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Real economic convergence and the impact of monetary policy on economic growth of the EU countries: The analysis of time stability and the identification of major turning points based on the Bayesian methods

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Abstract

This study analyzes the time stability of both the GDP beta convergence and the impact of monetary policy variables on economic growth in EU27 countries during 1993-2010 and EU15 during 1972-2010. To address the problem of variables' selection, Bayesian model pooling (BMP) is used while choosing the appropriate variables for the regression. To loosen the assumption of stability overtime, interaction terms of particular regressors are introduced with time dummies (the whole sample is divided into time intervals and is allowed for structural breaks). To address the problem of potential inconsistency of 'typical' estimators, the study employs Blundell and Bond's GMM system estimator. All the calculations are based on annual data and 3-year intervals. The main findings are: (1) The EU27 countries converged at the rate of about 5-6% per annum while the EU15 countries – at 3% p.a. (2) The pure mechanism of conditional convergence of the countries under study was rather constant over time. (3) The considered economic growth determinants, including all the variables related with monetary policy, exhibited mixed impact on economic growth, especially based on annual data. (4) These results have been obtained for the following turning points: 2004, 1998, and – in the case of EU15 countries – 1989.

JEL classification codes: C11, C23, O40, O47

Keywords: convergence, economic growth, growth factors, Bayesian pooling, EU countries

1. Introduction

In the literature there are many definitions of real economic convergence as well as many methods used in verifying the convergence hypothesis. For example Islam (2003) distinguishes 7 types of classifications: (a) convergence within a given economy and convergence between economies, (b) convergence of growth rates and convergence of income levels, (c) β and σ convergence, (d) absolute and conditional convergence, (e) global and local convergence, (f) GDP and TFP convergence, (g) deterministic and stochastic convergence.

The concept of income-level or real convergence is widely used and many theoretical as well as empirical papers on this subject have emerged in recent years. However, the lack of both single definition of convergence and single method of analyzing this phenomenon yielded huge diversity of the empirical evidence. The conclusions obtained by various authors depend to a large extent on the analyzed sample of countries, the model specification, and the estimation method. Regarding the latter, the set of explanatory variables treated as economic growth factors is extremely important. Even in the case of the same sample and the same method of econometric modeling, inclusion of different sets of explanatory variables in the regression model often yields different, not to say contradictory results. Sala-i-Martin, Doppelhofer, and Miller (2004, SDM hereafter) try to solve this problem using Bayesian averaging of classical estimates (BACE) approach which is a form of Bayesian model pooling (BMP) algorithm. Instead of using just one model, they estimate a large number of equations corresponding to all possible subsets of explanatory variables selected from an initially selected set of 'candidate-variables' (in the case of a large set of possible regressors, 'all' possible sets is replaced with 'a large number' of randomly drawn sets). The results are then averaged using specified weights.

Another problem that needs to be solved while performing growth regressions is the possible instability of the parameters. In most empirical studies it is assumed that the impact of a given variable is stable over time. Such a model specification, however, may not provide the full picture of the factors determining the pace of economic growth. The assumption of constancy of parameters overtime always

remains just an assumption and it does not show the full nature of the process of economic growth unless it is verified and proved to hold. The real world is very complicated, driven by many mechanisms and affected by many shocks, both from the inside and outside sources, so there are no reasons to assume a priori that the relationships between the macroeconomic variables are constant over time. This refers both to the pure convergence process, i.e. to the relationship between the initial income level and the subsequent growth rate, as well as to the impact of particular factors on the rate of GDP dynamics.

This study tries to shed some light on these doubts and questions. The aims of this analysis are twofold. The first goal is to check whether there has been any β convergence among the EU countries at all and – after confirming that the catching up process has actually taken place – to verify whether it has been constant over time and how strong it was. This will allow to formulate projections as to the future rate of the catching up process of the EU member states.

Secondly, this study focuses on the analysis of the time stability of the impact of selected macroeconomic variables on economic growth. As there is a huge number of variables that are widely recognized as the factors of economic growth, the analysis focuses on the subset of them. It examines mainly those variables that reflected monetary policy because monetary policy often raises questions on how it should be pursued to stimulate economic growth. The focus is given to the nominal variables representing monetary policy directly or indirectly: the variables that are controlled by the central bank (e.g. interest rates, money supply) as well as those that are basically affected by the actions conducted by monetary authorities (e.g. credit growth or inflation rate). The analysis tries to answer the question whether the impact of these monetary variables on economic growth was constant over time. If so, it would be a very good information for the monetary authorities because the effects of given actions could be easily projected. The answer 'no' to the question means, however, that the effects of monetary policy actions are hardly expectable: in some cases a given decision (e.g. interest rate cut) may yield more rapid economic growth, but in the other cases it may be counterproductive from the point of view of output. If the impact of monetary policy variables on economic growth were not constant over time, it would require to conduct monetary policy very carefully

because the effects of central bank decisions might be far away from those expected. Although this study focuses on monetary variables, it also includes a large number of other potential sources of economic growth – both 'deep' determinants of economic development, measuring countries' institutional environment, as well as the factors directly influencing the GDP dynamics from the demand-side and supply-side perspective.

In order to attain robustness to the sample specification, calculations are performed separately for the whole group of the 27 EU countries (EU27) and for the group of 15 'old' EU members (EU15). Another aspect of robustness is due to the fact that the analysis is based on the annual data as well as on the data transformed into three-year intervals. The calculations for EU15 cover the 1972-2010 period while the calculations for EU27 countries are based on the data from the years 1993-2010. Furthermore, in an attempt to maximize robustness of the analysis, BMP algorithm is applied to average on the results of estimation that are obtained with the use of Blundell and Bond's GMM system estimator. In order to take account of the possible instability of particular parameters overtime in result of existence of certain turning points, structural breaks of some of the variables are allowed for and the typically used growth regression equations are adjusted adequately.

This research method refers to the Bayesian model pooling. Just at the beginning it is worth to emphasize that this study is not the replica of the analysis conducted by SDM or any other authors. The analysis can be treated as a very interesting extension and supplement to the existing studies incorporating Bayesian modeling. This research yields a large scope of new knowledge on the sources of economic growth and its stability over time. The major differences between this study and the analysis conducted by SDM are the following. First, this analysis does not incorporate the BACE approach; a Bayesian model pooling is applied not to the classical estimates but to a much more advanced Blundell and Bond's GMM system estimator which is believed to be a better one in analyzing economic growth determinants and real convergence. Second, unlike SDM, this study is based on panel data (in the form of annual time series or 3-year intervals) meaning that the results should be more representative than those obtained on cross-sectional data. Third, this analysis focuses not only on identifying the most important economic

growth determinants but mainly – what is innovative also in comparison with many other empirical studies – on the analysis of convergence. It is assumed that real convergence does occur and the initial income level appears in all the estimated regression equations which may be regarded as a novum in terms of the existing studies incorporating BMP or BACE approaches. Last but not least, the study deals with identifying the stability of the examined relationships over time. It checks whether convergence occurred at constant or variable rates during the analyzed period; the same concerns the selected economic growth determinants, especially those that are related with monetary policy.

The report is composed of seven parts. Chapter 2, which appears just after this introduction, shows the theoretical issues related with β convergence and presents the review of literature in the context of convergence and Bayesian model pooling. Sections 3 and 4 present the general idea of BMP approach and describe the convergence model with instability that is applied in the study. Chapter 5 presents the data used. The results of the analysis are discussed in chapter 6 while section 7 shows some concluding remarks.

2. Theoretical issues and the review of the literature

The concepts of real convergence most often used in empirical studies are the following[1]: β convergence and σ convergence.

The β convergence exists if GDP of less developed countries (with lower GDP per capita) grows faster than the GDP of the more developed ones. This type of convergence can be analyzed in absolute or conditional terms. The existence of absolute convergence means that less developed countries always reveal higher economic growth while in the case of conditional convergence the catching-up process takes place only for those countries that tend to reach the same steady state which – in general – need not be the same across all economies. σ convergence exists if the differentiation of the GDP per capita levels between economies (measured e.g. by standard deviation of log GDP per capita) decreases over time.

The concept of β convergence is directly related with neoclassical models of economic growth (Solow, 1956; Mankiw et al., 1992). The main factor responsible for equalization of income levels is the neoclassical assumption of diminishing returns to capital. Countries which are capital scarce obtain higher productivity of that input, which in turn stimulates the investment processes and enhances rapid economic growth.

The concept of convergence can be explained based on the Solow model. The main equation describing the dynamics of the economy is:[2]

$$\dot{k}(t) = s \cdot f\left(k(t)\right) - \left(n + a + \delta\right) \cdot k(t), \qquad (2.1)$$

where: $k(t)$ – capital per unit of effective labor[3], $\dot{k}(t)$ – the increase of k per unit of time (the time derivative of k), $f(.)$ – output per unit of effective labor, n – population growth, a – technological progress, δ – depreciation rate, t – time. Assuming that the neoclassical production function if of the Cobb-Douglas form[4] $f(k) = k^{\alpha}$, dividing equation (2.1) by k yields:

[1] The distinction between β and σ was introduced into the literature by Barro and Sala-i-Martin (1990).
[2] For the derivation of equation (2.1), see e.g. Romer, 1996; Barro and Sala-i-Martin, 2003.
[3] Effective labor is the product of population (labor force) and the level of technology.
[4] To make the analysis more clear, the time subscripts t are omitted.

$$\frac{\dot{k}}{k} = sk^{\alpha-1} - (n + a + \delta). \tag{2.2}$$

The above equation shows the growth rate of capital per unit of effective labor during the transition period in the Solow model. Since output is proportional to capital, the growth trajectory given by (2.1) or (2.2) can also be interpreted in GDP terms.

Equation (2.2) can be used to show the concept of convergence. The derivative of $\dot{k}/k$ with respect to k equals:

$$\frac{d}{dk}(\dot{k}/k) = s(\alpha - 1)k^{\alpha-2} < 0. \tag{2.3}$$

The above expression is negative which means that the rate of economic growth decreases with income level (i.e. higher per capita income implies slower GDP growth). This suggests the existence of real economic β convergence.

The catching-up process confirmed by neoclassical models is not absolute. Suppose there are two separate economies. If both of them approach different steady states, less developed economy need not grow faster. The possibility of such an outcome indicates that the convergence explained by neoclassical models of economic growth is conditional, that is it occurs with regard to individual steady states to which the countries are tending. However, the respective neoclassical models of economic growth differ in terms of the value of the β coefficient. This coefficient indicates the rate of the catching-up process, according to the following equation:

$$\frac{\dot{y}}{y} = \beta(\ln y^* - \ln y), \tag{2.4}$$

where: y – GDP per capita in the period t, y^* – GDP per capita in the steady state. Equation (2.4) implies that the rate of economic growth depends on the income gap with respect to the steady state. The coefficient β shows what part of the distance towards the steady state the economy is covering during one period. For example, if $\beta = 0.02$, the economy is covering annually 2% of the distance.

In empirical studies, authors estimate β coefficients for different countries or regions. While the conditional convergence hypothesis is verified (which usually takes place in the case of heterogeneous samples), the key element is the proper

choice of explanatory variables for the econometric model. The set of explanatory variables in the regression equation should reflect the differences in steady states across individual countries in the best possible way.

The neoclassical Solow model assumes that the steady state depends, *inter alia*, on the savings rate and population growth. However, as any economic model, this is a simplified approach while in reality there are many factors determining the steady state. On the one hand, one can distinguish 'deep' determinants of economic development that measure the countries' institutional environment (political system, economic freedom, geopolitical location, cultural characteristics etc.)[5]. The 'deep' factors influence the 'direct' variables determining steady state. These include e.g. investments in various types of capital (physical and human capital), fiscal and monetary policy, the size of government (the ratio of government expenditure and tax revenue to GDP), openness, structure of the economy, productivity of the inputs, private sector development, and the quality of infrastructure.

The proper specification of steady state determinants is the key element to derive correct conclusions from the empirical studies on convergence. In the literature, authors analyze various convergence models that include different factors of economic growth. Economists do not have one common view on the set of variables which should be included in the regression equation. This can be seen in practically any review of literature.

Most empirical studies are methodologically related to the analyses conducted by Barro (see e.g. Barro 1991; Barro and Sala-i-Martin, 2003; Barro and Lee, 1994; Sala-i-Martin, 1996a,b) or by Mankiw et al. (1992). Barro et al. have been continuously conducting empirical studies on economic growth and convergence for various countries and regions. The following regression equation is usually estimated:

$$(1/T)\ln\left(y_{it} / y_{i,t-T}\right) = \alpha_0 + \alpha_1 \ln\left(y_{i,t-T}\right) + \sum_{k=1}^{K} \phi_k X_{k,it} + \varepsilon_{it}\,, \qquad (2.5)$$

where: y_{it} – income *per capita* of region or country i in period t, T – the number of years covered by one observation, $X_{k,it}$ for $k = 1,...,K$ – the set of control variables, ε_{it} – random factor. The left-hand side of (2.5) represents the rate of economic growth.

[5] Wojtyna (2002, 2007), Rapacki (2009, part III).

The first variable on the right-hand side ($\ln y_{i,t-T}$) measures the initial GDP per capita, so α_1 is used to draw conclusions about the existence and the rate of β convergence. The catching-up process takes place if α_1 is negative and statistically significantly different from zero. The convergence is conditional upon economic growth factors included in the set of control variables (X_k. for k=1,…K), while it is the absolute (unconditional) convergence when no control variables are included.

The value of β coefficient that measures the rate of convergence can be calculated as[6]:

$$\beta = -\frac{1}{T}\ln\left(1+\alpha_1 T\right). \tag{2.6}$$

Given the parameter β, it is possible to calculate the number of years needed for the countries to reduce by half the income gap towards their individual steady states, assuming that the average growth trajectories observed in the period under study remain unchanged (the so-called half-life). It is obtained as follows (see Romer 1996, p. 22-23 for details):

$$t^* = -\frac{\ln 0.5}{\beta} \approx \frac{0.6931}{\beta}, \tag{2.7}$$

where β in equation (2.7) is expressed as a decimal number.

The estimation of equation (2.5) became a very popular way of testing the convergence hypothesis and economic growth determinants and is known in the literature as the 'Barro regression'. The particular studies differ, however, in the set of control variables included in the regression equation. The selection of explanatory variables often reflects the arbitrary choice of the researcher to include a given

[6] Barro and Sala-i-Martin (2003, p. 467) analyze β convergence based on the neoclassical model and they derive the equation showing the relationship between the average annual GDP growth rate and the initial income level:

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

where y_{iT} and y_{i0} – GDP per capita of country i in the final and initial year, T – the length of period, β – the convergence parameter, a – a constant term, $w_{i0,T}$ – a random factor. The coefficient on initial income, i.e. $-[(1 - e^{-\beta T})/T]$, equals α_1 in equation (2.5). Thus, from $\alpha_1 = -[(1 - e^{-\beta T})/T]$ we get (2.6). For a small T the regression coefficient α_1 is very similar to the convergence parameter β, because if T tends to zero the expression $(1 - e^{-\beta T})/T$ approaches β.

variable and exclude some others. For example, Barro and Sala-i-Martin (2003) analyze more than 80 countries in the 1965-95 period (using three 10-year averages in order to be robust to business cycles and irregular shocks). Their conditional convergence equations include, except of initial per capita income, e.g.: the investment rate, school enrolment rates (at different levels), life expectancy, fertility, infant mortality, openness, terms of trade, government expenditure (e.g. on consumption, education, or military), inflation, the number and structure of the population, rule of law index, democracy index, corruption, quality of bureaucracy, civil liberties, financial indicators (the volume of credits and deposits), as well as many dummies representing the geographical area (East Asia, Latin America, Subsaharan Africa, OECD), access to sea, geographical altitude, and the institutional system. Their results indicate that the rate of conditional convergence equals 2.5% per annum.

Another important analysis on convergence has been carried out by Mankiw, Romer, and Weil (1992) (MRW hereafter). This study differs from that of Barro because MRW refer strictly to the Solow model. Control factors tested in the convergence equation are the same variables that determine the steady state according to the augmented Solow model, i.e. investment rate in physical capital (s_K), investment rate in human capital (s_H), and population growth (n). They estimate the following regression equation (where ζ_1 and ζ_2 are Cobb-Douglas production function parameters):

$$\ln y(t) - \ln y(0) = \left(1 - e^{-\beta t}\right) \frac{\zeta_1}{1 - \zeta_1 - \zeta_2} \ln s_K + \left(1 - e^{-\beta t}\right) \frac{\zeta_2}{1 - \zeta_1 - \zeta_2} \ln s_H +$$

$$- \left(1 - e^{-\beta t}\right) \frac{\zeta_1 + \zeta_2}{1 - \zeta_1 - \zeta_2} \ln \left(n + a + \delta\right) - \left(1 - e^{-\beta t}\right) \ln y(0) . \qquad (2.8)$$

Most of the empirical studies on β convergence are based on the Barro or MRW regressions. Individual studies differ in terms of the model specification, the econometric method of its estimation, the sample of countries and the length of the period, as well as the set of explanatory variables (the authors test many control factors, not only those considered by Barro or MRW). Hence, the results are highly diversified and there is still much room for cross-country analyses of convergence.

