TAF Journal of Administrative and Business Studies JABS

2019, **5**(5): 291-302

PRIMARY RESEARCH

Towards the similarity of the countries in terms of business cycle synchronization and income level equalization–empirical analysis

Michał Bernardelli [1], Mariusz Próchniak [2*], Bartosz Witkowski [3]

[1, 2, 3] SGH Warsaw School of Economics, Warsaw, Poland

Keywords

Catching up
Convergence
Extrapolation
European Union
Viterbi path

Received: 8 May 2019
Accepted: 9 August 2019
Published: 31 October 2019

Abstract

The article aims to verify the β convergence hypothesis in the entire EU28 group basing on the monthly data. Structural breaks in 2008 and 2013 have been introduced into the model basing on the turning points in the economic growth paths of the EU countries. The main value-added of the article is an assessment of monthly estimates of the rate of convergence with the use of the extrapolated data. The latter has been acquired using a monthly economic sentiment indicator based on the survey data. The β convergence hypothesis has been positively validated with the use of monthly data. However, different rate of convergence has been spotted between different turning points. Furthermore, big deviations of the estimates for extrapolated monthly data compared to the results based on the observed annual time series can be observed. The research focused on convergence every month enables a more profound analysis of the Gross Domestic Product (GDP) growth paths in the EU countries.

INTRODUCTION

Income level β convergence takes place when the less developed countries demonstrate a higher rate of economic growth than the more developed countries. Depending on the method of the analysis that has been selected to check for the existence and the rate of the process, contradictory conclusions can be found in the literature. Their source is not only the methods used, but also, if not to say: first of all, different data sets used in the analyses. Lack of robustness of the results concerning the convergence hypothesis is illustrated in the monography by Próchniak and Witkowski (2016). They are the short time series (especially in the case of post-socialist countries) and lack of stability over time of the attained results that make the analysis even more complicated. In most research, the dominating variable which describes the income level is related to the GDP. This means that the frequency of the data which are used to draw conclusions is in most cases not greater than annual and it is essential to wait 12 months so as to perform calculations for the next period (unless some forecasts are used for computation, those, however, are highly unreliable). In the case of GDP, quarterly statistics can be used, but this approach is rarely used - firstly, because of the need to eliminate seasonal fluctuations, and secondly – because it does not significantly improve the availability of data (quarterly GDP statistics are also published by statistical offices with large delay). It can be assumed that the existence of monthly data, which would correctly reflect fluctuations in domestic production and would be available without unnecessary delay, would allow not only a potentially more accurate estimation of the speed of the convergence process, but also a more frequent updating of calculations and thus identification of structural breaks in a more accurate way ahead of time.

The latter effect could be achieved provided that monthly data would be published relatively quickly and would reflect the reality, rather than expert forecasts, which often have little economic credibility. Theoretically, it is possible to use the GDP forecasts in convergence research and thus to obtain results taking into account the time series ending

*corresponding author: Mariusz Próchniak
†email: mproch@sgh.waw.pl

in the current or even a future period (and due to the time delays in the publication of the data, the forecast approach is very often used). It should be remembered, however, that the results are distorted due to the fact that data for recent years are just preliminary estimates. For example, the International Monetary Fund's forecasts are often used while the IMF makes annual forecasts of key economic indicators (including economic growth and GDP levels) even 5 years ahead (International Monetary Fund, 2017; Radya & Budi, 2019), but these are not results based on the real data.

The aim of this study is an attempt to estimate the rate of β convergence with the use of data with higher than annual frequency. In particular, the purpose of the article is to check whether the inclusion of monthly fluctuations in economic activity improves the inference as to the rate of convergence and what are the implications of such an approach in terms of the time stability of the catching-up process. The main research hypothesis, which is subject to verification in this study, says that determining the path of income convergence based on data more frequent than annual, and more specifically - monthly data, allows getting a complete picture of convergence.

In this study an attempt was made to estimate the rate of β convergence based upon time series which take into account monthly fluctuations in production dynamics and an analysis of time stability of parameters based on a model with structural breaks is carried out. Structural breaks are the turning points of the economic growth paths of the European Union (EU) countries. The survey covers 28 EU countries in the 1996-2017 period. In the regression equations, the dependent variable is the growth rate of real GDP per capita according to the Purchasing Power Parity (PPP). There are several variables in the set of regressors (including the initial income level per capita). This means that we analyze the phenomenon of conditional convergence. The β convergence model has been estimated for the entire period as well as for the sub-periods determined by turning points.

This paper supplements the earlier attempt to estimate the monthly rate of convergence (Bernardelli, Próchniak, & Witkowski, 2018; Lynn, 2015). The current study is based on an improved and modified methodology in line with the conclusions of the preliminary research.

While the method is commonly used in research devoted to convergence, the value added of the analysis is to propose a method of extrapolating data in order to extend the GDP per capita time series by consecutive months after the last year for which official data on the production volume are available. Extrapolation is performed on the basis of monthly observations of the Economic Sentiment Indicator (ESI). The ESI, based on survey data, is characterized by fast data availability. At the same time, it has very good leading and coincident properties in relation to changes in real economic activity e.g., (Matkowski, 1999; Revo, 2018).

