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Cycle and Income-Level Convergence in the EU Countries: An Identification of Turning Points Based on the Hidden Markov Models[4]

Summary

This paper aims to identify turning points in the economic growth paths of the European Union countries on the basis of the Hidden Markov Models. These turning points are then introduced as structural breaks in the β-convergence model. Such an approach combines the analysis of cyclical and income-level convergence. Quarterly GDP time series for the whole EU28 group has two turning points (in 2008 and 2013). The hypothesis about the β-convergence was successfully verified, but the β-convergence process had a different pace between the turning points, being the slowest (or not even existing) one in the 2008–2012 subperiod, i.e. during the global crisis.

Keywords: catching-up; convergence; hidden Markov model; European Union; Viterbi path

JEL Classification Codes: C61, E32, O47, O52

1. Introduction

β-convergence generally means that poor economies grow faster than rich ones. In empirical studies, there are various ways of testing β-convergence.

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Empirical evidence is also mixed, mainly in terms of the pace of the catching-up process and the stability over time[5].

The goal of this paper is to identify turning points in the economic growth paths of the European Union (EU) countries on the basis of the Hidden Markov Models and to analyze the time stability of the β-convergence based on the model with structural breaks (turning points).

In this paper the new approach in identifying turning points is explored. Hidden Markov Models (HMM) and Viterbi path both give quite accurate turning points based on the macroeconomic time series data. Turning points found on the basis of the HMM algorithm are then implemented as structural breaks in the β-convergence regression equation. Verification of the β-convergence model is done by the estimation of the regression equation parameters, where the dependent variable is the growth rate of real GDP per capita at PPP.

The empirical analysis carried out in the paper covers the 28 EU countries and the 1996–2016 period. Turning points are identified on the basis of annual and quarterly GDP statistics for different EU member states, supplemented by monthly economic sentiment indicators based on survey data. β-convergence model has been estimated for the whole period as well as for subperiods determined by the turning points given as a result of the HMM procedure.

This paper is organized as follows. After the introduction, the theoretical background of HMM and the Viterbi path are described. Also, the brief characteristics of the data are given. Section 3 is devoted to the identification of turning points, whereas in section 4 the analysis of β-convergence is presented. The last section concludes.

2. Methodology and data

The empirical analysis is composed of two steps. The first step involves the identification of turning points of the business cycles in the analyzed group of countries. Then, as the second step, the empirical verification of the β-convergence concept with structural breaks is tested. β-convergence means that less developed countries (with lower GDP per capita) grow faster than more developed

[5] A wide review of empirical studies is given in: Matkowski Z., Próchniak M., Rapacki R. (2016), Real Income Convergence between Central Eastern and Western Europe: Past, Present, and Prospects, *Ekonomista* 6, 853–892.

ones. Neoclassical models of economic growth[6] confirm this type of convergence in a conditional way meaning that it takes place if all the economies tend to reach the same steady state. Since the steady-state, or long-run equilibrium, need not be the same for the real economies, empirical verification involves the regression equation which includes numerous economic growth determinants.

In this study, the time stability of the β-convergence hypothesis is tested. It means that the convergence hypothesis with structural breaks is verified. Structural breaks in the β-convergence model are turning points identified on the basis of the procedure combining hidden Markov model, Viterbi path, and Monte Carlo simulations.

The concept of identification of turning points is based mainly on the Hidden Markov models, also known by the name of Markov-switching model, which were being under study over the years[7]. HMM can be treated as a generalization of the classical Markov models, where to the visible sequence of observations, the unobservable path of states is added. Using the Baum-Welch algorithm, model parameters are estimated, that is transition probabilities and the parameters of the probability distribution related to each unobservable state. Calculating the probabilities doesn't end the procedure because it still remains to establish the path of states. There are few ways to achieve this goal. One of them is a Viterbi algorithm, which seems to be particularly useful in macroeconomics. Use of the Viterbi path together with a Baum-Welch algorithm to get the globally optimal solution depends on the number of factors[8]. To get more reliable results, computations are performed repeatedly with the same set of data and different initial values. This approach is known as Monte Carlo simulations.

