciding with the ERM recovery, while Portugal does not have any structural break in its convergence rate.

In Table 4, the results are mixed. Despite the confirmatory increases of productivity in Austria and Portugal coincident with their membership, Spain and Sweden show dates possibly due to the other factors mentioned above. We again notice the same structural breaks in Austria (1986Q2) and Finland (at the beginning of 1990), later followed by a decrease in the productivity after the ERM crisis. Combining the outcome of both tables indicates the positive impact of the membership into the Union, either through an increase in productivity or the convergence rate or both, like in Austria.

Next, we examine the results of the Sen (2003) test that searches for the single "big" change either in the trend (productivity) and/or the mean (steady state). The results of this test are more easily interpretable since the test concentrates on the largest break. Table 5 reports the sequential F-max statistics, the dates and directions of the structural changes. The first line for each country represents the break test only in the trend (same as Banerjee et al., 1992), while the second line adds a break test for the mean as well (Sen, 2003). We obtain critical values for both tests since the original studies assume *iid* errors and exclude serial correlation. First observation is that there is a significant break in each test, though mostly at differing dates between the two versions of the test. Allowing for mean changes brings forth recessions as the choice of break points (Austria, Finland, Spain, and Sweden). Increased rates of productivity in Finland, Portugal and Spain around their membership dates, however, clearly support the implications of our theory. Portugal stands out by showing increased productivity in both versions of the test.

Correct inferences from the structural break tests are quite difficult, especially with complicated dynamics as our model. Different methods may produce different results, which is a natural outcome of the issues related to the structural change literature. The results can be sensitive to assuming a single break or multiple breaks; or whether the break is in the trend, the mean or whether it is a nonlinear system (regime switching). Despite such concerns, the reported results are encouraging because they generally suggest positive changes in the productivity growth and are significantly stronger compared to the panel data tests;

convergence or the steady states are never negative at the time of accession, which is supportive of our theory.

5. Are candidate countries converging?

Raising the candidate countries' per capita income to the EU level serves as the most tangible proof of the success of integration. Within these countries, significant progress toward per capita income convergence is seen as key in securing the political assent of the population to both transition and membership in the EU. For the EU countries, such income growth is important if excessive population movements from the new members to the old are to be avoided and if the EU's budget is not to be strained by transfers to lagging economies.

Besides the above considerations, evidence on real convergence of the candidate economies towards the EU standards and productivity developments also has important implications for the design of an optimal policy towards the euro zone. First, according to the Balassa-Samuelson effect, higher labor productivity leads to higher - structural - inflation that, through positive inflation differential, provokes a real appreciation of the currency. At the same time, increasing per capita income also increases domestic demand that puts some pressure on domestic prices, hence the real appreciation. (Égert, 2002 and Égert et. al, 2004). An optimal monetary policy therefore requires a good understanding of the real convergence process. Second, achieving some real convergence in the early stages of the integration process would make it easier for the candidate countries to satisfy the Maastricht criteria on nominal convergence such as low inflation and stable exchange rates. The supreme goal of integration is economic growth and thus real convergence and nominal convergence, with nominal stability, underpins real convergence. Finally, once admitted into the EMU, policymakers in accession countries will not be able to use monetary policy any longer to achieve further real convergence.

Despite its significance, this issue has not received much attention in the literature. [12] Only a few studies examine real convergence prospects for candidate economies. Kočenda (2001) studies the convergence of macroeconomic fundamentals in several groups of transition economies. Utilizing a commonly employed panel unit root technique and a sample period from January 1991 to December 1998, he finds considerable real convergence. Kutan and Yigit (2004) report a lower level of real economic convergence than those reported by Kočenda when a more recent panel estimation approach developed by Im, Pesaran, and Shin (2003), which allows for more heterogeneity in the convergence rates, is utilized. Brada et al. (2003) find clear evidence of increasing real sector convergence between some of the first-round candidate countries and EU.