Table 1
Empirical evidence on cross-country convergence

Authors	Countries	Period	Type	Yes/ no	Estimate of β (%) or the coefficient on initial income	Method
Mankiw, Romer, Weil, 1992	98 countries	1960-1985	abs. β	no	(–0.36%)	cond. β: regression based on the Solow model with (a) physical capital, (b) physical and human capital
	98 countries [(a)]	1960-1985	cond. β	yes	0.61%	
	98 countries [(b)]	1960-1985	cond. β	yes	1.37% ; 1.42%	
	22 OECD countries	1960-1985	abs. β	yes	1.67%	
	22 OECD countries [(a)]	1960-1985	cond. β	yes	1.73%	
	22 OECD countries [(b)]	1960-1985	cond. β	yes	2.03% ; 2.06%	
Islam, 1995	96 countries [(a)]	1960-1985	cond. β	yes	0.48% ; 0.59%	cond. β: regression based on the Solow model with (a, b) physical capital, (c, d) physical and human capital; equation estimated using (a, c) cross-section or pooled regression, (b, d) panel data (correlated or fixed effects)
	96 countries [(b)]	1960-1985	cond. β	yes	4.34% ; 5.07%	
	79 countries [(c)]	1960-1985	cond. β	yes	0.69% ; 1.11%	
	79 countries [(d)]	1960-1985	cond. β	yes	3.75%	
	22 OECD countries [(a)]	1960-1985	cond. β	yes	0.01% ; 0.02%	
	22 OECD countries [(b)]	1960-1985	cond. β	yes	6.70% ; 10.67%	
	22 OECD countries [(c)]	1960-1985	cond. β	yes	1.62% ; 1.87%	
	22 OECD countries [(d)]	1960-1985	cond. β	yes	9.13%	
Andrés, Doménech, Molinas, 1996	24 OECD countries	1960-1990	cond. β	yes	1.7% ; 2.9%	cond. β: regression based on the Solow model with physical and human capital, extended for additional variables: public spending, budget surplus, inflation, money supply, exports, time dummies
Evans, Karras, 1996	54 countries	1950-1990	cond. β	yes	–0.012	cond. β – control variables: investment, government consumption, exports & imports, labor force, human capital
Nonneman, Vanhoudt, 1996	22 OECD countries [(a)]	1960-1985	cond. β	yes	–0.343	cond. β: regression based on the Solow model with (a) physical capital, (b) physical and human capital, (c) physical, human, and technological capital
	22 OECD countries [(b)]	1960-1985	cond. β	yes	–0.384	
	22 OECD countries [(c)]	1960-1985	cond. β	yes	–0.516 ; –0.492	
Murthy, Chien, 1997	OECD countries [(a)]	1960-1985	cond. β	yes	2.1% ; 2.4%	cond. β: regression based on the Solow model with (a) physical and human capital, (b) physical, human, and technological capital
	OECD countries [(b)]	1960-1985	cond. β	yes	3.3% ; 3.8%	
Engel-brecht, Kelsen, 1999	17 APEC countries	1965-1990	abs. β	yes	0.88% ; 1.04%	abs. β: convergence equation estimated with different methods: (a) ordinary LS, trimmed LS, generalized LS for pooled data cond. β – control variables: (a) country dummies, (b) investment, population growth, human capital, agriculture, government expenditure, inflation, openness, country dummies
	17 APEC countries [(a)]	1965-1990	cond. β	yes	2.36%	
	17 APEC countries [(b)]	1965-1990	cond. β	yes	2.26% ; 5.17%	
Murthy, Upkolo, 1999	37 African countries	1960-1985	cond. β	yes	1.3% ; 1.7%	cond. β: regression based on the Solow model with physical and human capital
Silve-striadou, Balasubra-manyam, 2000	46 countries	1960-1994	abs. β	no	(–0.8%)	cond. β – control variables: FDI, exports, wage rate
	15 export-promoting count.	1960-1994	abs. β	yes	1.5%	
	31 import substituting c.	1960-1994	abs. β	yes	0.7%	
	46 countries	1960-1994	cond. β	no	(–0.5%);(–0.2%)	
	15 export-promoting count.	1960-1994	cond. β	yes	1.9%	
	31 import substituting c.	1960-1994	cond. β	yes	0.9%	

Authors	Countries	Period	Type	Yes/ no	Estimate of β (%) or the coefficient on initial income	Method
Smolny, 2000	16 industrialized countries	1951-1988	abs. β	yes	–0.021	cond. β – control variables: reconstruction effects (the reconstruction growth rate 1947-50 and the war-time gap 1946 vs. 1938)
	16 industrialized countries	1951-1988	cond. β	yes	–0.021	
Nakamura, 2001	50 countries	1965-1990	cond. β	yes	9.09%	cond. β: regression based on the Solow model with physical capital
Dobson, Ramlogan, 2002	19 Latin American countries	1960-1990	abs. β	yes	0.28% ; 0.45%	cond. β – control variables: population growth, investment, human capital, sectoral variables, country dummies
	19 Latin American countries	1960-1990	cond. β	yes/no	(–0.29%) ; +1.23%	
Miller, Upadhyay, 2002	83 countries	1960-1989	abs. β	yes	–0.000	cond. β: fixed effects
	83 countries	1960-1989	cond. β	yes	–0.035	
Barro, Sala-i-Martin, 2003	112 countries	1960-2000	abs. β	no		cond. β – control variables: human capital, government consumption, rule of law, democracy, openness, terms of trade, investment, inflation, time and regional dummies
	86 countries	1965-1995	cond. β	yes	2.5%	
Cole, Neumayer, 2003	110 countries [a]	1960-1996	abs. β	no	0.004	abs. β: (a) standard country-based income convergence, (b) population-based income convergence
	110 countries [b]	1960-1996	abs. β	yes	–0.003	
De la Fuente, 2003	18 OECD countries	1970-1995	abs. β	yes	–0.016	cond. β: regression based on the Solow model with physical, human and technological capital, extended for additional variables: trend, technology gap, labor force participation rate, unemployment, government spending
	19 OECD countries	1965-1995	cond. β	yes	–0.034	
Di Liberto, Symons, 2003	23 OECD countries [a]	1950-1990	abs. β	yes	–0.023	abs. β: convergence equation estimated with different methods: (a) OLS ('Barro regression'), (b) OLS pooling, maximum likelihood procedure, Anderson-Hsiao cond. β: fixed effects
	23 OECD countries [b]	1950-1990	abs. β	yes	–0.031 ; –0.027	
	23 OECD countries	1950-1990	cond. β	yes	–0.068	
Mello, Perrelli, 2003	100 countries	1960-1985	abs. β	no	0.020	cond. β: (a) control variables: human capital, government consumption, political instability, market distortion, investment, population growth; (b) regression based on the Solow model with physical and human capital
	90 countries	1960-1995	abs. β	no	0.005	
	100 countries [a]	1960-1985	cond. β	yes	–0.005 ; –0.004	
	90 countries [b]	1960-1995	cond. β	yes	–0.012	
Zhang, 2003	10 East Asian countries	1960-1997	abs. β	no		
Wane, 2004	7 WAEMU countries [a]	1965-2002	cond. β	yes	–0.06	cond. β: (a) control variable – time trend, (b) equation based on the Solow model with physical capital, human capital, time trend, and currency devaluation dummy
	7 WAEMU countries [b]	1965-2002	cond. β	yes	–0.11 ; –0.10	
Chowdhury, 2005	9 ASEAN countries	1960-2001 different subperiods	abs. β	no	+0.015 ; +0.187	cond. β – control variables: population growth, domestic savings
	9 ASEAN countries	1960-2001 different subperiods	cond. β	yes/no	–0.028 ; +0.181	
Giudici, Mollick, 2008	6 Eastern Caribbean countries	1977-2000	cond. β	yes	3.87% ; 4.43%	cond. β – control variables: population growth, savings rate, openness, consumption, government spending, investment

Notes: Column 4 informs about the type of β convergence (absolute or conditional). Column 5 gives the information on whether a given catching up process took place. The percentage values in column 6 inform that the coefficient β was calculated according to equation (2.6) or similar (a positive

percentage value confirms the existence of convergence while a negative percentage value – given in parentheses – denies the existence of convergence). If convergence coefficients had not been calculated, that column gives the estimated value of the parameter standing for initial income (a negative value confirms the convergence while a positive one does not).

There are many empirical studies on convergence described in literature – too many to mention all of them. Table 1 shows the review of selected papers. It must be noticed that the conclusions regarding the rate of convergence drawn by different authors are highly diversified for both different groups of countries considered and the method used. In general the estimated β coefficient usually does not exceed 5% although some studies indicate that it may be even greater than 10%. Also typically the more control variables are included in the analysis, the higher the estimates of β are. This finding is well confirmed in the case of OECD countries which are analyzed in a number of studies.

Naturally there is much more research in the field and only selected papers are mentioned in Table 1. Abreu et al. (2005) made a review of empirical studies on convergence published in English in journals listed in the EconLit database and found an enormous number of 1650 articles devoted to this topic. One implication of their (as well as any other) review of the literature is that the published results do not point to a single β-convergence parameter between various groups of countries or periods. That strongly suggests allowing for structural breaks in the growth process.

Since this study focuses on the EU countries, including the Central and Eastern European (CEE) countries, it is worth to describe in detail the literature review of the studies which deal with transition economies. There are not many such studies as compared with the worldwide analyses but it is possible to mention a few.

Sarajevs (2001) analyzes the convergence of 11 transition countries during the 1991-99 period. The study encompasses mainly the convergence towards the EU-15, but the convergence among the CEE countries is also tested. The author confirms the absolute β convergence among 11 transition economies, regardless of the estimation method (the author applies various dynamic panel data approaches).

Kaitila (2004) tests the absolute β convergence for 7 CEE countries using the period beginning between 1991 and 1994 and ending in 2001. The cross-sectional approach yields a clear-cut confirmation of a negative relationship between the initial income level and the growth rate while the panel data approach confirms the

existence of absolute convergence less evidently. For the period 1995-2001 the convergence coefficient equals 3.4% while for the years 1994-2001 the results are statistically insignificant.

Varblane and Vahter (2005) analyze β convergence of the 10 CEE countries during 1993-2004, using 3-year averages. The results depend on the estimation method of the model and the analyzed type of convergence. Regarding the unconditional convergence, the coefficient on initial income in the pooled least squares regression is negative but does not differ from zero in the sense of statistical significance (assuming reasonable significance level) yielding conclusion of no convergence. At the same time applying a fixed effects model brings about a negative and statistically different from zero convergence parameter which confirms the existence of absolute convergence. The conditional convergence is tested with three control variables: investment rate, exports rate, and inflation. The regression estimated with fixed effects confirms the existence of conditional convergence while using pooled LS yields unexpectedly a positive sign of the coefficient on initial income, which suggests the existence of divergence.

Matkowski and Próchniak (2005) show that the absolute β convergence among the 8 CEE countries took place at the rate of 3.4% during 1993-2003, while the convergence towards EU-15 occurred at the rate of about 2%. A newer analysis conducted by Rapacki and Próchniak (2012) confirms that 10 CEE countries converged at the rate of 2.6% during 1993-2007. Vojinović, Oplotnik, and Próchniak (2010) extended the study for CEE countries in order to account for conditional convergence with the following control variables: investment rate, consumption expenditure, general government balance, exports rate, inflation. Their results regarding conditional convergence vary depending on the exact set of explanatory variables. Wolszczak-Derlacz (2009) analyzes conditional convergence of EU-27 countries during 1990-2007 with the following control factors: investment rate, human capital accumulation (secondary and tertiary school enrolment, labor force with tertiary education, education expenditure as % of GDP), R&D spending (% of GDP), and net migration rate. The implied rate of convergence is 2.2-3.2%.

Rapacki and Próchniak (2007) conduct a very detailed analysis of absolute convergence for the whole group of 27 transition countries during 1990-2005. The

results indicate that both convergence and divergence tendencies have been observed in this group of countries. The clearly converging group was EU-8 (and EU-10). The wider group of 15 Central and South-Eastern European countries did not demonstrate any clear relationship between GDP growth rate and the initial income level while the Commonwealth of Independent States (CIS) countries rather diverged. The study carried out by Rogut and Roszkowska (2006) can be treated as an extension to that analysis because it covers 25 transition countries during 1991-2004 but it is based on the conditional convergence equations with the following control variables: investment rate, secondary and tertiary school enrolment ratio, government consumption (% of GDP), inflation rate. The conditional convergence has been found for all the analyzed groups of countries (CEE-8, CIS, and South-Eastern Europe) although the intensity of the catching-up process is quite different in particular groups.

Próchniak and Witkowski (2006) showed a slightly different model of conditional convergence for 126 countries (including transition economies) and the period 1975-2003. They assumed that apart from the initial income level, the economic growth is determined by gross capital formation, government consumption expenditure, trade balance, and money supply, whereas the volume of aid, literacy rate, age dependency ratio, and gross fixed capital formation are the variables determining directly the convergence parameter. Under such an innovative approach the convergence parameter β reached the level of even up to 22-25% for some countries, but it is not comparable with other research due to inclusion of some growth factors in the "convergence parameter".

There are also a number of studies covering transition countries but focusing on economic growth determinants. However, some of them deal also with convergence because initial income level is introduced into the regression equation as one of the explanatory variables. But the convergence itself is not the main area of interest in these analyses. For example, Grogan and Moers (2001) analyze 25 transition countries during 1990-98 introducing institutional measures (rule of law, investment law, property rights, and civil society) to the growth regressions. Falcetti, Raiser, Sanfey (2002) and Falcetti, Lysenko, Sanfey (2006) estimate – for 25 transition economies – a conditional convergence equation with the EBRD index of structural

reforms and fiscal balance, yielding mixed results as regards the influence of initial conditions on the subsequent growth rate. Fidrmuc (2003) examines the impact of liberalization and democracy on economic growth for 25 transition countries and shows the existence of conditional convergence. Awokuse (2007) verifies the causality between exports, imports, and economic growth for 3 CEE countries. Rusinova (2007) tests many control variables in growth regressions for 25 transition countries, including investment rate, secondary school enrolment, population growth, inflation rate, structural reforms, institutions, war and former Soviet Union dummies. Sukiassyan (2007) examines the relationship between inequality and growth for CEE and CIS countries, introducing into the growth model, apart from Gini coefficient, also educational measures, government expenditure, private sector share in GDP, and liberalization index. Many institutional variables for the sample of 25 transition economies are tested by Fidrmuc and Tichit (2009) – i.a. the reform index and the democracy index, the latter one being the average of political freedoms and civil liberties reported by the Freedom House. Pääkkönen (2010) introduces, i.a., index of economic freedom to the growth regression for 25 post-communist countries. Masten, Coricelli, Masten (2008) and Kutan, Yigit (2009) propose another growth models for 31 European countries (including CEE-10, Croatia, Ukraine, and Russia) and 8 CEE economies, respectively.

Generally, it can even be observed that for the same (or similar) group of countries and time period included in the analysis, the obtained rate of convergence differs when different set of control variables is used. A solution to the problem of the selection of independent variables is Bayesian model pooling. In literature there are studies that incorporate BMP to the analysis of economic growth determinants and convergence, but they are somewhat different from the approach applied in this study. The most recognized, crucial article of SDM is concentrated on the analysis of economic growth determinants. They analyze 98 countries and the 1960-1992 period and the study is based on the cross-sectional data. They include 67 control variables as the potential economic growth determinants. The initial income level is treated equally with the other control variables and does not appear in all regression equations which means: they accept initial GDP as a *potential* growth determinant, thus they accept that there *might be* some GDP convergence. They find 18 variables

robustly partially correlated with long-term growth and the strongest evidence is indeed found, among others, for the initial level of GDP per capita. Crespo Cuaresma and Doppelhofer (2007) propose an approach that is mostly related to this research. They apply Bayesian averaging of thresholds (BAT) to the same database as SDM (omitting, however, some statistically insignificant variables), and additionally allow for a form of instability of parameters, however their treatment of instability differs from the approach proposed here. Moral-Benito (2010) analyzed 73 world economies during the 1960-2000 period. His study was based on panel data divided into 5-year intervals. Ciccone and Jarociński (2010) use the BACE approach and the SDM database (with some modifications and augmentations) to show the differences in results obtained based on the GDP figures coming from different statistical sources. Próchniak and Witkowski (2012a) apply the BACE procedure to the sample of 127 countries during the 1970-2009 period divided into a panel comprising of 5-year intervals. In another analysis (Próchniak and Witkowski, 2012b) they analyze convergence in the group of transition countries with the same approach.