The identification of turning points is just a first stage of the verification of the β-convergence. To get the results needed to the second stage, the two-state HMM was used. Using more states is questionable, due to the length of the input time series. Some of the assumptions made during the calculation:

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6 Solow R.M. (1956), A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics* 70, 65–94; Mankiw N.G., Romer D., Weil D.N. (1992), A Contribution to the Empirics of Economic Growth, *Quarterly Journal of Economics* 107, 407–437; Nonneman W., Vanhoudt P. (1996), A Further Augmentation of the Solow Model and the Empirics of Economic Growth for OECD Countries, *Quarterly Journal of Economics* 111, 943–953.

7 See e.g. Hamilton J.D. (1994), Time Series Analysis, Princeton University Press, Princeton (New Jersey); Koskinen L., Oeller L.E. (2004), A Classifying Procedure for Signaling Turning Points, *Journal of Forecasting* 23, 197–214.

8 Bernardelli M. (2013), Non-classical Markov Models in the Analysis of Business Cycles in Poland, *Roczniki Kolegium Analiz Ekonomicznych SGH* 30, 59–74.

- state 1 is associated with the periods of relatively good conditions and state 0 is associated with a worse situation,
- only normal HMM was considered, which means that the observable component (economic time series being under the analysis) must satisfy the conditions

$$Y_n|_{X_n=0} \sim N(\mu_0, \sigma_0) \text{ and } Y_n|_{X_n=1} \sim N(\mu_1, \sigma_1), \tag{1}$$

- $\mu_0 < \mu_1$ meaning that state 1 is associated with a greater mean value,
- three criteria were taken into account to choose the best model for each time series: Akaike's information criterion (AIC), Bayesian information criterion (BIC) and the log likelihood value,
- the initial values for the Baum-Welch algorithm were chosen randomly with the use of independent and identically distributed draws from the univariate distribution,
- the number of draws used for model parameters estimation of the time series being under study was set to 1000.

All the computations, resulting in the two-state HMM and the Viterbi paths, proved to be stable. Identified turning points were used in the next stages of the research.

Verification of the β-convergence model is based on the regression equation where the dependent variable is the growth rate of real GDP per capita at PPP while the set of explanatory variables includes both the initial log GDP per capita level as well as the other variables that are control variables and are treated as economic growth determinants. The typical Barro regression[9] is used as in most cases when the β convergence is assumed. Since we consider the set of EU countries observed over time, panel data dynamic Blundell and Bond estimator is used. We allow for endogeneity of all the regressors as in most cases in macroeconomic research: this is because the considered explanatory variables are most likely to depend on the economic situation, which in turn means they are likely to be connected with the dependent variable via a two-way relation. However, two remarks need to be made. Firstly, in virtually each article devoted to the issue of GDP growth, the set of GDP growth factors used as regressors is different. This is due to subjectivity in this respect. In order to control for it, we apply Bayesian model averaging over the attained results, which can be viewed

[9] Barro R., Sala-i-Martin X. (2003), Economic Growth, The MIT Press, Cambridge – London.

as pooling over all the loglinear growth models that could be constructed with the presumed set of potential regressors[10]. Secondly, the dataset used in this research covers the period of the big financial crisis and in consequence, there is a serious risk of loss of stability of the considered regression. We thus allow for structural breaks at turning points of the GDP series. We allow for all the coefficients to change at the time of the turning points.

To identify turning points, the following time series were collected: annual GDP growth rates, quarterly GDP growth rates (compared with the analogous quarter of the previous year to avoid seasonal fluctuations), and monthly economic sentiment indicators from survey data for all the 28 countries and the 1996–2016 period (in the case of missing data the time period is shorter). The first two time series are taken from official statistics and show changes in the fluctuations of real output. Variables on the annual basis will be used in the estimation of the β-convergence model. However, when identifying turning points, annual time series may be too short. That is why quarterly and monthly variables are also used. It is also the robustness test of the HMM procedure.

GDP time series are not available on a monthly basis. In the studies on business cycles, the variables based on survey data are often employed to find turning points (peaks and troughs). Such variables have two advantages. First, they are available on a monthly basis, so it is possible to identify turning points more precisely. Second, they are available without a huge delay. So they allow to include in the analysis the last periods as well (indeed, economic sentiment indicator covers the period till March 2017). Earlier studies on this subject[11] show that the variables based on survey data are good substitutes of the official statistics in the business cycle research.