In all the above studies, industrial output is utilized as a proxy for real convergence. Estrin et al. (2001) examine the convergence of candidate countries' per capita income to that of the EU average. They find that, for the period 1970-1998, none of the transition-economy candidate countries exhibited convergence with the EU countries. Because the greater part of the sample period reflects the candidate countries' performance under communism, and because it also incorporates the output decline of the early years of the transition, this finding is not surprising, nor may it be entirely germane to the issue of convergence in the context of EU accession.

These limited studies do not use a theoretical framework, nor take into account of the role played by the integration parameter. The EU candidate economies have received significant amount of FDI from the EU and also increased their trade with them in the last decade. Such "imported" technological spillovers based on a less costly way of imitation of foreign innovations through both FDI and imports of goods are expected to help spur economic growth in the candidate countries. Our theoretical model is therefore also applicable to the

[12] Focus has been on nominal convergence. See, among others, studies by Backé et al. (2002), Brada and Kutan (2001, Čihák and Holub (2001, 2003), Janáčková (2000), and Richards and Tersman (1996).

EU candidate economies. The presence of sufficient stock of human capital endowment in these economies, which affects their ability to imitate technical progress, also complements the positive effects of new technologies created through FDI and trade (Lucas, 1988 and Nelson and Phelps, 1966). Thus, opening up to trade and FDI inflows in the framework of integration process raises productivity and hence stimulates real convergence.

Our theoretical model emphasizes the importance of including the capital enhancing invention variable, *Z*, in the endogenous growth models to capture the effects of international technology spillovers on productivity and convergence. It is therefore important to provide some *preliminary* estimates of real convergence for the candidate countries as well, indicating their progress so far. These preliminary results are useful to evaluate their further progress following their EU accession. Tables 6 and 7 report the results.

Table 6 analyzes convergence of the candidate economies to the EU standards, using French per capita GDP as a proxy, by applying the LSDV methodology. Relying on the results of *LR* tests and AIC criterion, we observe heterogeneity in each parameter estimate reported in Table 6. All likelihood ratio tests reject common growth rates and steady states at a minimum of 95% significance level indicating that all of these countries have distinct paces of progress toward the EU standards. Focusing on the first block, we also note a fairly fast convergence rate of some these countries like the Czech Republic, Hungary and Slovakia to the French GDP/capita since traditional estimates of non-OECD and oil importing countries average around 0.27. This finding is encouraging for these candidate countries because it indicates speedy convergence to EU income levels and a higher standard of living in the future.

We can't help but observe that the results also validate the LPS claim that increased heterogeneity raises the convergence speed. Comparing the first two sections of the table shows that convergence rates fall significantly when we constrain the productivity growth rates to be the same throughout the sample. Finally, we note the high productivity gains in Poland and Hungary,[13] and the lack of convergence of Malta to the Union, reflecting the differences in the amount of trade with the EU and FDI inflows from the EU. Of course, macroeconomic policies pursued by countries have also been an important factor for the convergence to EU standards.[14]

Results of Table 7 point to the common convergence rate option as the model of choice. The high convergence rate to the group average indicates a fast pace of integration within the group to common standards. Such a finding is consistent with earlier studies that find significant real convergence among the candidate transition economies (e.g., Brada et. al (2003), Kočenda, 2001 and Kutan and Yigit, 2003). This result indicates that despite the differences in their progress toward the EU standards, the candidate countries do not have significant outliers in the process of within group harmonization. This result is important for EU policymakers because it signals that the candidate countries would be integrated by the time they join the EU, and there may not be a need to admit countries one by one based on their level of integration with the EU. The last notable outcome is the negativity of some productivity gains, in this and most other parts of the table, due to the outstanding performance of Poland and Hungary.

7. Concluding observations and policy implications

We examine the impact of EU integration on productivity growth and convergence for recent EU entrants and use their experience to draw lessons for the candidate economies. We deviate from the general strand of literature by deriving an explicit formulation of theoretical

[13] Available empirical evidence supports this finding. In analyzing the impacts of FDI on labor productivity levels on manufacturing sectors Hungary, Poland and the Czech Republic, Barrell and Holland (2000) report significant productivity improvements in most sectors, while Schoors and van der Tol (2002) find that the presence of foreign firms creates positive spillover effects on productivity of local firms in Hungary.