Despite the fact that these are just a few of the growth and convergence studies that have been carried out with the use of Bayesian pooling approach which seems to be gaining popularity recently, it should be mentioned that not all the economists are in favor of this modeling style. For example, Hendry and Krolzig (2004) argue that instead of running millions of regressions it is sufficient to estimate properly one model to find economic growth determinants.

Many more works applying BMP can be found in literature and authors of most of them apply BACE algorithm. This is inappropriate if the analysis is based on panel data: the model (2.5) is essentially a dynamic one and should be estimated with the use of one of the GMM estimators, such as Blundell and Bond's system GMM. In some recent papers (e.g. Moral-Benito, 2010) this is done. However, this apparently is the first study in which BMP is applied to the estimates obtained with the use of Blundell and Bond's GMM system estimator allowing for structural breaks.

3. Bayesian model pooling

A typical problem with growth regressions that comes up in most empirical econometric research is related with the choice of proper form of the model which can become problematic even if well known theory of the considered phenomenon exists. Apart from the typically econometric assumptions, it is usually far from obvious which of the possible exogeneous variables should be included. As it has been already stated, this is an issue in the case of growth regressions. For instance, Moral-Benito (2011) claims that there are more than 140 variables proposed as growth factors in the mainstream of economic growth literature (although the analysis of just the research described in the previous section of this report suggests that this figure is underestimated). Certainly, it is neither efficient nor sensible to include them all, even assuming that a researcher has access to complete data. Usually though, incompleteness of the data set theoretically allows for inclusion of a few dozens of independent variables. One way of attaining growth empirics is to select those independent variables that reflect views of the researcher on what the true model is. This, however, is highly subjective whereas, as already discussed in previous section, different preselected sets of independent variables can lead to totally different conclusions, not to mention typical 'econometric' problems, such as a risk of omitted variables bias. That is the key reason for which BMP has gained popularity over the last decade (though it has been present in literature in a quite agnostic form for two decades already).

Let $H = \{V_1, V_2, ..., V_C\}$ be a set of C variables that according to researcher's beliefs *are* growth factors. Further let $X = \{Z_1, Z_2, ..., Z_K\}$ be a set of K variables considered as *possible* growth factors such that $Z_k \notin H$ for k=1,…,K. Denoting GDP growth as Y, one can consider exactly 2^K different linear growth regressions such that in each there will be all elements of H and one of the 2^K possible subsets of X (including the empty set). The key question is: is there conditional GDP β convergence and which of the potential growth factors should be considered as the main ones. Let us assume for the moment that the model would be estimated with the use of cross-sectional data, as it is in the paper by SDM. We actually do believe that *there is* some conditional GDP β convergence in the considered groups of EU

countries and thus lagged GDP level is included in H whereas all the considered growth factors in X. In order to estimate parameters reflecting the influence of particular Z_k's with k=1,…,K and V_c's with c=1,…,C on the dependent variable, denoted as $\beta_{Z_1},...,\beta_{Z_K},\beta_{V_1},...,\beta_{V_C}$ without restricting attention to a single model with selected elements of X, BMP algorithm can be used. The idea of BACE, which is one of the BMP algorithms used when a linear model is estimated via least squares method, is the following. First, all the possible 2^K above mentioned models denoted as M_1,…,M_J (J being thus equal to 2^K) are estimated. Also the subset of X used in M_j, j=1,…,J is denoted as X_j and the number of elements in M_j as K_j. However, even with moderate K this is barely feasible due to extremely long time required to estimate all the possible M_j's. In that case, instead of estimating all 2^K models that can be constructed, a large number of X_j's are drawn and models based on just the selected subsets of X are estimated and further analyzed, thus making $J<2^K$. As it can be seen in empirical research, this is a common practice (even the early birds, SDM, do so since their initial set of independent variables contained 67 variables) and it turns out that the estimators of $\beta_{Z_1},...,\beta_{Z_K},\beta_{V_1},...,\beta_{V_C}$ converge. Thus in the discussed case one can use for estimating and inference purposes just *some* drawn M_j's instead of *all* the possible ones, provided that J (the number of drawn M_j's) is large enough.

It is not known which of the M_j's is the true one, but some prior probabilities of relevance are assigned to each of them. This is not an obvious step, since there are various possibilities of defining priors. One possible approach is to assume that the prior probabilities are equal for all the variables in X. Further assuming independence of Z_k's, this is known as binomial priors since the prior probability of each M_j is derived from the binomial distribution. A further assumption regarding the number of Z_k's in the true model, $\bar{k}$, is required. Having set this parameter, one can see that the prior probability for each Z_k equals $\frac{\bar{k}}{K}$ and, more importantly, the prior probability for model M_j is

$$\mathrm{P}(M_j) = \left(\frac{\bar{k}}{K}\right)^{K_j}\left(1-\frac{\bar{k}}{K}\right)^{K-K_j}. \qquad (3.1)$$

This kind of priors is the most common one, although there still are further possibilities, such as for instance binomial-beta priors (Ley and Steel, 2009), the general idea of which is to treat $\bar{k}$ as random instead of fixed.

Let D be the dataset used. The main point of interest lies in the posterior probabilities of particular models $\mathrm{P}(M_j \mid D)$, that is the probabilities of relevance of each M_j. Those can be viewed as the prior probabilities 'corrected' by to which extent D supports the hypothesis that M_j is the true model. Using Bayes rule, these can be written as:

$$\mathrm{P}(M_j \mid D) = \frac{\mathrm{P}(M_j)\mathrm{P}(D \mid M_j)}{\sum_{i=1}^{J} \mathrm{P}(M_i)\mathrm{P}(D \mid M_i)}. \tag{3.2}$$

Let $\mathrm{L}(D,\theta_j)$ be the likelihood of M_j and θ_j be the vector of parameters of M_j. The probability of D being generated by M_j is:

$$\mathrm{P}(D \mid M_j) = \int \mathrm{L}(D,\theta_j)\mathrm{P}(\theta_j \mid M_j)\mathrm{d}\theta_j . \tag{3.3}$$

This is the point where different BMP algorithms start differing significantly. (3.3) is computationally highly problematic, SDM in their BACE algorithm suggest approximating (3.3) with the criterion proposed by Schwarz (1978), that is the Bayesian information criterion (BIC). Doing that simplifies (3.2) to:

$$\mathrm{P}(M_j \mid D) = \frac{\mathrm{P}(M_j) n^{-(K_j+C)/2} \mathrm{SSE}_j^{-n/2}}{\sum_{i=1}^{J} \mathrm{P}(M_i) n^{-(K_i+C)/2} \mathrm{SSE}_i^{-n/2}}, \tag{3.4}$$

where n stands for the total number of observations in the dataset D while SSE_j is the sum of squared residuals of M_j. (3.4) is crucial since in the next steps one can use it in order to find the probabilities of relevance of particular Z_k's as well as the estimates of $\beta_{Z_1},...,\beta_{Z_K},\beta_{V_1},...,\beta_{V_C}$ parameters. Both can be achieved if (3.4) is treated as weights (although Moral-Benito (2011) claims that doing that is more of an FMP standing for frequentist Bayesian pooling rather than BMP). Let $\hat{\beta}_{r,j}$ stand for the estimator of any parameter (whether β_{Z_k} or β_{V_c}) in model M_j, let $\hat{\beta}_r$ be the 'final' estimator of parameter r, being the result of the total BMP process. Let us

denote their variances as $\mathrm{Var}(\hat{\beta}_{r,j})$ and $\mathrm{Var}(\hat{\beta}_r)$ respectively. Finally, let $\mathrm{P}(Z_k \mid D)$ be the posterior probability of relevance of a given Z_k. Then

$$\hat{\beta}_r = \sum_{j=1}^{J} \mathrm{P}(M_j|D)\hat{\beta}_{r,j}\,, \tag{3.5}$$

$$\mathrm{Var}(\hat{\beta}_r) = \sum_{j=1}^{J} \mathrm{P}(M_j|D)\cdot \mathrm{Var}(\hat{\beta}_{r,j}) + \sum_{j=1}^{J} \mathrm{P}(M_j|D)\cdot(\hat{\beta}_{r,j} - \hat{\beta}_r)^2 \tag{3.6}$$

and

$$\mathrm{P}(Z_k \mid D) = \sum_{j:Z_k \in X_j} \mathrm{P}(M_j \mid D)\,. \tag{3.7}$$

However, if the model is estimated with a method different from the least squares, (3.4) will look differently. This is the case with convergence models based on panel data that are most commonly estimated with the use of GMM estimators which take proper care of the dynamics in the model. Their equally important feature is that applying least squares requires the assumption of strict exogeneity of the independent variables which in the case of macroeconomic modeling is problematic, not to say that practically cannot be fulfilled. This, however, can be overcome when instrumental variables estimators are used, so it is thus possible to relax the assumptions of exogeneity, treating selected independent variables as endogeneous or predetermined.

BMP with the use of GMM estimators requires changing the way (3.4) is computed. Let $\mathrm{Q}(\theta_j)$ be the GMM loss function that is minimized while estimating M_j. Kim (2002) shows that

$$\ln \mathrm{P}(D \mid M_j) = -0.5n\mathrm{Q}(\hat{\theta}_j) - 0.5K'_j \ln n \tag{3.8}$$

where K'_j stands for the (total) number of parameters of M_j, $\mathrm{Q}(\hat{\theta}_j)$ stands for the minimized value of $\mathrm{Q}(\theta_j)$, which is the limited information likelihood analog to Schwarz's BIC. That, after proper substitution, allows to write the posterior probability of M_j, the analog of (3.4) as:

$$\mathrm{P}(M_j \mid D) = \frac{\mathrm{P}(M_j)n^{-K'_j/2}\exp[-0.5n\mathrm{Q}(\hat{\theta}_j)]}{\sum_{i=1}^{J}\mathrm{P}(M_i)n^{-K'_i/2}\exp[-0.5n\mathrm{Q}(\hat{\theta}_i)]}\,, \tag{3.9}$$

whereas formulas (3.5)-(3.7) remain unchanged.

4. The β convergence model with instability

A number of papers devoted to GDP growth have been written, including some that make use of Bayesian pooling. The majority of them discuss also the problem of GDP convergence in the natural way: lagged GDP is usually included among the 'potentially relevant' growth factors.

In this research it is claimed that drawing trustworthy conclusions regarding the existence of convergence itself requires the use of panel data: on one hand a number of objects (say, countries), but on the other hand – certain time horizon are needed in order to make convergence analysis feasible. However, the use of panel data instead of cross-sectional data brings about the dynamics problem. Suppose one is interested in the growth regression:

$$\Delta \ln GDP_{it} = \beta_0 + \beta_1 \ln GDP_{i,t-1} + \gamma x_{it} + \alpha_i + \varepsilon_{it}, \qquad (4.1)$$

where $\Delta \ln GDP_{it}$ is the logarithm of GDP change of *i*-th country in period *t*, $\ln GDP_{i,t-1}$ is the lagged by (usually) one period GDP level of *i*-th country, x_{it} is the vector of growth factors and control variables, α_i is the individual effect of *i*-th country, β_0, β_1, γ are parameters of the model and ε_{it} is the error term. It is clear that $\ln GDP_{i,t-1}$ is endogeneous and it is also quite problematic to apply instrumental variables methods so as to estimate the autoregressive parameter. However, since $\Delta \ln GDP_{it} = \ln GDP_{it} - \ln GDP_{i,t-1}$, the $\ln GDP_{i,t-1}$ can be added to both hand sides of (4.1) which results in

$$\ln GDP_{it} = \beta_0 + (\beta_1 + 1) \ln GDP_{i,t-1} + \gamma x_{it} + \alpha_i + \varepsilon_{it} \qquad (4.2)$$

Naturally, $\beta_1 + 1$ is estimated as one parameter and obtaining the estimate of β_1 requires simply subtracting 1 from the estimate of $\beta_1 + 1$. 'Classical' fixed or random effects estimators are both inconsistent for finite number of time periods covered *T*, however it is relatively easy to propose some GMM estimators that can be used to estimate β_0, β_1 and γ in (4.2). Formerly used Arellano and Bond's (1991) estimator was the first well known of them, however it is the Blundell and Bond's estimator (Blundell and Bond, 1998) whose good statistical properties are confirmed even in smaller samples. That is why it currently is the most popular one

and it is used in the research. Considering the key assumptions, Blundell and Bond's approach requires basically no serial correlation of the error term, its zero expected value conditional upon the individual effects and the current values of the independent variables and, finally, additional moment condition, namely:

$$\mathrm{E}(\alpha_i \cdot \Delta \ln GPT_{i,2}) = 0 \tag{4.3}$$

for every country in the dataset (in the general formulation) with $\Delta \ln GPT_{i,2}$ standing for the change of the dependent variable's value from the first to the second period. Blundell and Bond's estimator and its particular properties shall not be discussed in great detail here – the interested reader can address the genuine paper. Still one thing worth mentioning about Blundell and Bond's estimator as applied in this research is that it generally makes use of two types of instruments: lagged levels and lagged changes of endogeneous and predetermined variables (for the strictly exogeneous variables there is no need to use lags, since they do not have to be instrumentalized at all). In the case of panel data sets that cover longer time period that means that the number of instruments can be huge. For instance, for the endogeneous variables, their values lagged by at least two periods can be used. So, for the series of length T=10, there are eight instruments for the 10th period. In most cases it is not a good idea to use excessive number of instruments in such a case: it is time consuming and, first of all, raises a risk of weak instruments problem in the case that the autoregression of the considered exogeneous variable is not very strong. It might seem trivial to mention the problem of slow computation of a model estimated with numerous instruments. It must though be emphasized that running BMP requires estimation of at least thousands (if not millions) of models, so long-lasting estimation process of each indeed plays a role. In order to reduce the risk of weak instruments problem as well as to save time, the number of instruments used has been reduced in the process of estimation: for each endogeneous and predetermined variable, no more than its two lags and levels are used as instruments.

Another problem related with many economic models, including (4.2), is the possible lack of stability. Writing the model in such a way also means assuming that β_0, β_1 and γ are constant overtime which seems doubtful except for the case of truly short period being considered. Nevertheless, with longer time horizon this

assumption will almost surely not hold, especially if some crucial moments are covered. For instance, if one was to consider a group of Central and Eastern European (CEE) countries in the period that covers late 80's or early 90's of the twentieth century (like, for example, Próchniak and Witkowski, 2012b), it would be rational to allow for structural break around the 1990. Certainly in the case of some of the independent variables assuming stability of the way they influence $\ln GDP$ is rational, still for some of them – it is not. It would thus be useful to take potential structural break into consideration.

Crespo Cuaresma and Doppelhofer (2007) consider the case of differing regimes overtime. In their model they introduce a set of variables that are potentially causing 'threshold nonlinearity'. The name 'nonlinearity' comes from the fact that the variables that change the regime overtime are introduced by means of interaction terms which, being a product of variables, can be viewed as nonlinear.

In this research the instability of the relation between the dependent and the independent variables is introduced in a manner that is partly similar to Crespo Cuaresma and Doppelhofer (2007). First, the set of considered independent variables is divided into two groups: those that are assumed to have stable effect on the dependent variables and those whose effect can vary overtime. Our economic beliefs for that preselection are used, which might be subjective though. In the next step the entire period covered by the considered panel is divided into a few subperiods and it is assumed that the way all independent variables affect the dependent variable is constant for a given subperiod, but might differ in different subperiods for the variables selected in the previous step. Then 'regime' variables: $R_1, R_2, \ldots, R_U$ with U standing for the number of subperiods the entire series have been divided into are introduced. Each $R_{u,it}$, standing for the value of 'R' variable for u-th subperiod (u=1,…,U), takes on a value of 1 for such observation on the i-th object (country) in period t that t is covered by the u-th subperiod and 0 otherwise. Let V_c be a variable whose influence on the dependent variable can be different in particular subperiods. In order to test for the stability of this influence, it is possible to follow one of two equivalent procedures. The first option is to include in H a set of independent variables that are products of V_c and particular R_u's, u=1,…,U, that is: $S_{V_c,1}=\{V_cR_1, V_cR_2, ..., V_cR_U\}$. In order to check for stability of the influence of the

considered V_c on the dependent variable, one would need to check for significance of differences in the parameters on such set of products that can be viewed as interaction terms of V_c and R_u's. Another possibility is to introduce into the model the V_c and the products of V_c with any U-1 of the total U R_u's, that is, for instance, $S_{V_c,2}=\{V_c, V_cR_1, V_cR_2,...,V_cR_{U-1}\}$. In this case checking for the discussed stability would consist in checking for significance of the $V_cR_1, V_cR_2,...,V_cR_{U-1}$ products themselves.