In the case of the β-convergence model, the following variables are included in the set of control factors:

- GDP per capita at PPP from the previous year (constant 2011 international $) [loggdp_t-1];
- Current account balance (% of GDP) [cab];

[10] For details, see for example: Próchniak M., Witkowski B. (2013), Time Stability of the Beta Convergence among EU Countries: Bayesian Model Averaging Perspective, *Economic Modelling* 30, 322–333; Próchniak M., Witkowski B. (2016), Konwergencja dochodowa typu beta w ujęciu teoretycznym i empirycznym, Szkoła Główna Handlowa w Warszawie, Warszawa.

[11] E.g. Matkowski Z., Próchniak M. (2008), Cyclical Fluctuations in Central and Eastern Europe and their Conformity with the Euro Area, paper presented at the 29th CIRET Conference, Santiago (Chile), 8–11 October 2008.

- General government balance (% of GDP) [gov_bal];
- General government total expenditure (% of GDP) [gov_exp];
- Inflation, average consumer prices (%) [inf];
- Total investment (% of GDP) [inv];
- Volume of exports of goods and services (% change) [exp].

The regression equation is estimated on the basis of annual panel data. Hence, the set of control variables includes mainly demand-side economic growth determinants which influence the dynamics of output in a given year. There are no variables which affect the long-run rate of economic growth, such as human capital indicators.

The analysis is based on the time series taken from the International Monetary Fund, World Bank, and Eurostat databases[12].

3. Identification of turning points

The first step of the analysis is the identification of turning points of the EU countries' business cycles. It turns out that the annual GDP time series are generally too short to find reliable peaks and troughs in the process of economic growth on the basis of the HMM procedure. Better results in terms of economic and mathematical validity are obtained for quarterly GDP statistics and monthly economic sentiment indicators.

Table 1 shows turning points identified with the HMM algorithm for quarterly GDP growth rates and monthly economic sentiment indicators from survey data for the individual 28 EU countries.

Table 1. Turning points identified with the use of the HMM procedure

Country	Turning points identified on the basis of:	
	quarterly GDP growth rates	monthly economic sentiment indicators from survey data
Western Europe (EU15)		
Austria	IV 2008; I 2010	10.1996; 05.2008; 04.2010
Belgium	IV 2008; IV 2009; I 2012; IV 2013	08.2001; 11.2003; 09.2008; 03.2010; 09.2011; 11.2013
Denmark	IV 2008; I 2010	07.1998; 02.2000; 02.2008; 12.2009
Finland	III 2008; II 2010; IV 2011	03.2001; 01.2004; 06.2008; 02.2010

[12] International Monetary Fund, *World Economic Outlook Database*, April 2017, http://www.imf.org/external/pubs/ft/weo/2017/01/weodata/index.aspx [dostęp 20.04.2017]; World Bank, *World Development Indicators Database*, 2017, http://databank.worldbank.org/ [dostęp 10.04.2017]; Eurostat, *Database*, 2017, http://ec.europa.eu/eurostat [dostęp 20.04.2017].