[14] Kaminski and Riboud (2000) emphasize the importance of the stability of macroeconomic policies pursued in Hungary.

effects of integration by introducing a new variable that captures the effects of international technology spillovers. We also provide empirical evidence on the theoretical implications of the model, using panel data estimation techniques and a battery of structural break tests.

The results regarding recent EU members reveal three interesting observations. First, downward bias in the convergence rate is confirmed when heterogeneity in productivity rates is not allowed. Comparison of the first two sections of all the tables shows slower convergence rates resulting from the imposition of a common productivity assumption. Second, almost all coefficient estimates are positively affected with membership to the EU. This result is supported by structural change tests of Bai and Perron (1998) and Sen (2003). Third, there is an increasing amount of harmonization, especially in convergence rates.

Regarding the candidate countries, in addition to the above observations, there is also a significant level of variation towards their progress to the EU standards of living. Some countries like the Czech Republic, Hungary, Slovakia, and Poland stand out in terms of productivity growth or convergence rates, while others seem to do poorly. An important policy implication of the heterogeneity result is that the candidate economies would exhibit different productivity and convergence levels, following their entry. At this stage, regional and structural funds, similar to those provided to the recent EU members, may be useful to help the poorer candidate countries catch up. However, evidence indicates that such funds are not able to generate long-run growth effects (Boldrin and Canova, 2003).

The candidate countries' economic conditions today look similar to those of Spain and Portugal at the time of their entry (Boldrin and Canova, 2003). Therefore, the costs and gains from joining the EU will likely to be similar to those experienced by these entrants. This observation, along with the harmonization experience these countries' growth rates display, signals that the differences in productivity and convergence levels are expected to fade out over time, a finding that is also supported by the increasing homogeneity within the candidate countries.

A larger and richer EU market with no exchange rate risk, which the recent entrants were not able to enjoy, will further facilitate the convergence process for the candidate economies. National policies encouraging further trade and FDI flows with the EU, as well as free labor and capital mobility, along with supply side and fiscal reforms, will therefore play a much more important role to achieve growth rates higher than EU averages and hence real convergence. The evidence of positive impact of integration on growth rates and productivity reported in this paper suggests that gained benefits over time will be more than outweigh the expected short-run consequences of the accession process, thereby making Europe a more prosperous place for all the parties involved.

References

Backè, P., J. Fidrmuc, T. Reininger, and, F. Schardax, 2002, Price Dynamics in Central and Eastern European EU Accession Countries, Emerging Markets Finance and Trade*,* 39(3) 42-78.

Bai, J. and P. Perron, 1998, Estimating and Testing Linear Models with Multiple Structural Changes, Econometrica, 66, 47-68

Baltagi, B., 1995, Econometric Analysis of Panel Data", Ch. 8 (Chichester, England; John Wiley, and Sons).

Banerjee, A., R. L. Lumsdaine, and J. H. Stock, 1992, Recursive and Sequential Tests of the Unit-Root and Trend Break Hypothesis: Theory and International Evidence, Journal of Business and Economics Statistics, 10, 271-287.

Barrel, R. and D. Holland, 2000, Foreign Direct Investment and Enterprise Restructuring in Central Europe, Economics of Transition, 82, 477-504.

Barro, R. J., 1991, Economic Growth in a Cross Section of Countries Quarterly Journal of Economics, 106(2), 407-43.

Barro, R. J., and X. Sala-i-Martin, 1992, Convergence, Journal of Political Economy, 100(2), 223-51.

Ben-David, B., 1996, Trade and Convergence among Countries, Journal of International Economics, 40, 279-98.

Bernard, A. B. and S. N. Durlauf., 1995, Convergence in International Output, Journal of Applied Econometrics, 10(2), 97-108.

Bernard, A. B. and S. N. Durlauf, 1996, Interpreting Tests of Convergence Hypothesis Journal of Econometrics, 71(1-2), 161-73.