The above mentioned strategies might not be equivalent for the $X=\{Z_1,Z_2,...,Z_K\}$ set anymore. The problem lies in the way particular Z_k's are drawn for particular M_j's in subsequent replications of BMP. Two strategies are possible here. One of them is to draw groups of variables rather than variables themselves. Suppose one believes that the influence of a given Z_k on the dependent variables varies overtime. In such a case interaction terms of the Z_k and particular R_u's are added to the X set. 'Drawing groups' means that if Z_k is drawn as a part of X_j for a given M_j, then automatically all its interactions are added to X_j as well. The second strategy would consist in treating interactions of Z_k and particular R_u's as separate variables being a part of X. The advantage of the first strategy is that fewer replications of BMP are needed and that it seems slightly more logical. However, the posterior probabilities computed in BMP would not be calculated separately for each of the interactions – those would be found for the entire group. One would thus not be able to use Bayesian posterior probabilities in order to conclude whether it is just the Z_k that influences the dependent variable in some, constant overtime, way, or maybe is the influence of the Z_k different in particular subperiods. The second drawing strategy seems better in this respect: posterior probabilities are found for each interaction term separately and it can thus be concluded that, for instance, there is Bayesian confirmation of the influence of Z_k on the dependent variable, but there is no confirmation of such an influence's variability overtime.

The second drawing strategy is thus adopted, that is draw separate variables, interaction terms included, rather than groups. Similarly as in the case of H set, considering a variable with potentially unstable influence on the dependent variable overtime either $S_{Z_k,1}=\{Z_kR_1, Z_kR_2,...,Z_kR_U\}$ or

$S_{Z_k,2}=\{Z_k, Z_kR_1, Z_kR_2,...,Z_kR_{U-1}\}$ can be included in X. However with the second (individual) drawing strategy it is better to include $S_{Z_k,1}$ rather than $S_{Z_k,2}$ in X. The rationale behind that is the following. Suppose $S_{V_c,2}$ is used as a part of X. In the case of a model with all elements of $S_{Z_k,2}$ included, the last subperiod (the one for which no interaction term of Z_k and R_u has been introduced) becomes a reference subperiod. The parameter estimated on Z_k reflects then only the influence of Z_k on the dependent variable in the reference subperiod whereas the parameter on each interaction term of Z_k and a given R_u reflects the difference between the influence of Z_k on the dependent variable in period u and the reference period. However, in an M_j in which the only element included from $S_{Z_k,2}$ is the Z_k itself, the parameter on Z_k reflects its influence on the dependent variable in the entire period covered by the dataset. Thus the economic interpretation of the parameter on Z_k differs in particular models which certainly is the effect one would like avoid. Still this problem does not appear if $S_{Z_k,1}$ is included in X and that is why that solution is applied. As already mentioned, in the case of V_c variables, whether $S_{V_c,1}$ or $S_{V_c,2}$ are used, the above discussed problem does not exist since the whole set H is included in every M_j, thus $S_{V_c,2}$ can also be used should that be more convenient.

5. Data

The research hypotheses are verified for two groups of countries. The first one includes all the 27 EU member states (EU27): Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and UK. For this group of countries the calculations cover the 1993-2010 period. For this group the analysis begins in 1993, not earlier, due to one reason. It is necessary to exclude the period of transformation recession that took place in all the CEE countries at the beginning of the 1990s. During the transformation recession, unlike to the typical capitalist crises, the economies behave very unexpectedly and analyzing macroeconomic relationships for that period does not bring reliable results. Of course, in some CEE countries the recession lasted longer than till 1993; however, it is impossible to cut a lot of years from the analysis because the results would not be representative. The 1993-2010 period is chosen which should be a very good period showing the transition process of the post-communist countries, their accommodation policies aiming at joining the EU, the period of EU accession as well as the first years of the membership in the enlarged EU. The analysis for this group should indicate how did the process of EU27 convergence look like (and notably the convergence of the CEE countries towards the Western Europe) and what were the factors determining economic growth in that period. The stability over time of the analyzed relationships in the enlarged EU is of special interest.

The second group of countries includes only the old 15 EU member states (EU15), which are known as well-developed market economies. For this group of countries, the analysis covers a longer period: 1972-2010 due to the fact that these countries did not suffer the transformation recession at the beginning of the 1990s and in the earlier years they had been developing market economies with all the features typical for capitalist countries. The analysis for this group will show whether there are differences in the process of convergence and the impact of selected variables on the pace of economic growth between the broad group of more

heterogeneous countries including old and new EU members and a more homogenous group of EU15 countries only. The analysis for the latter group will also show whether the end of the socialist area and the accession of the CEE countries to the EU changed the forces driving the economies of Western Europe.

All the calculations are carried out on the two types of panel data: annual time series of the variables involved and figures transformed into three-year subperiods. Each of these methods of data transformation has its own strengths and weaknesses.

The main benefit of including annual panel data is a large number of observations, which increases the statistical significance of the estimated model. However, annual data are biased because they are largely influenced by business cycles and irregular movements; the latter ones being the result of various supply-side and demand-side shocks, both internal and external (the good example is the recent global crisis). For that reason in empirical studies on economic growth the cross-sectional approach is widely used by averaging the time series for the whole period or for several subperiods (encompassing typically 3-, 5-, or 10-year intervals). Such an approach allows the researcher to smooth the time series and analyze the medium-term or long-term relationships between the variables involved, getting rid of the short-term fluctuations. The longer are the subperiods for which the data are averaged, the smoother are the variables and the longer-term relationships between them are evidenced. However, when averaging the data, the number of observations falls dramatically leading to a reduction of statistical significance of the results. Hence, this research incorporates the 3-year time intervals to achieve a reasonable compromise between the statistical and economic significance. In the case of 3-year intervals, the calculations for the EU27 countries are based on the following subperiods: 1993-1995, 1996-1998, 1999-2001, 2002-2004, 2005-2007 and 2008-2010, while those for the EU15 countries include also the subperiods: 1972-1974, 1975-1977, 1978-1980, 1981-1983, 1984-1986, 1987-1989, 1990-1992.

The results for the annual data and 3-year intervals need not be the same. Moreover, they may be entirely different because of the factors mentioned above (annual data and 3-year averaged data document different relationships: short-term and medium-term respectively, so the outcomes may vary). Nevertheless, the

inclusion of both types of data transformation is a kind of a robustness check of the results.

Summing up, the analysis is conducted for the following samples:

- EU27 countries and annual data (1993-2010),
- EU15 countries and annual data (1972-2010),
- EU27 countries and 3-year subperiods (1993-2010),
- EU15 countries and 3-year subperiods (1972-2010).

Since the same methodology and the same explanatory variables are applied to all these four samples, all the results are directly comparable.

For the purpose of the analysis, the following data have been collected. Economic growth is measured by GDP per capita at purchasing power parity (PPP) in constant prices. In the case of annual data, economic growth is calculated as the difference between the natural logarithm of GDP per capita levels in the two consecutive years. In the case of 3-year subperiods, the rate of economic growth is calculated as the difference between the log GDP per capita levels in the final year of a given subperiod and the final year of a previous subperiod, divided by 3 in order to express annual changes. The variable measuring initial income level, which is the key variable from the point of view of convergence, equals – in the case of yearly data – the natural logarithm of GDP per capita at PPP in the preceding year or – in the case of 3-year time intervals – the log GDP per capita at PPP in the final year of the preceding subperiod. This variable is included in each estimated model.

In this study 22 growth factors listed in Table 2 are tested as control variables reflecting the differences in steady states. This group encompasses both 'direct' factors, which have an immediate impact on economic growth from the demand-side and supply-side perspective, as well as 'deep' growth determinants, representing the countries' institutional environment. The selection of control variables is in line with the review of empirical studies: growth factors which are most often used in the studies on convergence are included but, of course, this choice does not include the full list of possible determinants. Special attention is paid to those variables that are related with monetary policy. Namely, five variables regard monetary policy: interest rate (%), inflation (annual %), annual change (in % points) of the domestic credit provided by banking sector in % of GDP, money growth (in constant prices),

and monetization ratio (broad money/GDP). In the case of subperiod data, all the control variables are taken as averages for the respective years included in a given subperiod.

Table 2
The set of explanatory variables

Name	Type*	Description	Source
lngdp0	EI	Lagged log GDP per capita at PPP (2005 constant prices)	PWT 7.0
int_rate	EI	Interest rate (%)	EC, WDI
Inf	EI	Inflation (annual %)	IMF, WDI
cred	EI	Annual change (in % points) of the domestic credit provided by banking sector in % of GDP	WDI
money_gr	EI	Money growth (in constant prices)	EC, WDI
monet	EI	Monetization ratio (broad money/GDP)	EC, WDI
inv	EI	Gross fixed capital formation (% of GDP)	WDI
gov_cons	EI	General government consumption expenditure (% of GDP)	WDI
open	EI	Openness ((exports + imports) / GDP)	WDI
fdi	E	Net FDI inflow (% of GDP)	WDI
school_tot	E	Average years of total schooling (population ages 15+)	BL
school_ter	E	Percentage of population (ages 15+) with completed tertiary education	BL
edu_exp	E	Education expenditure (% of GNI)	WDI
serv	E	Services value added (% of GDP)	WDI
econ_free	P	Index of economic freedom (0-10 scale; 10 = the best outcome)	FI
dem	P	Democracy index: average of civil liberties and political rights (0-1 scale; 1 = the best outcome)	FH
life	X	Log of life expectancy at birth (years)	WDI
fert	X	Log of fertility rate (births per woman)	WDI
pop_15_64	X	Population ages 15-64 (% of total)	WDI
pop_tot	X	Log of population, total	WDI
pop_gr	X	Population growth (annual %)	WDI
pop_den	X	Log of population density (people per sq. km of land area)	WDI
tel	X	Telephone lines (per 100 people)	WDI

*E = endogeneous; X = exogeneous; P = predetermined; I = interaction terms introduced
Source: BL – R.J. Barro, J.-W. Lee, Education Statistics Database, 2012 (http://databank.worldbank .org/); EC – Eurostat, Database, 2012 (http://epp.eurostat.ec.europa.eu); FH – Freedom House, Freedom in the World Database, 2012 (http://www.freedomhouse.org/); FI – Fraser Institute, Economic Freedom of the World Database, 2012 (http://www.freetheworld.com/); IMF – IMF, World Economic Outlook Database, September 2011 (http://www.imf.org/external/pubs/ft/weo /2011/02/weodata/index.aspx); PWT 7.0 – A. Heston, R. Summers, B. Aten, Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, March 2011 (http://pwt.econ.upenn.edu/); WDI – World Bank, World Development Indicators Database, 2012 (http://databank.worldbank.org/).

The variables included into the set of control factors are divided into three subgroups: endogenous, predetermined and strictly exogenous variables, as required for the Blundell and Bond's GMM system estimation. (In the case of OLS

regression, all the variables are assumed to be exogenous; however, Blundell and Bond's GMM system estimator requires that the variables be divided into three mentioned subgroups.) The division is made on the basis of the economic theory, but, to some extent, it reflects our own opinions and there is some room for an arbitrary choice. First of all, all the variables that are associated with monetary and fiscal policies are treated as endogenous. This reflects the fact that they are likely to be mutually correlated with GDP. Economic policy affects of course the rate of economic growth, but on the other hand the actions taken up by the government and the central bank depend on the current rate of economic development. For example a decrease in interest rate accelerates economic growth, but it is also the fast economic growth and inflationary pressure that often lead the central bank to raise interest rates. There is also empirical evidence that government expenditure both determine and are influenced by the level of GDP. Similarly, inflation may be the result of rapid economic growth but also it may be detrimental to further output expansion. Such bilateral relationships occur in the case of most variables related with monetary and fiscal policy and that is why they are assumed to be endogenous.

Further variables treated as endogeneous include all the factors related with components of aggregate demand. For instance the level of investment (in terms of both gross fixed capital formation and foreign direct investment) as well as the openness rate are treated as endogenous since it is believed that rapid economic development enhances to invest (especially by foreign companies, but also by domestic entities) as well as it determines the level of import which is included in the openness ratio. Also the variables related with human capital are classified as endogenous due to the fact that slow economic growth does not allow for rapid accumulation of human capital. If the economy develops slowly, few resources are devoted for human capital accumulation (e.g. there are low expenditures on R&D and education) and that is why it is reasonable to assume that human capital accumulation is an endogenous variable. Finally, the value added in services is assumed to be endogeneous due to the belief that services are the most productive sector and they highly influence the economic growth but it is also the rapid economic growth that is significantly stimulated by the expansion of the service sector in the case of countries under study (EU members).

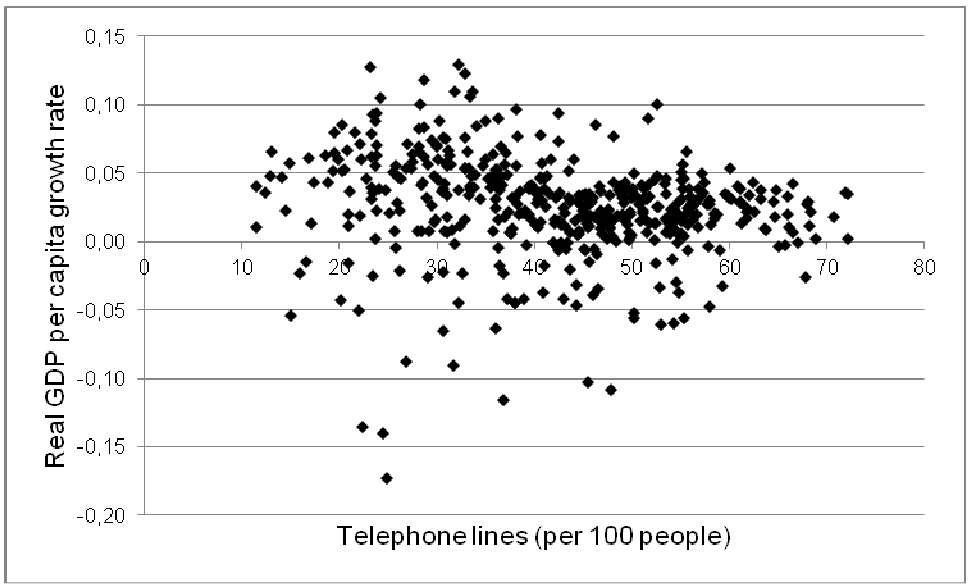
The set of predetermined variables includes two qualitative indices referring to deep economic growth determinants that measure the countries' institutional environment. These include index of economic freedom and democracy index. The main idea of classifying index of economic freedom as predetermined is the fact that it is a qualitative index compiled of a number of category indices many of which represent the country's macroeconomic performance observed in the earlier (not the current) years. Hence, past values of GDP may influence to some extent the current values of this variable, so it is treated as predetermined. The feature of being constructed mostly on the former performance is also shared by the democracy index.

All the remaining variables mainly related with pure demography and health situation are assumed exogeneous since population level, growth and density, as well as the health of the society are not directly determined by the level of GDP (at least in the short run). This group includes the intensity of telephone lines (being a proxy for the quality of infrastructure) which is believed to be determined by world technological progress rather than the level of GDP of a given country except for very long horizon inference. However, this variable is not the best measure of infrastructure development as in the last years we may observe a slight fall in the number of fixed-telephone lines; but this fact concerns only the end of the period, that is very small part of all the observations.

It is necessary to mention once more that the division of the explanatory variables into three categories (endogenous, predetermined and strictly exogenous variables) reflects to some extent an arbitrary choice of the researcher in any study on economic growth determinants. This is because real world is very complex, driven by a lot of mechanisms, and there are deep links between macroeconomic, social, political, and demographical factors. In this analysis, the division of variables into respective categories was based, among others, on the assumption, that if a given variable seems to be more exogenous than another one, it is better to include the former one into the set of exogenous factors while the latter one – into another group (e.g. predetermined or endogenous set) if that variable better fits into such a group. The distribution of the variables on the figure helps to make a decision whether a given variable may be treated as exogenous or not. For example, Figure 1 plots the

scatter diagram between real GDP per capita growth rate (i.e. the explained variable in the untransformed convergence model) and the number of telephone lines which is the explanatory variable treated as exogenous. The figure does not point to any clear-cut strong relationship between the two variables involved, allowing to include telephone lines into the exogenous set of control factors.

Figure 1
Real GDP per capita growth rate vs. telephone lines, EU27 countries and annual data



Source: Own calculations based on: Heston A., Summers R., Aten B., *Penn World Table Version 7.0*, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, March 2011 (http://pwt.econ.upenn.edu/); World Bank, *World Development Indicators Database*, 2012 (http://databank. worldbank.org/).