Country	Turning points identified on the basis of:	
	quarterly GDP growth rates	monthly economic sentiment indicators from survey data
France	I 2008; I 2010; IV 2011	08.1997; 07.2008; 08.2010; 08.2011; 10.2015
Germany	IV 2008; II 2011	06.2001; 02.2006; 07.2008; 04.2010
Greece	II 2008; III 2013	10.2008; 03.2014; 04.2015
Ireland	III 2007; III 2013; I 2016	n.a.
Italy	IV 2008; I 2010; IV 2011; I 2014	07.2008; 12.2009; 08.2011; 11.2013
Luxembourg	III 2008; IV 2009	04.1997; 04.2001; 02.2004; 06.2008; 03.2016
Netherlands	III 2001; III 2005; III 2008	09.2008; 10.2014
Portugal	IV 2002; IV 2003; IV 2008; I 2010; I 2011; IV 2013	10.2001; 09.2006; 06.2008; 05.2014
Spain	III 2008; I 2015	10.2007; 03.2014
Sweden	I 2008; IV 2009; IV 2011	04.2001; 05.2004; 06.2008; 12.2009; 09.2011; 08.2013
UK	III 2008; I 2010	02.2008; 07.2013
	Central and Eastern Europe (including Cyprus and Malta)	
Bulgaria	I 2002; IV 2008	07.1998; 04.2001; 12.2008; 01.2015
Croatia	III 2008; III 2015	11.2008; 03.2014
Cyprus	IV 2008; III 2015	12.2008; 12.2014
Czech Rep.	IV 2008; II 2010; III 2011; I 2014	02.2000; 10.2008; 09.2014
Estonia	I 2008; III 2010	10.1998; 07.2000; 08.2007; 04.2010
Hungary	I 2007; III 2013	06.2006; 07.2010; 05.2011; 10.2013
Latvia	I 2008; III 2010	04.2008; 11.2010
Lithuania	III 1999; I 2000; IV 2008; II 2010	09.2008; 09.2010
Malta	I 2009; IV 2009	06.2008; 05.2010
Poland	III 2000; II 2003; III 2008	01.1998; 06.2006; 11.2008
Romania	I 1997; II 2000; I 2009; III 2013	04.1997; 04.2000; 11.2008; 08.2014
Slovakia	I 1999; I 2000; IV 2008; I 2010	02.1999; 06.2000; 10.2008; 06.2010
Slovenia	IV 2008; IV 2013	07.1999; 10.2008; 05.2014

Source: own calculations.

Data in Table 1 are quite mixed both between the countries as well as between the two variables (GDP time series and economic sentiment indicators). However, some common tendencies can be found.

Firstly, the majority of turning points take place in the second half of the 2000s or the first half of the 2010s. This outcome is not a coincidence. It is undoubtfully caused by the global crisis and the crisis in the euro area. Big

turmoil in the rates of economic growth during the crisis implied that there are very few turning points (especially for the Western European countries) in the first years of the analyzed period, including the 1990s decade. Turning points in the 1990s were identified only for Austria, Denmark, France and Luxembourg (on the basis of monthly data) in the case of old EU member states and for Bulgaria, Estonia, Poland, Slovenia (based on monthly data), Lithuania (quarterly data), and Romania and Slovakia (both quarterly and monthly data) in the case of new EU member states.

Second, the lack of turning points in the beginning of the analyzed period concerns mainly Western European countries (including Malta and Cyprus). These countries did not suffer the transformation recession and their economic growth paths during the 1990s were rather stable over time (instability was not so large as that caused by the global crisis). However, in the case of new EU member states from Central and Eastern Europe, turning points often appeared during the 1990s. For these countries, the role of 'integration anchor' was very important and affected significantly the dynamics of output in a sense that fluctuations in economic activity in the early years of the analyzed period were quite large as compared with those observed during the global crisis.

Thirdly, for both groups of countries, we can observe a turning point just prior to the global crisis (approximately in 2008). This holds for the majority of countries. Many countries also notice another turning point after the end of the global crisis.

The above outcomes show the necessity of introducing structural breaks into the convergence model.

4. Analysis of β-convergence

The regression equation with structural breaks requires the introduction of the same turning points for the whole group of countries. Calculating averages on the basis of data in Table 1 is not a proper method. To find such structural breaks, we identify turning points on the quarterly GDP growth rates for the whole EU28 group (weighted average). The additional restriction was imposed in the HMM procedure to avoid numerous structural breaks which would make it impossible to estimate properly the regression equation (there must be several observations in each subperiod between the two consecutive structural breaks).

As the result, the following turning points were identified for the quarterly GDP growth rates for the EU28 group (see Figure 1):

- III 2008 – a peak;
- III 2013 – a trough.