Boldrin, M. and F. Canova, 2003, Regional Policies and EU Enlargement, CEPR Discussion Paper No. 3744.

Brada, J. C. and A. M. Kutan, 2001, The Convergence of Monetary Policy between Candidate Countries and the European Union, Economic Systems, 25(3), 215-231.

Brada, J. C., A. M. Kutan, and S. Zhou, 2003, Real and Monetary Convergence between the European Union and Transition-Economy Candidate Countries: Market Integration and Policy Coordination, forthcoming in Journal of Banking and Finance.

Čihák, M. and T. Holub, 2001, Convergence of Relative Prices and Inflation in Central and Eastern Europe, IMF Working Paper 01/124.

Čihák, M. and T. Holub, 2002, Price Convergence to the EU: What Do the 1999 ICP Data Tell Us?, The Czech National Bank Working Paper 02/2003.

Crespo-Cuaresma, J., D. Ritzberger-Grünwald, and M. A. Silgoner, 2002, Growth, Convergence and EU Membership, National Bank of Austria Working Paper No. 62.

Dowrick, S. and D. Nguyen, 1989, OECD Comparative Economic Growth 1950-85: Catch-Up and Convergence, American Economic Review, 79(5), 1010-30.

Égert, B., 2002, Investigating the Balassa-Samuelson Hypothesis in Transition: Do We Understand What We See? A Panel Study, Economics of Transition, 10(2), 273-309.

Égert, B., I. Drine, K. Lommtzsxh, and C. Rault, 2004, The Balassa-Samuelson Effect in Central and Eastern Europe: Myth or Reality?, forthcoming Journal of Comparative Economics.

Estrin, S., G. Urga, and S. Lazarova, 2001, Testing for Ongoing Convergence in Transition Economies, 1970 to 1998, Journal of Comparative Economics, 29(4), 677-691.

Evans, P., 1998, Using Panel Data to Evaluate Growth Theories, International Economic Review, 39, 295-306.

Evans, P. and G. Karras, 1996, Convergence Revisited, Journal of Monetary Economics, 37, 249-65.

Fleissig, A. and J. Strauss, 2001, Panel Unit-Root Tests of OECD Stochastic Convergence, Review of International Economics, 9(1), 153-62.

Henrekson, M., J. Thorstensson, and R. Thorstensson, 1997, Growth Effects of European Integration, European Economic Review, 41, 1537-57.

Im, Kyung S., Pesaran, M. Hashem, Yongcheol Shin, 2003, Testing for Unit Roots in Heterogeneous Panels, Journal of Econometrics, 115(1), 53-74.

Islam, N., 1995, Growth Empirics: A Panel Data Approach, Quarterly Journal of Economics, 110(4), 1127-70.

Janáčková, S., 2000, Price Convergence and the Readiness of the Czech Economy for Accession to the European Union Eastern European Economics, 38(4), 73-91.

Judson, R. A. and A. L. Owen, 1999, Estimating Dynamic Panel Data Models: a Guide for Macroeconomists, Economics Letters, 65, 9-15.

Kaminski, B. and M. Riboud, 2000, Foreign Investment and Restructuring: The Evidence from Hungary, Technical Paper 453, The World Bank, Washington, D.C.

Kočenda, E., 2001, Macroeconomic Convergence in Transition Economies, Journal of Comparative Economics, 29(1), 1-23.

Kutan, A. M. and T. M. Yigit., 2004, Nominal and Real Stochastic Convergence within the Transition Economies: Panel Evidence, Journal of Comparative Economics, 32, 23-36.

Lee, K., M. H. Pesaran, and R. Smith, 1997, Growth and Convergence in Multi-country Empirical Stochastic Solow Model, Journal of Applied Econometrics, 12(4), 357-92.

Lucas, R.E. 1998, On the Mechanics of Economic Development, Journal of Monetary Economics, 22(1), 111-31.

Martin, C. and F. J. Velázquez, 2001, An Assessment of Real Convergence of Less Developed EU Members: Lessons for the CEEC Candidates, Working Paper No. 5/2001, European Economy Group.