The chosen set of explanatory variables does not include the full list of possible economic growth determinants. For example, nominal variables representing international links between a given country and the external world, such as exchange rates, are not tested here. The same concerns some other variables related with international trade, e.g. export and import rates, trade balance or current account balance. Those variables are excluded due to several reasons. In the case of exchange rates it would be relatively difficult to find its proper measure that could be included in the regression equation. For example, for some counties the exchange rate against the euro would be better while for some other ones – that against the US dollar. Another cause is related with the fact that many countries under study have a

common currency – the euro. In such a case the variance is zero and the exchange rate loses its power in explaining differences between the rates of economic growth. The possession of euro concerns not only the majority of the EU15 countries but also some EU10 countries.

Variables such as the rate of export, the rate of import, trade balance or current account balance are not tested here due to the following reasons. First, the set of control variables was chosen to be of a reasonable size and thus some variables, especially those that are not directly related with the aim of the research, had to be chosen rationally with avoidance of doubling information. Such decision was made in the case of export and import rates as well as trade and current account balances because of the belief that the openness rate is a better measure of international trade. As the openness rate includes both export and import, the other variables that could be chosen were omitted from the analysis. Second, over a one-year period, one might expect that trade and current account balances both reveal rather a reverse causal relationship with economic growth: it is likely that the growth rate of GDP determines these balances in a given year.

Finally, relatively big number of nominal variables related with monetary policy reflects the aim of the research. As this analysis focuses, *inter alia*, on testing the impact of monetary policy on economic growth, there is a greater number of nominal variables than would be in other typical studies on economic growth determinants.

As it was mentioned earlier, one can doubt whether the influence of all the independent variables on the dependent variable is stable overtime. Most of all, one can doubt whether the rate of conditional convergence is stable overtime in varying macroeconomic conditions and the same refers to the variables closely related with monetary policy. In order to take account of that, variables believed to have an unstable impact on the rate of growth are included in the model with their interactions with time dummies that allow for structural breaks. In such a case it is always an issue when the structural breaks took place, however, in most cases the crucial moments in global economy are likely to be the proper choice.

First of all, the time stability of the convergence parameter is analyzed. That is why the variable measuring the initial GDP per capita level is included with

interactions. Since the initial income level appears in all the estimated models, it is characterized by interactions of the type $S_{V_c,2}$ (the lagged GDP per capita is the only variable included in the *H* set). Second, the interactions are also present in the case of all the variables representing monetary and fiscal policy because the impact of economic policy on GDP dynamics is likely to vary over time. It depends on many factors, including the internal and external sources, and it might be different between the 1970s, 1980s, 1990s, and 2000s. The economic and political situation in the world is changing continuously and there are no reasons to believe that the impact of economic policy on GDP growth is constant. For example, during the contractionary periods fiscal and monetary tightening could have completely different effects as compared with the expansionary periods. That is why structural breaks are introduced for all these variables. Finally, interactions are also present in the case of the investment rate and the openness ratio to check whether they exhibited varying impact on the rate of economic growth. All the explanatory variables except lagged GDP for which varying impact on economic growth is assumed are included into the model with the $S_{Z_k,1}$ type of interactions.

Before carrying out the analysis, the crucial years for the structural breaks have to be introduced. When introducing structural breaks for the 1993-2010 period, an important assumption has been made. Namely, structural breaks are assumed to be the same for the whole analyzed sample: they do not differ between the EU15 countries and the CEE10 economies. This reflects the fact that the whole group under study is treated in this research as a relatively homogenous one, with similar forces driving their economies, vulnerable to the same worldwide shocks both from the demand-side and supply-side perspective. Since the countries in the enlarged European Union are strongly integrated, due to – among others – high flows of people and factors of production inside the EU as well as strong political and economic cooperation, it is possible to assume that structural breaks might be the same for at least the majority of them. Another aspect is the fact that allowing structural breaks to vary, it is necessary to make some other assumptions regarding the deepness of the division of the countries into subgroups. Structural breaks could be assumed to be different for EU15 and CEE10 groups; for the countries that have the euro and those who do not; but also structural breaks could be assumed to be the

same for the countries that have strong historical links due to, i.a., geographical location regardless of whether they adopted euro or not (e.g. Estonia, Latvia and Lithuania; Portugal and Spain; or the Scandinavian countries) while different between these subgroups. Hence, in this analysis it is assumed that structural breaks are constant in the whole analyzed sample of countries. Another aspect – but of minor importance – is the fact that introducing different structural breaks for various countries would increase the complexity of the model; this could be done in a separate, new analysis treated as the extension to this study.

In the case of EU27 countries, two structural breaks in 1998 and 2004 respectively are tested in this study. The first one is related with the date of the Russian crisis (being also an approximate half-life between the end of transformation recession in most of the CEE countries and the year of the EU enlargement for the CEE area). This could show whether the impact of particular variables changed between the period that was much more affected by the transformation from a centrally-planned to market-based system (i.e. the years 1993-1998) and the period that was rather influenced by preparations to EU enlargement (1999-2004). In the early years of transition, economic growth paths of the CEE countries were less influenced by the EU policies, encompassing EU structural and aid funds. Moreover, the Russian crisis, when GDP in Russia fell by more than 5% in 1998, might affect many of the countries under study because of their very strong links with Russia. An additional argument for choosing the year 1998 as the structural break is the fact that on January 1st, 1999 the euro was introduced to non-cash transactions in 11 Western European countries (except Greece). Since separate structural breaks for different groups of countries are not included, the year 1998 has the theoretical background for being valid for both groups of countries (Central and Eastern Europe as well as Western Europe).

The choice of 2004 as the second structural break is obviously the moment of EU biggest enlargement to include the Central and Eastern European countries. One may believe that the EU enlargement could significantly affect the relationships between the macroeconomic variables of the EU countries. The structural break in 2004 concerns the whole analyzed sample of countries because EU enlargement was important not only for new EU entrants but also for old EU members. Labor and

capital movements, EU structural and aid funds, and international trade directions all changed or could change significantly after 2004 implying that EU enlargement influenced significantly the macroeconomic situation in the whole Europe.

In the case of EU15 countries, the third structural break is introduced in 1989 which results from the fact that it is considered as the end of the socialist era in most of the transition countries. In 1989, market economies emerged in Central and Eastern Europe and there are reasonable expectations that the mechanisms driven the development of EU15 countries could change significantly in that year.

Another reason for the selection of structural breaks refers to the preliminary assessment of statistical data. According to the initial pre-screening of some time series taken from the IMF database, like the dynamics of world output and world exports, as well as due to economic reasons, one may expect the existence of structural breaks in the years 1989, 1998, and 2004. For example, the selection of the year 1989 may be explained referring to the fact that the world economy was growing quite rapidly in the second half of the 1980s with average GDP growth rates being equal to 3.5-4.5% per annum during 1985-1989 (IMF, 2012). However, the year 1989 was the last year of quite a rapid economic growth. Then, the world economy slowed down to 3.3% in 1990 and 2.2% per annum during 1991-1993. As the EU countries are developed market economies with strong international links relating to the flows of goods, services, labor and capital, their economies largely depend on the growth tendencies observed in the world economy. Hence, the structural break was likely to take place in 1989 when the growth path of the world economy changed from moderate economic growth in the second part of the 1980s to slow economic growth in the first part of the 1990s. This – along with the fall of socialism – could change significantly the mechanisms of economic growth in Western European countries. That is why the year 1989 was chosen as the structural break.

In a similar way, it is possible to explain the choice of the second structural break: the year 1998. In that single year, due to the Russian crisis, the world economy slowed down to 2.6% while in the years before, i.e. during 1994-1997, global GDP was growing at moderate rates of 3.3-4.1% per annum. The 1998 structural breaks are seen not only in the case of global economic growth but also in

the case of some other variables, e.g. the dynamics of exports or – broader – the dynamics of international trade. Namely, during 1998-1999, the world economy noticed a large negative shock in the development of international trade. For example, trade volume of goods and services was growing at the rate of 7.0-10.3% per annum during 1994-1997 and then significantly slowed down to 4.9% in 1998 and 5.6% in 1999. The dynamics of world exports also decelerated from 6.7-10.8% during 1994-1997 to 4.9% in 1998 and 5.1% in 1999. The countries of the enlarged EU, notably the CEE countries, are largely dependent on international trade and FDI inflows and these changes in development tendencies of world output and world exports could affect those countries considerably.

The year 2004, that is the year of EU enlargement, also affected significantly the development paths of EU countries. For example, in terms of output growth and the growth of exports, the year 2004 turned out to be a local maximum. According to the aggregated data on output growth for the whole European Union, GDP growth rate achieved its local maximum value of 2.6% in 2004; in the two years before, economic growth rates were equal to 1.4% and 1.6% respectively while in 2005 – 2.3%. Similarly, the aggregated dynamics of exports of goods and services in the euro area amounted to 7.9% in 2004, being much higher than in the years before (2.7% in 2002 and 1.7% in 2003) and in the year after (5.3% in 2005) (IMF, 2012).

All these factors are additional arguments for the choice of the years 1989, 1998 and 2004 as structural breaks. Of course, the main argument of choosing a given year for the structural break should be based on economic reasons. That is why these initial pre-screenings of data are rather treated as complementary arguments to those described in the narrative way.

In this study we understand 'identifying possible structural breaks' more as 'statistically checking whether the potential structural breaks suggested by global macroeconomic situation in economies of interest and certain descriptive statistics in some of the core macroeconomic time series' as described above. Basing on this, we concluded whether the data do confirm suspicions in this field. It might though seem tempting to try to catch the potential structural breaks with the use of pure statistical analysis. We do not apply this method for two reasons.

Firstly, there always exists a risk of discovering a 'relationship' which indeed is spurious, even if the properties of time series of interest are of the statistically best quality. That suggests that if such a purely statistical approach can be at least partly replaced with economic rationale – we believe that to be the correct way of proceeding. It must be emphasized again that the core of this paper is to identify possible growth factors among the economically reasonable ones: one could mention many of them, but there is no single theorem that would point out one, doubtlessly relevant set of growth factors. Thus we use economic rationale to preselect variables (conditional on data availability) and at that stage – purely statistical approach to select out of those the relevant ones, thus using as much as possible of the theoretic approach and replace it with statistical empirics ones it becomes essential. We believe that in the case of selecting possible structural breaks the economic rationale supported by weak suggestions from the above mentioned time series is good enough.

Secondly, purely statistical approach is infeasible here. We might try to catch the structural breaks by for example using the very same method as for identifying relevant growth factors, namely using BMP. In this case that would imply dividing the considered time series into subperiods in random way and testing for adequacy of a given way of dividing them. This could be done by introducing interaction terms not for a priori assumed subperiods, but for an assumed number of randomly created subperiods: in this case the randomness would refer to drawing some moments of structural breaks. Nevertheless, there are numerous ways those can be drawn and all the possibilities (or at least a high number of them) would need to be checked, whereas in the second stage BMP for particular variables would need to applied in each case. That means running the estimation procedure described in this paper as many times as the number of drawn combinations of structural breaks is. Even estimating the models described in this paper lasts a few weeks (the problem of highly time consuming GMM estimations carried out thousands times). Imposing additionally the process of drawing the structural breaks would make the estimation last most likely a few years given the technical possibilities of even high quality computers. We thus limit our attention to the feasible approach presented here.

The structural breaks for the EU15 countries for the before-1989 period are not introduced because of the belief that the number of structural breaks should not be very large as well as due to the fact that the years 1972-1989 are not so important in meeting the aims of the analysis and verifying the research hypotheses. The newest period encompassing the years 1990s and 2000s is of greater importance. Moreover, additional structural breaks during 1970s or 1980s would be also the result of some arbitrary choice. There are several points in time at which structural breaks could exist while the research method does not allow to introduce all of them because there should be a sufficiently large subperiod between the consecutive structural breaks. That is why the before-1989 period is not divided into shorter subperiods.

Since the considered time series are available till 2010, it is tempting to allow for an additional structural break in 2008 standing for the beginning of the global economic and financial crisis. However, that would make the time spans between particular structural breaks very short and cover so few observations that the results would be based on the models with the number of degrees of freedom close to zero and thus unreliable. Nevertheless, from the macroeconomic point of view the 2008 structural break should definitely be considered, hence the proper analysis should be done as soon as sufficient number of observations makes it feasible and sensible which requires probably about 3 to 5 years. Thus the last subperiod of 2005-2010 includes both the pre-crisis and post-crisis years and the results for that span should be viewed as averaged for both positive and negative situation in the market that could be observed in those years.

Summing up, in the case of EU27 countries the time intervals between turning points are the following: 1993-1998, 1999-2004, and 2005-2010, while in the case of EU15 countries they are: 1972-1989, 1990-1998, 1999-2004, and 2005-2010.

The study is based on a 'partly balanced' panel. This means that if a given observation is included, there are no missing values of any of the explanatory variables from the H and X sets for that observation: a property required for (3.4) and (3.9) to hold. However, the panel is not fully balanced because for some countries there are no observations for all the years covered by the sample: about 15% country-year observations are missing.

6. Empirical results

Relatively high number of considered growth factors enforced estimation of only some, randomly selected models (based on randomly selected subsets of explanatory variables). For each of the groups: EU27 and EU15 half a million models have been estimated, however, none of the parameter estimates was changing significantly anymore while further models were drawn and estimated.

The results of the analysis are illustrated in Tables 3-7. Following the results that regard the variables in the case of each interaction terms with time dummies have been included in the model, the reference period is the 2005-2010 subperiod. In the regression models the explained variable was the level of GDP per capita and not the growth rate. That is why the estimated coefficients on lagged GDP shown in Tables 3-6 are not the typical convergence coefficients. Table 7 presents the direct results of the convergence analysis, that is the computed rates of convergence and half-times. All the above results were computed under the assumption that $\bar{k}$, the number of variables from the *X* set in the 'true' model, is about 25% of total *K*. This gives $\bar{k}$ equal to 10 for the EU15 and 12 for the EU27 group. Since it is difficult to provide sensible explanation of the given $\bar{k}$ selection (unless there is clear mainstream in the literature, which is not the case here), a robustness check parallel analysis for different $\bar{k}$'s was carried out. That brings no notable differences in the conclusions, thus only the results for the above mentioned $\bar{k}$ are described in the report.

The presentation and interpretation of the results starts with the analysis based on the annual data as reported in Tables 3 and 4. Then, the results for the models estimated using 3-year subperiods are discussed and given in Tables 5 and 6.

Table 3
Estimation results for the EU27 countries, annual data

Regressor	Period / subperiod	Estimate	Standard deviation	Pseudo t statistics
lngdp0	2005-2010	0.94869697	0.00609974	155.53
	Difference between 1993-1998 and 2005-2010	0.00080219	0.00058218	1.38
	Difference between 1999-2004 and 2005-2010	0.00258925	0.00039941	6.48
int_rate	1993-1998	–0.00000009	0.00000001	–5.96
	1999-2004	–0.00002427	0.00001932	–1.26
	2005-2010	0.00007299	0.00004210	1.73

inf	1993-1998	–0.00000003	0.00000001	–5.47
	1999-2004	–0.00000024	0.00000017	–1.43
	2005-2010	0.00000001	0.00000000	8.78
cred	1993-1998	0.00003754	0.00000950	3.95
	1999-2004	0.00000542	0.00000673	0.80
	2005-2010	–0.00000003	0.00000001	–3.84
money_gr	1993-1998	0.00072031	0.00011261	6.40
	1999-2004	0.00000103	0.00000141	0.73
	2005-2010	0.00322305	0.00025384	12.70
monet	1993-1998	0.00000050	0.00000029	1.70
	1999-2004	–0.00000023	0.00000015	–1.51
	2005-2010	0.00000016	0.00000005	3.01
inv	1993-1998	0.00004685	0.00001892	2.48
	1999-2004	0.00000180	0.00000104	1.73
	2005-2010	–0.00000000	0.00000000	–4.67
gov_cons	1993-1998	0.00000149	0.00000301	0.50
	1999-2004	–0.00000314	0.00000258	–1.21
	2005-2010	–0.00000000	0.00000000	–6.24
open	1993-1998	0.00002990	0.00001677	1.78
	1999-2004	–0.00000000	0.00000000	–2.08
	2005-2010	0.00002058	0.00000294	7.01
fdi	The whole period 1993-2010	0.00000000	0.00000000	4.50
school_tot	The whole period 1993-2010	0.00000000	0.00000000	3.48
school_ter	The whole period 1993-2010	–0.00000000	0.00000000	–2.86
edu_exp	The whole period 1993-2010	0.00000049	0.00000024	2.06
serv	The whole period 1993-2010	–0.00000000	0.00000000	–1.53
econ_free	The whole period 1993-2010	0.00000000	0.00000000	7.82
dem	The whole period 1993-2010	–0.00000000	0.00000001	–0.20
life	The whole period 1993-2010	–0.00051825	0.00285562	–0.18
fert	The whole period 1993-2010	–0.00189187	0.00057620	–3.28
pop_15_64	The whole period 1993-2010	0.00023486	0.00019188	1.22
pop_tot	The whole period 1993-2010	–0.00216847	0.00054220	–4.00
pop_gr	The whole period 1993-2010	–0.00012959	0.00029212	–0.44
pop_den	The whole period 1993-2010	–0.00025675	0.00011220	–2.29
tel	The whole period 1993-2010	0.00001986	0.00000518	3.84

Note: If 0.00000000 or –0.00000000 appears, it means that the absolute value of the estimate (or standard deviation) is lower than 0.000000005.