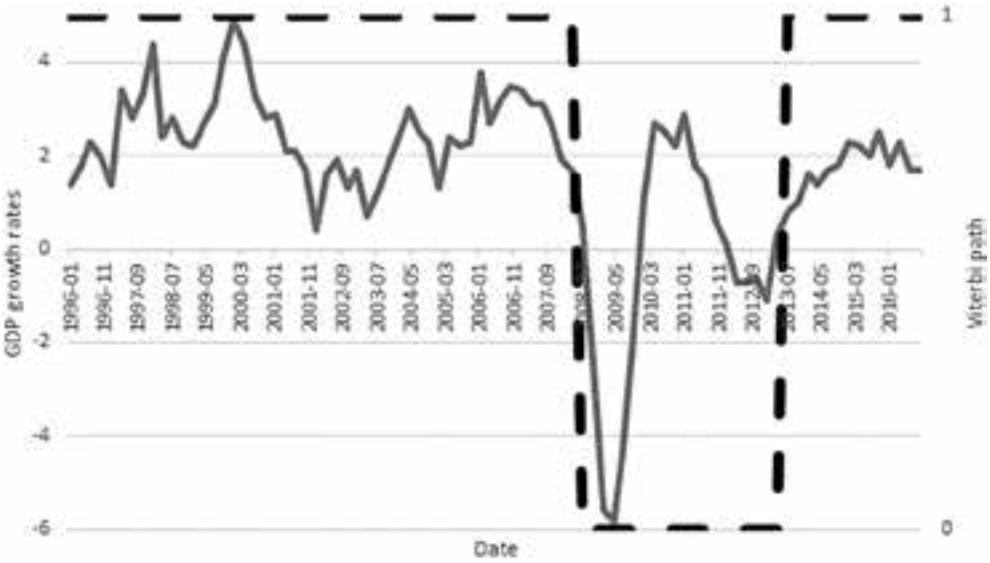

Figure 4. Turning points based on quarterly GDP growth rates for the EU28 group
Source: own calculations.

This result is in line with the outcomes for the individual countries described in Table 1. The first turning point was observed just prior the crisis while the second one – after the global crisis. Hence, the regression equation will include two structural breaks (in 2008 and 2013).

β-convergence model has been estimated for the whole period (1996–2016) as well as for the three shorter subperiods (1996–2007, 2008–2012, and 2013–2016). Such an approach makes it possible to assess how the pace of convergence changed over time between the structural breaks.

Table 2 shows the results of model estimation for the whole period. The adopted methodology requires that the level of GDP per capita in the current year, instead of the growth rate, be the explained variable. It means that the convergence is confirmed if the coefficient standing on GDP per capita from the previous period is less than 1.

Table 2. Regression estimation of the β-convergence model for the whole 1996–2016 period, EU28 countries

Regressor	Estimate	Standard error	*p*-value
loggdp_t-1	0.97052	0.00348	0.000
cab	0.00065	0.00023	0.011
gov_bal	0.00365	0.00032	0.000
gov_exp	–0.00216	0.00025	0.001
inf	–0.00007	0.00002	0.028
inv	0.00387	0.00027	0.000
exp	0.00277	0.00010	0.000

Source: own calculations.

The results shown in Table 2 confirm the existence of conditional β-convergence. The coefficient for initial income level equals 0.97052, that is less than 1. Moreover, it is statistically significant (*p*-value = 0.000). This outcome indicates that countries with lower GDP per capita grew on average faster than more developed ones, *ceteris paribus*. The convergence is conditional on the growth factors included as the explanatory variables in the regression equation. These results are in line with the economic literature. There are many studies about the catching-up process in the enlarged European Union and the majority of them confirms the existence of convergence in the EU, although the pace and strength of this process are different[13].

The model estimated for the whole period is economically and statistically valid also as regards the other explanatory variables. All of them are statistically significant (at 5-percent significance level) while the sign of the estimated

[13] For the most recent studies, see e.g.: Batóg J. (2013), Analiza krańcowej pionowej konwergencji dochodowej typu β w krajach Unii Europejskiej w latach 1993–2010, *Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania* 31, 39–47; Grzelak A., Kujaczyńska M. (2013), Real Convergence of the European Union Member States – Evaluation Attempt, *Management* 17, 394–405; Rapacki R., Próchniak M. (2014), Wpływ członkostwa w Unii Europejskiej na wzrost gospodarczy i realną konwergencję krajów Europy Środkowo-Wschodniej, *Ekonomia* 39, 87–122; Forgó B., Jevčak A. (2015), Economic Convergence of Central and Eastern European EU Member States Over the Last Decade (2004–2014), *European Economy Discussion Paper* 001; Matkowski Z., Próchniak M., Rapacki R. (2016), Income Convergence in Poland vis-à-vis the EU: Major Trends and Prospects, in: Weresa M.A. (ed), Poland. Competitiveness Report 2016. The Role of Economic Policy and Institutions, World Economy Research Institute, Warsaw School of Economics, Warsaw, 37–55; Jóźwik B. (2017), Realna konwergencja gospodarcza państw członkowskich Unii Europejskiej z Europy Środkowej i Wschodniej. Transformacja, integracja i polityka spójności, Wydawnictwo Naukowe PWN, Warszawa.