Nelson, R. and E. Phelps, 1966, Investment in Humans, Technological Diffusion and Economic Growth, American Economic Review, 61, 69-75.

Nerlove, M. 2000, Growth Rate Convergence, Fact or Artifact? An Essay on Panel Data Econometrics, Panel data econometrics: Future directions: Papers in honor of Professor Pietro Balestra, 3-33, Elsevier Science, North-Holland.

Ng S., and P. Perron, 1995, Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection of the Truncation Lag, Journal of American Statistical Association, 90, 268-281.

Quah, D., 1992, International Patterns of Growth: Persistence in Cross-Country Disparities Working Paper (London School of Economics, London).

Richards, A. J. and G. H. R. Tersman, 1996, Growth , Nontradables, and Price Convergence in the Baltics, Journal of Comparative Economics*,* 23(2), 121-145.

Rivera-Batiz, R. A., and P. M. Romer, 1991, Economic Integration and Growth Quarterly Journal of Economics, 56, 531-55.

Schoors, K. and B. van der Tol., 2002, Foreign Direct Investment Spillovers Within and Between Sectors: Evidence from Hungarian Data, Working Paper 2002/157, Gent University.

Sen, A., 2003, On Unit-Root Tests When the Alternative Is a Trend-Break Stationary Process, Journal of Business & Economics Statistics, 21, 174-184.

Tomljanovic, M., and T. J. Vogelsang, 2002, Are U.S. Regions Converging? Using New Econometric Methods to Examine Old Issues, Empirical Economics, 27, 49-62.

Wagner, M. and J. Hlouskova, 2002, The CEEC10's Real Convergence Prospects, CEPR Discussion Paper Paper No. 3318.

Table 1: Growth in Spain and Portugal before and after joining the EU (de-mean with France)				
Coefficient	*Portugal* (pre-1986)	*Spain* (pre-1986)	*Portugal* (post-1986)	*Spain* (post-1986)
		All heterogeneous		
g	0.18***	0.07***	0.10***	0.07***
μ	3.02	3.84	0.65	0.70
1-*λ*	0.59*	0.58**	0.09***	0.09***
	LR = 7.16***	*Common productivity growth*		*LR* = 0.99
g	0.07***		0.08***	
μ	-0.13	3.86	0.47	0.73
1-*λ*	0.01	0.58**	0.06***	0.10***
	LR = 0.001	*Common convergence rate*		*LR* = 0.00
g	0.18***	0.07***	0.10***	0.07***
μ	2.99	3.87	0.65	0.70
1-*λ*	0.58***		0.09***	
	LR = 12.96***	*Common productivity and convergence rate*		*LR* = 1.88§
g	0.17*		0.07**	
μ	0.67	0.77	0.51	0.53
1-*λ*	0.10***		0.07***	

Notes: *g* represents technological/productivity growth, *μ* is a mixed variable that shows different steady states, and 1-*λ* is the convergence rate. Growth rates are annualized values. Values for *μ* rather than *c* are reported in these tables due to the implications of the theoretical section about this parameter. Significance values are not reported for *μ* since it is composed of the product of three parameters. Critical values used for LR tests are 3.84 (2.71) for χ_1^2 (first two tests) and 5.99 (4.61) for χ_2^2 (last test). *** indicates significance at 99% while ** and * correspond to significance at 95% and 90%, respectively. § indicates choice by AIC criterion.

Table 2: Growth in Austria-Finland-Sweden before and after joining the EU (de-mean with France)