Source: Own calculations.

Table 4
Estimation results for the EU15 countries, annual data

Regressor	Period / subperiod	Estimate	Standard deviation	Pseudo t statistics
lngdp0	2005-2010	0.96761658	0.01128426	85.75
	Difference between 1972-1989 and 2005-2010	0.00253899	0.00069719	3.64
	Difference between 1990-1998 and 2005-2010	0.00423123	0.00091735	4.61
	Difference between 1999-2004 and 2005-2010	0.00278702	0.00088374	3.15
int_rate	1972-1989	–0.00000318	0.00000095	–3.34
	1990-1998	–0.00061155	0.00012599	–4.85
	1999-2004	0.00139167	0.00049918	2.79
	2005-2010	0.00002137	0.00011565	0.18

inf	1972-1989	–0.00002917	0.00000384	–7.59
	1990-1998	–0.00113149	0.00020877	–5.42
	1999-2004	0.00001605	0.00001911	0.84
	2005-2010	0.00123344	0.00009851	12.52
cred	1972-1989	0.00000172	0.00000095	1.81
	1990-1998	0.00000383	0.00000200	1.92
	1999-2004	0.00001447	0.00001072	1.35
	2005-2010	0.00000338	0.00000223	1.51
money_gr	1972-1989	0.00042369	0.00007428	5.70
	1990-1998	0.00063097	0.00011678	5.40
	1999-2004	0.00001977	0.00001438	1.37
	2005-2010	0.00062360	0.00009832	6.34
monet	1972-1989	0.00000328	0.00000124	2.65
	1990-1998	0.00000456	0.00000628	0.73
	1999-2004	–0.00000148	0.00000036	–4.17
	2005-2010	0.00005371	0.00001108	4.85
inv	1972-1989	0.00000000	0.00000000	4.32
	1990-1998	0.00001091	0.00004161	0.26
	1999-2004	0.00019630	0.00006515	3.01
	2005-2010	0.00000080	0.00000019	4.22
gov_cons	1972-1989	–0.00010647	0.00001477	–7.21
	1990-1998	–0.00101141	0.00012283	–8.23
	1999-2004	–0.00027304	0.00007318	–3.73
	2005-2010	–0.00000014	0.00000003	–5.57
open	1972-1989	–0.00000036	0.00000013	–2.85
	1990-1998	0.00011976	0.00001694	7.07
	1999-2004	–0.00000839	0.00000384	–2.19
	2005-2010	0.00010404	0.00000898	11.59
fdi	The whole period 1972-2010	0.00000000	0.00000000	2.37
school_tot	The whole period 1972-2010	0.00000000	0.00000000	1.07
school_ter	The whole period 1972-2010	–0.00000000	0.00000000	–0.93
edu_exp	The whole period 1972-2010	–0.00000023	0.00000004	–5.90
serv	The whole period 1972-2010	–0.00000000	0.00000000	–8.25
econ_free	The whole period 1972-2010	0.00000000	0.00000000	10.23
dem	The whole period 1972-2010	0.00000000	0.00000000	1.37
life	The whole period 1972-2010	0.00628078	0.03040007	0.21
fert	The whole period 1972-2010	–0.00219297	0.00100408	–2.18
pop_15_64	The whole period 1972-2010	0.00010911	0.00002762	3.95
pop_tot	The whole period 1972-2010	–0.00184465	0.00025471	–7.24
pop_gr	The whole period 1972-2010	–0.00000548	0.00019350	–0.03
pop_den	The whole period 1972-2010	–0.00020637	0.00016513	–1.25
Regressor	Period / subperiod	Estimate	Standard deviation	Pseudo t statistics
tel	The whole period 1972-2010	0.00028841	0.00004509	6.40

Note: If 0.00000000 or –0.00000000 appears, it means that the absolute value of the estimate (or standard deviation) is lower than 0.000000005.

Source: Own calculations.

Table 5
Estimation results for the EU27 countries, 3-year intervals

Regressor	Period / subperiod	Estimate	Standard deviation	Pseudo t statistics
lngdp0	2005-2010	0.8411676	0.0280225	30.02
	Difference between 1993-1998 and 2005-2010	–0.0036748	0.0025602	–1.44
	Difference between 1999-2004 and 2005-2010	0.0014898	0.0019353	0.77
int_rate	1993-1998	–0.0048074	0.0012922	–3.72
	1999-2004	–0.0039319	0.0029438	–1.34
	2005-2010	–0.0333684	0.0112508	–2.97
inf	1993-1998	–0.0014109	0.0004908	–2.87
	1999-2004	–0.0041562	0.0025144	–1.65
	2005-2010	–0.0125343	0.0089374	–1.40
cred	1993-1998	0.0105771	0.0044438	2.38
	1999-2004	0.0110072	0.0039406	2.79
	2005-2010	0.0142319	0.0021619	6.58
money_gr	1993-1998	0.0109234	0.0041306	2.64
	1999-2004	0.0011154	0.0014136	0.79
	2005-2010	0.0142684	0.0010678	13.36
monet	1993-1998	0.0008914	0.0006582	1.35
	1999-2004	–0.0000694	0.0001747	–0.40
	2005-2010	0.0005567	0.0001411	3.95
inv	1993-1998	0.0035771	0.0032861	1.09
	1999-2004	–0.0015012	0.0032736	–0.46
	2005-2010	0.0216083	0.0046485	4.65
gov_cons	1993-1998	–0.0035088	0.0050381	–0.70
	1999-2004	–0.0001393	0.0034297	–0.04
	2005-2010	–0.0139464	0.0040355	–3.46
open	1993-1998	0.0001742	0.0004444	0.39
	1999-2004	–0.0000069	0.0002742	–0.03
	2005-2010	0.0007084	0.0002318	3.06
fdi	The whole period 1993-2010	0.0011645	0.0002409	4.83
school_tot	The whole period 1993-2010	–0.0277656	0.0176972	–1.57
school_ter	The whole period 1993-2010	–0.0010020	0.0033095	–0.30
edu_exp	The whole period 1993-2010	0.0484915	0.0156463	3.10
serv	The whole period 1993-2010	–0.0031216	0.0024013	–1.30
econ_free	The whole period 1993-2010	0.0107829	0.0014874	7.25
dem	The whole period 1993-2010	0.0552237	0.0172573	3.20
life	The whole period 1993-2010	1.7254940	0.6017617	2.87
fert	The whole period 1993-2010	–0.1513745	0.1044685	–1.45
pop_15_64	The whole period 1993-2010	–0.0021997	0.0059631	–0.37
pop_tot	The whole period 1993-2010	0.0089047	0.0168049	0.53
pop_gr	The whole period 1993-2010	0.1234318	0.0268021	4.61
pop_den	The whole period 1993-2010	0.0102475	0.0264350	0.39
tel	The whole period 1993-2010	0.0083239	0.0012950	6.43

Source: Own calculations.

Table 6
Estimation results for the EU15 countries, 3-year intervals

Regressor	Period / subperiod	Estimate	Standard deviation	Pseudo t statistics
lngdp0	2005-2010	0.8996424	0.0365547	24.61
	Difference between 1972-1989 and 2005-2010	0.0051169	0.0038058	1.34
	Difference between 1990-1998 and 2005-2010	0.0064526	0.0035283	1.83
	Difference between 1999-2004 and 2005-2010	0.0048682	0.0033670	1.45
int_rate	1972-1989	–0.0026148	0.0029940	–0.87
	1990-1998	–0.0112211	0.0030022	–3.74
	1999-2004	0.0300408	0.0119509	2.51
	2005-2010	–0.0059003	0.0132251	–0.45
inf	1972-1989	–0.0061756	0.0017521	–3.52
	1990-1998	–0.0191578	0.0047512	–4.03
	1999-2004	0.0243921	0.0129845	1.88
	2005-2010	0.0748554	0.0130343	5.74
cred	1972-1989	0.0010168	0.0011265	0.90
	1990-1998	–0.0000020	0.0017435	–0.00
	1999-2004	0.0033409	0.0017404	1.92
	2005-2010	0.0059634	0.0016319	3.65
money_gr	1972-1989	0.0034427	0.0012561	2.74
	1990-1998	0.0051629	0.0013713	3.76
	1999-2004	0.0041284	0.0020908	1.97
	2005-2010	0.0098519	0.0011610	8.49
monet	1972-1989	0.0007869	0.0006804	1.16
	1990-1998	0.0007538	0.0005724	1.32
	1999-2004	–0.0002328	0.0001316	–1.77
	2005-2010	0.0001303	0.0001121	1.16
inv	1972-1989	0.0009981	0.0031497	0.32
	1990-1998	–0.0060716	0.0030746	–1.97
	1999-2004	0.0027365	0.0034844	0.79
	2005-2010	0.0176284	0.0036823	4.79
gov_cons	1972-1989	–0.0053973	0.0025150	–2.15
	1990-1998	–0.0098676	0.0030743	–3.21
	1999-2004	–0.0043566	0.0028591	–1.52
	2005-2010	–0.0065335	0.0029251	–2.23
open	1972-1989	–0.0006247	0.0003043	–2.05
	1990-1998	0.0006067	0.0002911	2.08
	1999-2004	0.0002213	0.0002441	0.91
	2005-2010	0.0003637	0.0002153	1.69
fdi	The whole period 1972-2010	0.0005972	0.0001828	3.27
school_tot	The whole period 1972-2010	0.0051499	0.0067225	0.77
school_ter	The whole period 1972-2010	0.0029660	0.0020665	1.44
edu_exp	The whole period 1972-2010	–0.0133161	0.0068220	–1.95
serv	The whole period 1972-2010	–0.0045377	0.0021866	–2.08
econ_free	The whole period 1972-2010	0.0653805	0.0124757	5.24
dem	The whole period 1972-2010	–0.1954462	0.1276077	–1.53
life	The whole period 1972-2010	0.1404357	0.0540191	2.60
fert	The whole period 1972-2010	–0.0830319	0.0459849	–1.81
pop_15_64	The whole period 1972-2010	0.0138916	0.0041998	3.31
pop_tot	The whole period 1972-2010	–0.0494132	0.0116641	–4.24
pop_gr	The whole period 1972-2010	0.0303991	0.0145875	2.08
pop_den	The whole period 1972-2010	–0.0032993	0.0129152	–0.26

Regressor	Period / subperiod	Estimate	Standard deviation	Pseudo t statistics
tel	The whole period 1972-2010	0.0042178	0.0007861	5.37

Source: Own calculations.

Table 7
The results of β convergence

Subperiod	The hypothetical coefficient on initial income in the normalized convergence model[a]	The coefficient β	The number of years needed for the countries to reduce by half the distance towards the steady state (half-life)
EU27 countries, annual data			
1993-1998	–0.05050084	5.18%	13.4
1999-2004	–0.04871378	4.99%	13.9
2005-2010	–0.05130303	5.27%	13.2
EU15 countries, annual data			
1972-1989	–0.02984443	3.03%	22.9
1990-1998	–0.02815219	2.86%	24.3
1999-2004	–0.02959640	3.00%	23.1
2005-2010	–0.03238342	3.29%	21.1
EU27 countries, 3-year intervals			
1993-1998	–0.1625072	5.91%	11.7
1999-2004	–0.1573426	5.71%	12.1
2005-2010	–0.1588324	5.77%	12.0
EU15 countries, 3-year intervals			
1972-1989	–0.09524066	3.34%	20.8
1990-1998	–0.09390496	3.29%	21.1
1999-2004	–0.09548936	3.35%	20.7
2005-2010	–0.10035756	3.53%	19.7

[a] The normalized (untransformed) convergence model assumes that the GDP per capita growth rate is the explained variable.

Source: Own calculations.

6.1. Results of the convergence analysis – annual data

The first part of the discussion concerns the results obtained for the EU27 group. Among those countries the estimate of the parameter on the one year lagged GDP level in the 2005-2010 period equals 0.948697. In order to get the 'typical' convergence parameter (β_1 in the (4.1) equation) this must be subtracted from 1 yielding –0.051303, which – as suggested by the pseudo *t* statistics – confirms the existence of statistically significant β-convergence among the EU27 countries

during the 2005-2010 period at any reasonable significance level. Of course, the convergence is conditional on the growth factors included in the analysis and the countries might not tend to one common hypothetical steady-state, but to different steady-states determined by the explanatory variables included in the regression equations. Applying formula (2.6) gives the estimated rate of convergence for the years 2005-2010 equal to 5.27%. However, as it was mentioned in the previous section, this could have differed through this period in result of highly changing world economic situation in this period and should be understood as just an average.

In order to attain the estimated convergence coefficient in the untransformed model for the 1993-1998 subperiod, it is necessary to add the estimate of the respective interaction term parameter to the above, yielding [0.948697 – 1] + 0.000802 = –0.050501. Using (2.6) this stands for the 5.18% rate of annual convergence at that time, which could suggest that during the years 1993-1998 the convergence process occurred slower than the average in the years 2005-2010, however using pseudo *t* for the interaction of lagged GDP with the first subperiod dummy clearly shows that in this respect the difference between 1993-1998 and 2005-2010 is actually not statistically significant. Similar calculation is performed in order to obtain the estimate of the rate of convergence for the 1999-2004 subperiod, yielding coefficient standing on lagged GDP equal to –0.048714 and the rate itself being 4.99%. This parameter is less than 5.18% (for the 1993-1998 period) and further less than 5.27% (for the 2005-2010 period), indicating slower β-convergence process and in this case the difference from the reference period is statistically significant. Given the value of the β-convergence parameter, it is possible to estimate the number of years needed for the countries to reduce by half their distance towards the steady state (assuming that steady-states differ only in terms of the control variables considered in the analysis), which equals 13.4, 13.9 and 13.2 years in subsequent subperiods. Thus regardless of the subperiod, a 50-percent reduction of the distance towards the steady-state requires about 13-14 years.

High convergence rates seem to be caused by huge differences in marginal products of the inputs in the countries under study. The countries that are poorer record much higher factor productivity and achieve more rapid economic growth (in conditional terms) than the richer ones. However, this also means that gains from

being poorer may be exhausted quite soon and increasing GDP due to the pure convergence process is limited as according to the obtained results: higher output negatively affects GDP dynamics in the next year.

The results differ significantly when only the group of EU15 is considered. For the reference 2005-2010 subperiod, the estimated coefficient on lagged GDP computed in the same way as for the EU27 equals –0.032383 and is statistically significantly negative, which again confirms the existence of the conditional convergence among the EU15 countries during 2005-2010. The estimated average convergence rate for this subperiod equals 3.29%, according to which the estimated catching-up process of the Western European countries is considerably slower than that observed in the entire enlarged European Union. Similarly, considering the estimated parameters on the interaction terms and using (2.6) allows to conclude that the estimated rate of convergence in EU15 accounted to 3.03% in 1972-1989, 2.86% in 1990-1998 and 3.00% in 1999-2004. Although each of the respective interaction terms is statistically significantly different from zero, which suggests that the convergence rate has not been the same throughout the considered period in this group, the maximum differences hardly exceed 0.3 percentage points per annum, which makes them negligible from the economic point of view – this is also reflected in the estimated half times required to equalize the level of GDP. In the years 1972-1989 estimated half-life equals 22.9 years, in 1990-1998 – 24.3 years, in 1999-2004 – 23.1 years, and in 2005-2010 – 21.1 years.

One drawback of this part of the analysis is that it does not reveal long-term relationships: it is just the *yearly* panel data and a one year lag of GDP that are used in the model and not 3- or 5-year long subperiods data that would improve on this problem. This however is to big extent enforced by the nature of the problem. The risk of instability of the growth process overtime requires the analysis based on time series or panel data as opposite to for instance SDM research based on cross-sectional data. On the one hand the series used cannot cover an excessive period of time due to both lack of trustworthy macroeconomic data and highly different nature of growth processes in the old times, especially in the case of CEE countries. On the other hand, following the typical strategy of basing the analysis on the observations of 3 to 5 years each (instead of annual ones) would make the number of observations

too low to draw trustworthy conclusions, mostly regarding the stability issue. It is certainly very difficult to find a compromise between the long term nature of the process of growth on the one hand and the need for sufficient number of observations in the not-too-long series on the other hand and should be considered while interpreting the above results. The robustness check to these yearly panel data will appear later in the report as a similar analysis is conducted based on 3-year intervals.