coefficient corresponds with the economic theory and the theoretical structural model. There is the strong positive impact of investments and exports on economic growth. Good fiscal stance (low budget deficit) is also conducive to the growth of output. The results show that inflation negatively affects the GDP dynamics. In the case of inflation, however, the true relationship may be nonlinear because both high inflation and deflation may hamper economic growth.

To assess the pace of the catching-up process between the structural breaks, the analogous convergence model was estimated for three shorter subperiods. The results are given in Table 3.

Table 3. Regression estimation of the β-convergence model for three subperiods, EU28 countries

Regressor	Estimate	Standard error	*p*-value
1996–2007			
loggdp_t-1	0.98323	0.00332	0.000
cab	–0.00009	0.00027	0.000
gov_bal	0.00383	0.00047	0.000
gov_exp	–0.00244	0.00029	0.000
inf	–0.00007	0.00002	0.009
inv	0.00401	0.00031	0.000
exp	0.00126	0.00012	0.000
2008–2012			
loggdp_t-1	0.99666	0.01433	0.000
cab	–0.00055	0.00067	0.201
gov_bal	0.00231	0.00081	0.181
gov_exp	–0.00052	0.00084	0.317
inf	–0.00092	0.00118	0.129
inv	0.00605	0.00081	0.000
exp	0.00359	0.00018	0.000
2013–2016			
loggdp_t-1	0.98557	0.01078	0.000
cab	0.00477	0.00079	0.001
gov_bal	0.00409	0.00096	0.042
gov_exp	–0.00255	0.00041	0.002
inf	–0.00573	0.00109	0.000
inv	0.00372	0.00076	0.012
exp	0.00376	0.00031	0.000

Source: own calculations.

The results presented in Table 3 confirm the economic and statistical validity of the conditional convergence equation. In most cases, the signs of the estimated coefficients are in line with the theoretical structural model; moreover, they are usually the same as in the equation estimated for the whole period. Regression coefficients are usually statistically significant at the 5-percent significance level (except a few variables for the 2008–2012 subperiod).

The models estimated for all the three subperiods confirm the existence of conditional β-convergence in the first and the third considered subperiod. However, during the crisis period, the estimated loggdp_1–1 parameter is statistically significantly different from 0, but is not significantly different from 1 (assuming typical significance levels), which means that the existence of β-convergence in the 2008–2012 period has not been proved, though, on the other hand, no trace of divergence was found either.

The pace of the catching-up process was different in various subperiods. To assess how the pace of convergence evolved over time, we calculate the values of the parameter β that measures the speed of convergence. We also evaluate half-lives (half-life is the time needed to reduce the gap towards the hypothetical steady-state by half)[14]. The results are given in Table 4.

Table 4. Parameters β and half-lives

Period	Coefficient on initial income in the transformed regression model	Coefficient on initial income in the untransformed regression model	Parameter β	Half-life (years)
1996–2016	0.97052	–0.02948	2.99%	23.2
1996–2007	0.98323	–0.01677	1.69%	41.0
2008–2012	0.99666	–0.00334	0.34%	206.9*
2013–2016	0.98557	–0.01443	1.45%	47.7

Source: own calculations; * we provide the results for the 2008–2012 period for technical reference, however, lack of significant differences between the parameter estimate and 1 suggest that the numbers in the 2008–2012 should be interpreted with great caution or not interpreted at all.