Coefficient	*Austria* (pre-1995)	*Finland* (pre-1995)	*Sweden* (pre-1995)	*Austria* (post-1995)	*Finland* (post-1995)	*Sweden* (post-1995)
			All heterogeneous			
g	0.05*	0.045	0.045	0.045	0.08***	0.045
μ	1.56	0.52	1.25	2.57	2.46	4.40
1-λ	0.20***	0.06***	0.15***	0.32***	0.33***	0.56*
	LR = 2.09§		*Common productivity growth*			*LR* = 4.34
g		0.05*			0.045	
μ	1.63	0.42	1.25	2.56	0.15	4.20
1-λ	0.20***	0.05***	0.15***	0.32***	0.01***	0.53**
	LR = 3.27		*Common convergence rate*			*LR* = 0.90§
g	0.06*	0.045	0.045	0.045	0.08***	0.045
μ	0.88	0.90	0.89	2.96	2.75	3.00
1-λ		0.11***			0.37***	
	LR = 7.38		*Common productivity and convergence rate*			*LR* = 12.17***
g		0.045			0.045	
μ	0.91	0.92	0.92	0.97	0.95	0.95
1-λ		0.11***			0.12***	

Notes: Insignificance for g indicates replacement with the productivity rate and steady state coefficient estimates for France, namely 0.045. Significance values are not reported for μ since it is composed of the product of three parameters. Critical values used for LR tests are 9.49 (7.78) for χ_4^2 and 5.99 (4.61) for χ_2^2 .

Table 3: BP Structural Break Test Results in Autoregressive Coefficient (Convergence Rate)						
Country	*UDmax*	*WDmax*	*Sequential (2|1)*	*Sequential (3|2)*	*BIC choice*	*Break dates at 5%*
Austria	18.80***	47.06***	14.79**	0.06	0	1987Q4 ↓ 1996Q3 ↑
Finland	28.33***	62.17***	4.77	0.05	2	1990Q3 ↑
Portugal	5.60	7.13	11.85**	12.50**	2	
Spain	32.17***	80.54***	0.04	0.0004	0	1984Q3 ↑
Sweden	289.44***	724.48***	0.01	28.23***	0	1982Q4 ↑ 1993Q3 ↑ 1996Q4 ↑

Notes: A maximum of three breaks are allowed due to sample size. UDMAX and WDMAX results are for the double maximum tests of Bai & Perron (1998). The sequential tests examine the likelihood of having i+1 breaks given that i breaks exist. BIC choice column refers to the number of breaks according to the Bayesian Information Criterion. The confidence intervals for the break dates are not reported to save space. Break dates are reported when the double maximum tests point to the existence of at least one break.

Table 4: BP Structural Break Test Results in the Trend Coefficient (Productivity Growth)						
Country	*UDmax*	*WDmax*	*Sequential (2|1)*	*Sequential (3|2)*	*BIC choice*	*Break dates at 5%*
Austria	11.88***	19.21***	8.66**	5.56	0	1986Q2 ↓ 1994Q2 ↑
Finland	30.27***	46.12***	12.33***	2.09	2	1989Q3 ↑ 1992Q3 ↓
Portugal	7.92*	17.63***	3.63	4.29	0	1984Q3 ↑
Spain	9171.7***	22857.0***	4.57	1.22	0	1997:03 ↓
Sweden	11.74	18.98	2.11	4.29	0	1984:03 ↑

Notes: The autoregressive coefficient is held constant to capture the gradual breaks in the trend as opposed to sudden ones.

Table 5: Single break test (Sen, 2003) results for trend and mean breaks

	Austria				*Finland*				*Sweden*			
	F-max	*Date*	*ΔM*	*ΔT*	*F-max*	*Date*	*ΔM*	*ΔT*	*F-max*	*Date*	*ΔM*	*ΔT*
Trend alone	63.12**	1987Q2		(+)	14.80**	1996Q2		(+)	11.59**	1990Q3		(−)
Trend + Mean	11.40**	1992Q4	(−)**	(+)	76.72**	1991Q3	(−)**	(+)	79.32**	1992Q1	(−)**	(+)
	Portugal				*Spain*							
	F-max	*Date*	*ΔM*	*ΔT*	*F-max*	*Date*	*ΔM*	*ΔT*				
Trend alone	14.96**	1984Q1		(+)	65.00**	1986Q4		(+)				
Trend + Mean	32.40**	1985Q4	(+)**	(+)	36.10**	1993Q2	(−)**	(+)*				

Notes: Critical values derived in Monte Carlo simulations for sequential F-max test are 7.93, and 9.17 for stationary break models at 90%, and 95%, respectively. *ΔM* represents a change in the mean, while *ΔT* is the change in trend.