6.2. Results of the economic growth determinants analysis – annual data

The report does not present here all the results on economic growth determinants because it focuses on those variables which are related with monetary policy. However, some other variables yield interesting implications and thus the most important results considering those other variables are mentioned here as well, supplemented by some comments and opinions. The core results for the EU27 are presented first and they are followed by the discussion of the EU15 estimation main figures and conclusions.

The impact of the interest rate on economic growth turned out to be quite varying over time. For the EU27 countries in the first two analyzed subperiods, a negative relationship between interest rate and economic growth could be observed, but during 2005-2010 the estimated coefficient on the interest rate was positive. For the years 1993-2004 this is in line with the economic theory and the basic macroeconomic models. As the investment function suggests, high interest rate negatively affects investment, decelerating the pace of economic growth. In the last analyzed subperiod, the opposite situation occurred however. This positive relationship between interest rate and economic growth might be somewhat related with the global economic and financial crisis and very disturbing situation observed in the analyzed countries in the last years. Interest rates were very low recently. Central banks were decreasing interest rates to boost the economy. However, these actions did not succeed in many cases and despite a fall in interest rates the rate of economic growth did not accelerate. This finding has some policy implications. Generally, it is not true that there is unambiguous negative relationship between

interest rate and economic growth in the case of world economies. That is why the monetary policy aiming at a permanent cut of interest rates is not always the best policy option. In some circumstances, low interest rate may not guarantee rapid economic growth. That is why policy makers should be very careful in deciding whether to raise or cut interest rates.

The results obtained for the EU27 do not unambiguously confirm negative impact of inflation on economic growth. In most years this impact was negative but the results of the study also suggests that there have been years when it was positive. Trying to explain these differences one should notice that many of the CEE countries in the 1990s, i.e. just after the transformation recession, noted high inflation rates. Such a high inflation is obviously an obstacle in achieving rapid economic growth. In the last subperiod, however, inflation rates among the EU members have been low (two-digit inflations occurred extremely rarely while some countries in these years even faced deflation). In such circumstances, low inflation (or even deflation) need not be a factor conducive to rapid economic growth and that is why a positive sign of the parameter has been obtained. This outcome is of course related with the global crisis which had demand-side rather than supply-side origins, being accompanied by low inflation. Like in case of the interest rate, this study shows that inflation exerts a differentiated impact on economic growth: high inflation is undoubtedly an obstacle to GDP growth, but excessively low inflation or deflation do not stimulate GDP either. This result has also policy implications as it shows that central banks should not set inflation target as low as possible, regardless of the macroeconomic performance of a given country; sometimes it is better to set a targeted inflation rate a little bit higher and to allow for some price increase because it will be conducive to economic development.

The variable related with financial sector development, that is the annual change of the domestic credit, clearly shows how dangerous the excessive lending in the last years was. During 1993-1998, far before the global crisis when public indebtedness was not extremely high, the estimated coefficient on this variable turned out to be positive and statistically significantly different from zero. This relationship is in line with the theoretical structural model suggesting that financial sector development is conducive to economic growth. However, recently the level of both private and

especially public indebtedness of many EU countries has been enormous. Many countries suffer from high cost of repaying loans and such a level of debt hampers the growth of GDP which is confirmed by this study. While in 1993-1998 credit expansion significantly contributed to GDP, the results obtained for the next analyzed subperiod do not suggest any statistically significant relationship between these variables although the sign of the estimated parameter is positive. Moreover, during 2005-2010, i.e. in the period that includes the global crisis, the relationship between credit growth and economic growth turned out to be negative and statistically significant. This outcome demonstrates that credit growth needn't be conducive to rapid economic development and the good example are the Baltic states. These countries' growth of GDP was mainly based on credit and partly because of this the Baltics suffered the biggest recession in 2009; some of these countries noted also the fall of GDP in 2008 and/or 2010. This result yields also policy implications. Namely, it is sometimes necessary for the authorities (both the central bank as well as the other institutions responsible for the financial sector regulation, such as Komisja Nadzoru Finansowego in Poland) to restrict credit growth, e.g. by tightening the administrative rules of borrowing and/or raising interest rates.

The two variables that represent the growth of and the stock of money supply do not reveal a stable impact on economic growth either. In the case of EU27 countries, the real money growth shows a positive and statistically significantly different than zero relationship with economic growth for the years 1993-1998 and 2005-2010; for the middle subperiod of 1999-2004, no clear-cut relationship between these variables has been evidenced: although the sign of the averaged coefficient is positive it is statistically not different from zero assuming reasonable significance levels. The results for the monetization ratio are quite similar. In the last distinguished subperiod, this variable is positively and statistically significantly related with economic growth; in the years 1999-2004, the monetization ratio reveals an unexpected negative impact on economic growth (although statistically insignificant); in the 1993-1998 period, the money supply-GDP ratio shows a positive influence on GDP dynamics but statistically insignificant. These results indicate that the EU27 countries do not show a stable relationship between the

monetary aggregates and economic growth. In some periods an increase in money supply was conducive to output expansion; in the other years, however, high money supply did not lead to rapid economic growth.

The last outcome is another demonstration that the variables reflecting monetary policy do not reveal an unambiguous impact on economic growth. In some years, the positive relationship has been evidenced, in some other years – a negative one.

The results do not indicate a clear-cut positive impact of investment on economic growth. On the one hand, positive and statistically significant relationship was noted in the years 1993-1998 but on the other hand in the last distinguished subperiod the negative impact was evidenced.

The outcomes show some counterproductive effects of the government expenditure policy. In 1993-1998, the sign of the estimated coefficient standing for government consumption was positive (although insignificant); in the next subperiod it became negative and also insignificant; however, during 2005-2010, that estimate was negative and statistically different from zero. These results indicate that government consumption has become more and more unproductive in the last two decades. Indeed, what matters – first of all – is public investment, and not public consumption. Fiscal expansion by stimulating government consumption is counterproductive although it is very popular from the social point of view because such expenditures are related with a direct and immediate transfer of money from government to households and firms. However, the study demonstrates that such results are not conducive to output growth.

There are some differences between the results for the EU27 and the sole EU15 group. Moving on to the results for the latter group, mixed impact of the interest rate on economic growth as well as that of inflation on economic growth has been found in the analyzed period. In the first two analyzed subperiods, the negative and statistically significant relationship between these two variables and economic growth was evidenced, which is in line with the most popular view that an interest rate cut leads to an increase in GDP while rapid inflation decelerates economic growth: such a situation seemed to prevail in Western Europe during the three decades (between early 1970s and late 1990s). The economic growth could be then stimulated by applying economic policies aimed at reducing inflation and lowering

interest rates. However, during 1999-2004 and 2005-2010 none or even positive relationship between these two variables and economic growth has been found. Such outcomes can be due to unstable macroeconomic situation in many Western European countries in the last years as well as they might be related with the global economic and financial crisis. Under such circumstances, achieving rapid economic growth by applying fiscal and monetary policies aiming at combating inflation and reducing interest rates turned out to be ineffective. Such mixed results leave a lot of space for uncertainty considering the direction of the impact of inflation and the interest rate on economic growth in future. This is a challenge for policy makers as economic policies in terms of anti-inflationary measures and interest rate settings have to be conducted very carefully in order to achieve the assumable policy goals.

Unlike in the case of the EU27 countries, the results for domestic credit growth do not allow to raise precise conclusions. This is because a statistically significant relationship between this variable and economic growth was not achieved for any of the analyzed subperiods. The estimated coefficients are however positive meaning that financial sector development was rather conducive to economic growth as it should be so for the well-developed market economies.

The results concerning the influence of money growth suggest the existence of positive relationship between this variable and GDP dynamics. In the 1972-1989, 1990-1998, and 2005-2010 statistically significantly positive estimates of the coefficient on the growth rate of money supply have been obtained. For the 2000-2004 subperiod, the respective estimate was positive but not statistically significantly different from zero. Hence the typical mechanism of monetary policy has been confirmed in most periods: the growth of money supply contributed to higher economic growth.

The results for the monetization rate do not allow us to achieve robust findings. Like in the EU27 countries, for the 1999-2004 subperiod the estimated coefficient is negative and statistically significantly different than zero, but for the remaining subperiods it is positive but not necessarily statistically significant.

Unlike EU27 countries, the results for the EU15 countries seem to confirm a clear-cut positive relationship between the investment rate and economic growth (the positive and statistically significantly different from zero coefficient was estimated for all the subperiods except the years 1990-1998).

The model demonstrates that government expenditures on consumption are ineffective in terms of output acceleration. In the case of the EU15 countries, negative and statistically significantly different than zero estimates of the coefficients standing for government consumption have been obtained in all the considered subperiods. It shows that, unlike investment expenditure, government consumption spending is counterproductive. In the case of the EU27 countries, counterproductive effects have been evidenced only in the last two subperiods which may be caused by the fact that during the 1990s the CEE countries had a large idle capacity resulting from the transformation recession; as the result, in the early years of transition growth could be achieved simply by increasing consumption expenditure.

In the case of economic growth determinants included in the regressions without interaction terms with time dummies, the results obtained for the EU15 are very similar to those for EU27 countries, yet some minor differences may be noted. In both cases the index of economic freedom proves to be the variable with clearest positive impact which confirms the positive impact of regulations and institutional environment on economic growth. Quite the opposite, the democracy index proves irrelevant. This result is probably due to the fact that all the Western European countries are fully democratic and thus variance of the respective variable is close to zero, which in turn makes it infeasible to attain the true influence of this factor.

The results regarding human capital variables are not in line with typical macroeconomist's expectations. However, in both groups higher economic growth in per capita terms was observed in the countries that are less populated, i.e. which have lower number of citizens, lower population density, and weaker tendency towards increasing the size of population. Yet again in short horizon this factor differs mostly across countries but not overtime. It is thus likely that the results for these variables are affected by individual characteristics of particular countries rather than by the demography itself. Yet there are differences in the conclusions obtained for further demographic variables for the two considered country groups. Contrary to the EU27, in the EU15 countries the influence of the size of population aged 15-64 on GDP growth is found to be significantly positive. This reflects the theoretical relationship according to which the higher the share of economically

active population is the more rapid economic growth should be expected. It can be suspected that this theoretical relationship has not been evidenced in the whole EU27 group due to high unemployment rates prevailing in many CEE countries: an increase in the number of population ageing 15-64 did not necessarily yield higher employment levels in the latter group of countries and as a result it need not have contributed to the output expansion, yet in the EU15 group this has not been a problem (until the further crisis years) thus the expected influenced has been confirmed empirically.

6.3. Results of the convergence analysis – 3-year intervals

As in the case of annual data, the reference period for the lagged GDP variable is the 2005-2010 subperiod. For these years, the estimated coefficient on initial GDP equals 0.8412 for the EU27 countries which means that the estimated coefficient standing for initial income in the untransformed convergence regression equals: 0.8412 – 1 = –0.1588. The pseudo *t* statistics amounts to 30.02 meaning that, given reasonable significance levels, the estimated coefficient is statistically significantly different from zero. These results indicate the existence of β-convergence among the EU27 countries during 2005-2010. This demonstrates that the average 3-year growth rate of GDP was negatively related with the initial income level. Of course, the convergence is conditional on the growth factors included in the analysis. It is assumed that the countries do not tend to one common hypothetical steady-state, but to different steady-states determined by the explanatory variables. Given the estimated coefficient on initial income, it is possible to calculate the β-convergence parameter. Applying formula (2.6) by substituting –0.1588 for α_1 and 3 for T (i.e. the length of one subperiod in terms of number of years), yields $\beta = 5.77\%$.

For the EU27 countries and the 3-year averages there are no statistically significant differences in the pace of the convergence process between the respective subperiods which is the result similar to the annual data. The β-convergence parameter for the first subperiod encompassing the years 1993-1998 equals 5.91%. Hence, during 1993-1998 the convergence process occurred somewhat more rapidly than in 2005-2010; however, the pseudo *t* statistics for the lagged GDP in interaction

with the first subperiod equals –1.44 being less than 2 in absolute terms. This means that the estimated coefficient on initial income for the years 1993-1998 was not statistically significantly different than that for 2005-2010 demonstrating that the convergence process of the EU27 countries in the 1993-1998 period was not statistically faster (assuming reasonable significance levels) than in 2005-2010. The parameter β for the 1999-2004 subperiod equals 5.71%. The pseudo *t* statistics for the estimated coefficient on lagged GDP in interaction with the second subperiod equals 0.77 pointing also to no statistically significant difference.

Given the value of the β-convergence parameter, it is possible to estimate the number of years the countries need to reduce by half their distance towards the steady state (assuming of course that steady-states differ only in terms of the control variables included in the model). Applying equation (2.7), the half-lives are about 12 years for the EU27 countries.

The results based on the 3-year intervals are quite similar to those for the annual data where the betas are equal to 5.18%, 4.99%, and 5.27% respectively for the subperiods 1993-1998, 1999-2004, and 2005-2010.

The research allows to derive the following findings. First, the analysis indicates a very rapid pace of β-convergence process among the EU27 countries as compared with many other studies. The applied methodology, namely Blundell and Bond's GMM system estimator, better extracts the pure convergence rate as compared with the other studies incorporating standard econometric techniques. Moreover, since the Bayesian model pooling is used, this result is not spurious that would be so in the case of estimating only one model with the arbitrary (and to some extent random) choice of explanatory variables. Millions of regressions have been estimated here and the convergence rate of about 5-6% seems to reveal a true relationship between the initial income level and the subsequent growth rate. The additional robustness confirmation is derived from the fact that these convergence rates have been obtained based on both annual time series and 3-year subperiod averaged figures.

Second, it turns out that the speed of convergence among the EU27 countries did not differ much between the respective subperiods. The benchmark subperiod includes the years 2005-2010 for which the β-coefficient equals 5.77% in the case of 3-year intervals and 5.27% in the case of yearly data. For the earlier subperiods the

betas amount to 5.91% or 5.18% during 1993-1998 and 5.71% or 4.99% during 1999-2004. They are mostly statistically indifferent than those for the reference subperiod.

Third, the analysis based on 3-year intervals makes it possible to better extract the true relationship between the initial income level and the growth rate. That is why the estimates of β based on the 3-year intervals are slightly higher (by about 1 percentage point).

In most applied work it is just assumed that the rate of relative convergence is constant overtime. In this research this is to big extent confirmed empirically and it has important policy implications. Should the rate of relative GDP convergence remain stable, it would mean a possibility for the CEE countries to achieve the Western Europe's income level. However, active economic policy measures are necessary for that purpose: governments' policies should aim at bringing the values of the variables included in the study for the CEE countries to the levels seen in EU15 (in the areas in which the CEE countries lag behind). This means that the authorities should focus on investment in both physical and human capital, sound fiscal and monetary policies, private sector development, economic freedom etc. While controlling for these variables, the analysis suggests that the pure convergence mechanism occurs significantly faster than it is suggested by most empirics, so the equalization of income levels on average terms between the CEE and EU15 is possible and could be attained sooner than forecast in most papers but it requires, inter alia, high quality of fiscal and monetary policies. An additional positive conclusion that can be drawn from the smoothness of the convergence processes is that regardless of the shocks affecting the countries in the future, the EU27 group as a whole should be expected to continue to diminish the income gap between the individual countries and the EU15 group. It must though be emphasized that this conclusion is drawn without considering the recent economic crisis possible consequences. Also it should be stated that the individual CEE countries may reveal different economic growth path than the above discussed average for the whole group.

In a similar way, it is possible to calculate the convergence parameters for the EU15 countries. Those are equal to about 3% for 3-year intervals – the same level as

in the case of annual data. The estimated coefficients based on 3-year intervals are not statistically significantly different between the respective subperiods.

The results of this study imply that the group of Western European countries converges slower than the whole group of the enlarged EU. It is thus possible to infer that the convergence among the EU27 countries is mainly driven by the convergence of CEE towards EU15. Indeed, looking at the official statistics, the CEE countries recorded more rapid economic growth rates than the EU15 economies while the GDP of the former ones used to be much lower.

According to the obtained results, the EU15 countries caught up at the rate of about 3% per year during the whole 1972-2010 period to their individual steady states, yet in particular subperiods, the estimated convergence rates were oscillating at about 3%. This is by far lower than the approximate 5-6% attained for the whole EU27 and there is a natural explanation of this difference. The EU15 countries are a far more homogenous group in terms of their economic level and the leaders of the group are not much more developed than the rest of its members. At the same time, the EU27 are much more diversified in terms of their GDP level and general economic performance. Joining the EU, the CEE countries gained simplified access to modern technologies and common market, which simplified their catching-up process with the old EU economies. As usual, the beginning of catching-up process proves to be more dynamic than in the situation when most differences have already been smoothed, which makes the EU27 relative differences level up faster than the relative difference among just the EU15.