Data in Table 4 indicate that the process of convergence was unstable overtime. The slowest (if any) catching-up process took place during the 2008–2012 subperiod, that is during the global economic and financial crisis. For this subperiod, the parameter β stood at statistically insignificant 0.34% as compared

[14] The formulas according to which the parameters β and half-lives are calculated are given in: Próchniak M., Witkowski B., *Konwergencja dochodowa… op.cit.*, 58, 77.

with 1.69% in the 1996–2007 subperiod and 1.45% in the 2013–2016 subperiod. As we can see, the global crisis negatively affected the convergence tendencies in Europe. This outcome is in line with some other studies that indicated a deterioration in the process of convergence during the last years[15]. Since 2013, the catching-up process has accelerated again. If these tendencies are maintained, we can thus expect a further narrowing of the income gap between the more and less developed countries of the enlarged European Union.

Given these results, it is necessary to stress that convergence is not an automatic process. The countries may or may not converge. Everything depends on many factors, including the external and internal environment, economic policy, political situation etc. Hence, there is not guarantee that the catching-up process will be maintained in the future. Moreover, some divergence tendencies cannot be excluded.

The convergence process in Europe is not very rapid. The half-life for the whole period equals 23.2 years. It means that if the economic growth tendencies observed during 1996–2016 are maintained in the future, the countries of the enlarged EU will need almost 25 years to reduce by half their distance toward a hypothetical steady-state. These are similar estimates to those for the absolute convergence regression model without any additional control variables[16].

5. Conclusions

The analysis carried out in this paper yields the following findings:

- The HMM method makes it possible to identify turning points of the economic growth paths of the individual countries. When applied to the growth rates of GDP (on a quarterly basis) or economic sentiment indicators from survey data (on a monthly basis), the HMM algorithm identifies numerous turning points for the individual countries. There are many differences between the

[15] See e.g.: Mucha M. (2012), Mechanizm dywergencji gospodarczej w strefie euro, *Ekonomista* 4, 487–498; Stańisić N. (2012), The Effects of the Economic Crisis on Income Convergence in the European Union, *Acta Oeconomica* 62, 161–182; Borsi M.T., Metiu N. (2013), The Evolution of Economic Convergence in the European Union, *Deutsche Bundesbank Discussion Paper* 28/2013; Monfort M., Cuestas J.C., Ordóñez J. (2013), Real Convergence in Europe: A Cluster Analysis, *Economic Modelling* 33, 689–694.

[16] Matkowski Z., et al., Income Convergence… *op.cit*.

individual countries but some common tendencies (e.g. turning point prior to the global crisis) can also be found.

- For the quarterly GDP growth rates and the EU28 group as a whole, two turning points were identified: 3rd quarter of 2008 (a peak) and 3rd quarter of 2013 (a trough). These turning points were implemented as structural breaks in the β-convergence regression model.
- The catching-up process of the EU countries was not stable over time. The slowest convergence took place during the 2008–2012 subperiod, i.e. during the global crisis, when one may have serious doubts whether there was any convergence process at all. In the two remaining subperiods (1996–2007 and 2013–2016) the convergence was faster.
- Estimated regression equations have good statistical and economic properties which increases the reliability of the results. The application of the Bayesian model averaging approach reduces the bias due to improper selection of the explanatory variables.

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Konwergencja cykliczna i dochodowa krajów UE: identyfikacja punktów zwrotnych z użyciem ukrytych modeli Markowa

Streszczenie

Celem artykułu jest identyfikacja punktów zwrotnych w ścieżkach wzrostu gospodarczego krajów Unii Europejskiej na podstawie ukrytych modeli Markowa. Uzyskane tą metodą punkty zwrotne są następnie wprowadzone jako załamania strukturalne do modelu konwergencji typu β. Ujęcie łączy analizę zbieżności cyklicznej i dochodowej. Kwartalny szereg czasowy PKB dla całej grupy UE28 ma dwa punkty zwrotne (w latach 2008 i 2013). Hipoteza o konwergencji β została pozytywnie zweryfikowana, ale okazało się, że zbieżność β zachodziła w różnym tempie między punktami zwrotnymi. Najwolniejsza była w podokresie 2008–2012, czyli w trakcie globalnego kryzysu.

Słowa kluczowe: doganianie, zbieżność, konwergencja, ukryty model Markowa, Unia Europejska, ścieżka Viterbiego

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