Table 6: Estimation of growth in EU candidate countries (demean with France)				
	Country/Coeff.	*g*	*μ*	*1-λ*
All heterogeneous	*Czech Rep.*	0.10***	-0.56	0.31***
	Estonia	0.04	-0.13	0.09***
	Hungary	0.23***	-0.99	0.42***
	Latvia	0.14**	-0.37	0.15***
	Lithuania	0.18***	-0.64	0.23***
	Malta	0.06***	-1.37	-0.11
	Poland	0.29***	-0.52	0.20***
	Slovakia	0.12***	-0.74	0.32***
Common Productivity Growth	*Czech Rep.*	0.06***	-0.28	0.18***
	Estonia		-0.15	0.10***
	Hungary		-0.02	0.03***
	Latvia		-0.20	0.10***
	Lithuania		-0.34	0.17***
	Malta		-1.38	-0.11
	Poland		-0.02	0.04***
LR = 18.25**	*Slovakia*		-0.17	0.09***
Common convergence rate	*Czech Rep.*	0.09***	-0.37	0.21***
	Estonia	0.20***	-0.54	
	Hungary	0.22***	-0.47	
	Latvia	0.18***	-0.59	
	Lithuania	0.15***	-0.54	
	Malta	0.04	-0.24	
	Poland	0.29***	-0.57	
LR = 29.21***	*Slovakia*	0.11***	-0.47	
Common productivity growth and convergence rate	*Czech Rep.*	0.12***	-0.26	0.15***
	Estonia		-0.31	
	Hungary		-0.26	
	Latvia		-0.36	
	Lithuania		-0.32	
	Malta		-0.20	
	Poland		-0.28	
LR = 51.17***	*Slovakia*		-0.32	

Notes: Cyprus and Slovenia are left out due to data unavailability. Insignificance means parameter values are not significantly different than the French values. Significance values are again not reported for μ since it is composed of the product of three parameters. 95% (99%) critical values used in the LR tests are 14.07 (18.48) for χ^2_7 (first two tests) and 23.69 (29.14) for χ^2_{14} (for the last test).

Table 7: Estimation of growth in EU candidate countries (demean with group average)

	Country/Coeff.	g	μ	$1\text{-}\lambda$
All heterogeneous	*Czech Rep.*	-0.07***	0.14	0.25***
	Estonia	0.01	-0.02	0.14***
	Hungary	0.03**	0.04	0.35***
	Latvia	0.03**	-0.23	0.36***
	Lithuania	0.06***	-0.24	0.35***
	Malta	-0.10**	0.21	0.19***
	Poland	0.09***	-0.19	0.50***
	Slovakia	-0.04	0.00	0.19***
Common Productivity Growth	*Czech Rep.*	0.04***	-0.01	0.06***
	Estonia		-0.05	0.17***
	Hungary		0.04	0.35***
	Latvia		-0.25	0.37***
	Lithuania		-0.18	0.31***
	Malta		0.01	0.07***
	Poland		-0.04	0.27***
LR = 16.22**	*Slovakia*		-0.04	0.09***
Common convergence rate	*Czech Rep.*	-0.07***	0.17	0.29***
	Estonia	0.06***	-0.12	
	Hungary	0.04***	0.02	
	Latvia	0.02*	-0.18	
	Lithuania	0.04*	-0.17	
	Malta	-0.12***	0.36	
	Poland	0.10***	-0.12	
LR = 10.07	*Slovakia*	-0.06***	0.04	
Common productivity growth and convergence rate	*Czech Rep.*	-0.01	0.04	0.15***
	Estonia		-0.01	
	Hungary		0.04	
	Latvia		-0.07	
	Lithuania		-0.03	
	Malta		0.10	
	Poland		0.01	
LR = 54.27***	*Slovakia*		-0.02	

Notes: 95% (99%) critical values used in the LR tests are 14.07 (18.48) for χ^2_7 (first two tests) and 23.69 (29.14) for χ^2_{14} (for the last test).