The results of this analysis in terms of conditional β-convergence are more reliable than those evidenced by the other authors due to several reasons. First, the Bayesian pooling of estimates is a method of data analysis which is not biased by an arbitrary choice of the variables that are included in the regression equation. In fact, these results are free of this selection bias (except, of course, some initial preselection of the time series). A huge number of regression equations is estimated, each of them being based on a different set of variables chosen from the preliminary dataset. Such a method of analysis is not included in any of the studies except those that incorporate Bayesian pooling of estimates. Second, unlike in many other studies based on Bayesian modeling, this analysis applies Blundell and Bond's GMM

system estimator which is a more advanced and better tool to verify the research hypotheses (but some weaknesses of this methodology, like any other research method, still persist). Most authors who incorporate the Bayesian approach use the Bayesian averaging of classical estimates and estimate the growth regressions using standard OLS estimators. In this study, however, Blundell and Bond's GMM system estimator is used to extract the true value of the β-convergence coefficient. Third, unlike the studies conducted by the other authors, the initial income level is the variable which is included here in all the regression equations. The initial GDP per capita level is thus treated differently than the other economic growth determinants; the latter ones may appear in a given regression equation or not meanwhile the initial GDP per capita level always is included as one of the explanatory variables. As the result, this methodology seems to be better for estimating the true value of the convergence parameter.

However, lack of economically significant differences in the rate of convergence process between the respective subperiods may result from the fact that the chosen structural breaks do not exactly fit the real ones. It is also possible that allowing for different structural breaks could yield different results and maybe different results on the rate of convergence would be obtained. Testing for different structural breaks is one of the possible extensions of this research. Moreover, lack of significant differences may reflect the fact that macroeconomic relationships indeed tend to vary over time but very slowly and that is why the differences between the respective subperiods are not as significant as one might expect.

6.4. Results of the economic growth determinants analysis – 3-year intervals

The impact of both the interest rate and inflation on economic growth was negative and mostly statistically significantly different than zero in the case of EU27 countries. These outcomes show that the calculations based on 3-year intervals indicate somewhat more stable results in terms of these two economic growth determinants. However, the results for the EU15 countries and 3-year intervals are again mixed because none, the positive or negative relationship between these two variables (interest rate and inflation) and economic growth has been evidenced.

The empirical results for the impact of inflation and interest rate on economic growth often are similar because changes in interest rate tend to match changes in inflation. For example, according to the Fischer hypothesis, the fluctuations in interest rates reflect the fluctuations in inflation. For the EU27 countries, a negative impact of inflation on economic growth has been evidenced for all the considered subperiods. This is in line with the classical model according to which inflation is countercyclical and it is by no way a factor conducive to economic growth. Hence, the data averaged into 3-year subperiods better than annual data demonstrate that inflation negatively affects economic growth although in the case of EU15 countries and the last two subperiods (1999-2004 and 2005-2010) a positive relationship between inflation and GDP dynamics was recorded.

The results for the annual change of the domestic credit are quite stable over time for the EU27 countries. The positive and statistically significantly different than zero relationship between this variable and economic growth has been obtained for each subperiod confirming the theoretical structural model according to which financial sector development is conducive to economic growth. For the EU27 group, the change of domestic credit is the third variable (after interest rate and inflation) for which the results do not differ much between the consecutive subperiods (at least in terms of the direction of the relationship). This may reveal the fact that, unlike annual data, subperiod-averaged figures evidence longer-term relationships which are more stable. However, the results for the EU15 group in terms of credit growth are again mixed.

3-year averaged data indicate that money growth reveals rather a positive impact on economic growth as positive and statistically significant relationships were obtained for all (except one) subperiods – both for EU15 and EU27 groups. However, the results for the remaining variables for which structural breaks are introduced (monetization ratio, investment rate, government consumption, and openness rate) usually vary between the respective subperiods pointing to a lack of stability of the respective relationships. But some conclusions arise. For example, the calculations based on 3-year intervals confirm the earlier finding that government expenditures on consumption are counterproductive in terms of output acceleration for both groups of countries.

Moreover, the study based on 3-year intervals – as in the case of annual time series – does not indicate a clear-cut positive impact of investment on economic growth both in the case of EU15 and EU27 countries. How to comment these surprising results? While the positive relationship between investment and economic growth is obvious, one may raise arguments in order to try to explain a negative impact observed in some subperiods. The model suggests that investments relatively often might flow into unproductive activities. In other words, investment outlays were not so productive to affect significantly the rate of economic growth (some other variables turned out to be more significant). Maybe this result emphasizes the need for the revision of some government programs promoting investment. For example, special economic zones, which were created in many transition countries, might not yield expected outcomes from the point of view of their impact on economic growth. Another example involves some types of expenditures which are classified as investments but they do not have a real impact on the level of potential output. For instance, a purchase of a notebook by a firm is classified as an investment outlay but its impact on the production capacity of a given country is rather weak. This is an advice for EU policy makers because not all the EU structural and aid funds have large supply-side effects; some of the EU programs reveal rather demand-side effects. The appearance of the negative sign of the estimated coefficient for the investment rate implies that the authorities should pay special attention in performing policies aimed at accelerating investments.

In the model based on 3-year intervals the estimated coefficient for the index of economic freedom is positive and statistically significantly different than zero for both the EU27 and EU15 countries. Like in the case of annual data, this result indicates a clear-cut and strong positive relationship between the scope of economic freedom (or – more widely – favorable institutional environment) and output growth.

Summing up, in the case of both annual time series and 3-year intervals, for a number of variables their influence on the GDP growth has been found to vary over subsequent periods. Such a result confirms the suspicion that stability of the growth relationship is not always a fact and this should be reflected by the structure of the model. Nevertheless one should be very careful while interpreting the above

discussed estimates. It is not absolutely clear whether it is just the GDP growth that depends on the factors denoted by the control variables or is it the other way round. That is reflected in the construction of the model that assumes endogeneity of those terms and thus one must be very cautious while stating the conclusions drawn on the basis of the discussed estimates.

Conducting monetary policy is undoubtedly a very difficult task for the authorities. The analysis based on annual data and – although to a lesser extent – the analysis based on 3-year intervals both show that monetary variables do not reflect a stable impact on economic growth. These ambiguities concern all the monetary variables tested in this study: interest rates, monetary aggregates, inflation, and credit growth. These results are in contrast with the pure convergence mechanism. The initial GDP per capita turned out to have a stable negative impact on the subsequent rate of economic growth while in the case of monetary variables the opposite tendencies have been recorded. This means that it is extremely difficult to raise unambiguous recommendations for monetary policy makers in terms of the variables tested in this study; monetary policy tools must be chosen individually for a given country and a given period after a careful analysis of all the macroeconomic environment.

7. Concluding remarks

The results allow for formulation of some interesting findings. In the case of annual data, the key findings are the approximate 5% per annum rate of convergence for the whole group of the EU27 countries during the 1993-2010 period and the lower 3% per annum rate for the more narrow EU15 group during 1972-2010 (but also in the 1993-2010 period itself). In the case of 3-year intervals, the rate of convergence is about 6% for the EU27 countries during 1993-2010 and still about 3% for the EU15 countries during 1972-2010. The subperiod-averaged data allow for better extraction of the pure rate of conditional convergence than the annual data.

The pure mechanism of conditional convergence of the countries under study is found to be quite constant over time regardless of whether the models are estimated using annual data or 3-year intervals: the differences between particular subperiods were not as huge as it could be expected considering the length of the period under study and thus the varying macroeconomic conditions throughout this time.

Quite contrary, the considered economic growth determinants, including all the variables related with monetary policy (interest rate, inflation, credit growth, money growth, and monetization ratio), exhibited mixed and in some cases highly different impact on economic growth overtime for both EU27 and EU15 groups, notably based on annual data. However, in the case of EU27 countries and 3-year intervals, some of the monetary variables (interest rate, inflation, credit growth, and money growth) revealed relatively stable impact on economic growth between the respective subperiods but only in terms of the direction of the relationship; taking into account the fact that a number of estimated coefficients was not statistically significantly different than zero – the existence of the stability cannot be however guaranteed.

In the study, the following turning points were checked for the possible instability. In the case of EU15 countries, three turning points were introduced and assumed to be in 1989, 1998, and 2004 while in the case of EU27 countries only two latter ones were considered. Turning points were chosen to reflect in the best way the possible distortions resulting from changing macroeconomic environment. Real economic convergence turned out to be insensitive with regard to the chosen turning

points while most of the economic growth determinants revealed differentiated impact on GDP dynamics between these structural breaks.

The analysis confirms the existence of a very rapid pace of β-convergence process as compared with many other studies. However it is likely that this difference is due to the application of BMP with Blundell and Bond's GMM system estimator, which allows for a more accurate extraction of the pure convergence rate as compared with many other studies that incorporate standard econometric techniques applied to single models based on an arbitrary (and to some extent maybe even coincidental in result of high subjectivity) selection of control variables. We trust that the use of BMP reduces the risk of obtaining spurious relationships which could take place in result of i.a. omitted variable bias or overparametrization.

Although the estimated rate of convergence at the level of 5-6% for EU27 and 3% for EU15 is certainly a novum given the existing mainstream of knowledge, some authors have already found results of similar magnitude in spite of the existence of the 'legendary 2%' yearly convergence rate. Individual studies differ in this respect, often pointing to lower or higher convergence parameters. Abreu et al. (2005), who analyzed 619 convergence models found in 48 different studies, argue that the average convergence coefficient calculated based on these models equals indeed about 2% but according to them it is not proper to claim that the 2% is the 'natural' convergence rate since various convergence models are estimated based on different samples. Furthermore, models based on the Solow formula and those that take account of differences in fiscal policy and financial sector development yield the estimates of the convergence coefficient largely exceeding the 'legendary 2%' level. They also find that significantly higher convergence rates are found in the studies based on panel data in which LSDV or GMM estimators are used. Given this view, the results described in this report are by no means 'strange'.

Some interesting findings arise in result of the comparison of the results for the EU27 and EU15 groups. First, the convergence among the EU27 group is based mainly on the convergence of CEE countries towards EU15. The convergence inside the EU15 group was not rapid enough to level up the obtained convergence rate inside the EU27 group as a whole, which is well visible in the difference between the convergence rates found for these two sets of countries. The fact that a large part

of the fast catching-up process of the EU was caused by convergence of the new EU member states towards the old EU members is confirmed by statistical data which show that the EU15 countries have recorded on average higher GDP levels and lower growth rates as compared to the CEE countries, most of which belong to the EU27 but not the EU15 group. Yet the Western European countries also converged in conditional terms towards their individual steady-states. Since the main rationale behind the convergence process is diminishing marginal product of capital, the results discussed in this report show that the Western European countries with higher GDP per capita noted lower productivity of the inputs and slower growth as compared with the countries with lower GDP per capita.

Quite contrary to the initial doubts, the conditional convergence process among both the EU27 and the EU15 countries have been quite stable over time although its slight instability in the EU15 group has been found (based on annual data). These results represent a clear-cut and persistent tendency of the EU member states to converge. Extrapolating these findings, one may expect that the convergence process might remain constant and stable in the next years, which implies that a rapid acceleration of economic growth (above the levels resulting from the convergence mechanism) just because a given country is poorer than another one is unlikely to occur in future. It must though be stated that all the results are obtained in the relative terms and those will hold only provided that the catching-up countries make successful efforts to level up their steady states. This should be possible provided that the economic, infrastructural, social and demographic factors reflected by the set of control variables involved in this study are equalized throughout the considered sample of countries. As far as the above mentioned lower stability of the convergence process in the EU15 group is concerned, this partly is the result of the longer considered period. The slowest rate of convergence of the EU15 countries was noticed in the 1990-1998 period while the highest one was the average of the years 2005-2010. The relatively slower convergence process observed in Western Europe at the beginning of the 1990s might have been caused by the fact that the richest EU15 countries were the biggest winners of the fall of socialism in Central and Eastern Europe. Opening of the CEE economies that took place when the transition period in the post-communist region began provided new opportunities for

selling high-quality goods and services to the emerging markets and those were the richest Western European countries that largely benefited from it. This 'rich get richer' process might be reflected in a slightly lower pace of convergence in the 1990's era. On the other hand, in the 2005-2010 period the catching-up process was relatively fast, which probably resulted from the fact that low-income countries have not been affected by the effects of the global crisis as strongly as the highest-income ones due to, inter alia, some beneficial treatment from the richer neighbors, including debt reductions of highly indebted EU member states and the foreign aid. Nevertheless, the discussed differences are low enough to accept the assumption adopted by most papers regarding constancy of the convergence rate as sufficient in view of the empirical results found in this analysis.

Unlike in the case of the pure convergence mechanism, the calculations show that monetary variables do not reflect a stable impact on economic growth. This was evidenced mainly by the models based on annual data but also – although to a lesser extent – those based on 3-year intervals. These ambiguities concern all the monetary variables tested in this study: interest rates, the growth of and the stock of money supply, inflation, and credit growth. This outcome is in line with the idea that conducting monetary policy is a very difficult task for the authorities. It is thus extremely difficult to raise unambiguous recommendations for monetary policy makers in terms of the variables tested in this study; monetary policy tools must be chosen individually for a given country and a given period after a careful analysis of all the macroeconomic environment.

Referring to the future perspectives of the convergence process, it is possible to conclude as follows. As the research has confirmed a relatively stable time path of convergence during the 1993-2010 period for the EU27 countries and the 1972-2010 period for the EU15 countries (but different among the two considered groups), it may be expected that the observed tendencies will continue. Namely, it is likely that future convergence process will occur at the same pace of about 3% per annum for the EU15 countries (in conditional terms with regard to those properties of the steady-states which are represented by the control variables) and about 5-6% per year for the EU27 countries (also in conditional terms). Hence, the study implies that future catching up tendencies in Europe will be driven by the convergence of

the CEE countries towards 'old' EU member states while the convergence inside the EU 'core' will be weaker. It is thus possible to expect further income equalization between Central and Eastern Europe and Western Europe. Regardless of any further economic shocks from the demand-side or supply-side perspectives, the convergence process is likely to continue. Indeed, the EU countries are rather a homogenous group so they similarly react to internal and external factors (e.g. global crises) and the convergence path seems to be unaffected by those shocks. Moreover, convergence is analyzed here in conditional terms so it is measured towards individual steady-states to which the countries are tending. Since control variables account for country-specific factors, the conditional catching up process is likely to take place at the same rates as in the past even if some growth factors change considerably. Of course, as any economic estimate or projection, these forecasts (or estimations) cannot be treated as 100 percent sure. There is still much room for the other empirical studies on economic growth and convergence incorporating different econometric methods, different samples of countries, and different time periods. However, this should be thought of as a short or medium term forecast. The fact that the estimated convergence rate among EU27 is so much stronger than among the core EU15 suggests that it is the group of 'new' EU countries that mostly catch up with the level of development of the old ones, thus making the convergence process stronger in the whole EU. We can thus expect the rate of convergence of the new EU countries to be asymptotically tending towards the approximate 3% p.a. of the better developed old ones. Nevertheless, this process cannot take place immediately and should be observed probably no sooner than after the forthcoming decade if not later – especially considering the fact, that in view of global crises, the rate of economic growth of poorer countries cannot be assumed to start boosting soon.

There are several possible extensions of this analysis that are worth doing in future. First of all, it is particularly interesting to carry out a similar research with different structural breaks. The inclusion of different structural breaks may be twofold. Firstly, it is possible to consider a model in which structural breaks vary for individual countries and different groups of countries (e.g. the CEE10 economies and the former EU members). Secondly, it is interesting to estimate a model in

which structural breaks are not introduced at given points in time but they are randomly chosen out of the possible set of initially preselected ones. The results could be then averaged to calculate the relative importance of a given year as a structural break. This extension requires advanced econometric techniques in the form of Bayesian pooling. If implemented, possible future analysis would include two levels of Bayesian pooling: the first one concerning the relative importance of a given explanatory variable as an economic growth determinant and the second one – the relative importance of a given year as a structural break. This type of analysis will be innovative and would broaden the knowledge on the nature of the convergence process in the European Union.

Second, it is worth to make a robustness test of the GMM method. Namely, it would be interesting to apply standard BACE approach (that is, OLS regressions) to the same dataset and compare what are the differences in the results due to only a different method of model estimation (GMM vs. OLS). It is of course possible to extend this robustness analysis to some other methods of model estimation, different than OLS or GMM.

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