The use of the survey based ESI to forecast changes in economic activity on a monthly basis took place in the following way. At the beginning, hypothetical time series on the volume of output were created with a monthly frequency and the speed of the convergence process was calculated on their basis. Then, the monthly estimates of the convergence rate obtained this way were compared with the results of estimation based on annual data.

The paper consists of five parts. After the introduction, the data used in the study and their short characteristics are presented. The identification of turning points with the use of hidden Markov models as in Bernardelli, Próchniak, and Witkowski (2017) is applied. The third part describes methodological details related to the adopted approach to extrapolation of time series and the Blundell and Bond system estimator, which was used to estimate the econometric income convergence model. Analysis of β convergence on a monthly basis is presented in the next, fourth part. The article ends with a summary and presentation of the most important results.

CHARACTERISTICS OF THE DATASET

The study used time series from databases of the Eurostat (2018), International Monetary Fund (2017), and World Bank (2017). Since many empirical studies show that conditional convergence analysis gives a better picture of convergence see e.g., (Rogut & Roszkowska, 2006), more variables than the initial level of GDP per capita have been included in the econometric convergence model. Namely, the following variables were used as a set of control factors in the β convergence model:

- GDP per capita at PPP in the previous year (constant 2011 prices, USD) [loggdp_*t*-1]
- CPI inflation (%) [inf]
- Investment rate (% GDP) [inv]
- Dynamics of exports of goods and services (% change) [exp].

The set of control variables takes into account mainly demand determinants of economic growth, which affect the most the annual fluctuations of the volume of production. The analysis does not include variables that would influence long-term economic growth determinants, such as human capital or institutions. These types of variables affect the economic growth from the supply side and do not

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

sufficiently explain the annual volatility of GDP per capita growth rates.

In addition to the above mentioned explanatory variables, time dummies are included. These are typically included in dynamic panel data models. Some of the reasons of their inclusion is the elimination of deterministic trend and the cyclical effect in the data.

Structural breaks in 2008 and 2013 have been included in the model (other structural breaks were, for example, introduced by Próchniak and Witkowski (2013). These breaks were determined on the basis of turning points in the economic growth paths of EU countries, identified with the use of hidden Markov models in the paper by Bernardelli et al. (2017). The identification of turning points in the aforementioned study was performed on the basis of the quarterly GDP growth rates for the total group of 28 EU countries (although the cited paper also uses estimates of structural breakdowns based on monthly economic sentiment indicators from survey data). The following turning points have been identified for the EU28 group:

- Q3 2008–peak.
- Q3 2013–trough.

This is illustrated in Figure 1.

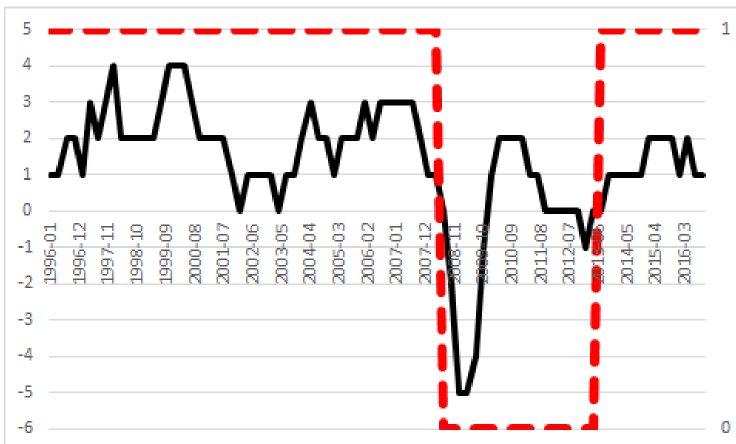

FIGURE 1. Turning points identified on the basis of quarterly GDP growth rates for the whole EU28 group. Source: Bernardelli et al. (2017).

Due to the introduction of structural breaks into the β convergence model, the regression equations in this study have been estimated for the entire period (1998-2016) as well as for three shorter sub-periods (1998-2007, 2008-2012 and 2013-2016). This approach allows assessing how the rate of convergence varied over time between structural breaks.

The analysis was not limited to the use of annual data. Extrapolation of the time series for subsequent months was also performed on the basis of monthly ESIs based on survey data carried out in individual EU countries [1].

The economic sentiment indicator is a compound index calculated as a weighted average of five sentiment indicators in particular sectors of the economy: industry (with a weight of 40%), construction (5%), services (30%), retail trade (5%) and households (20%). Sectoral indicators are arithmetic means of seasonally smoothed balances of answers to questions regarding a given subject area (e.g., industrial production in the case of the industry economic sentiment indicator). The overall ESI is calculated as an index with an average of 100 and a standard deviation of 10 for a specific period. The ESIs are published by the European Commission on a monthly basis.

Research devoted to the use of survey data in economic analyses see e.g., (Matkowski & Próchniak, 2008) prove that they are a good substitute for official statistics. Adamowicz, Dudek, and Walczyk (2004) show the usefulness of surveys for diagnosing and forecasting the economic situation. In turn, Adamowicz, Dudek, Pachucki, and Walczyk (2012) present an interesting analysis of cyclical fluctuations in selected EU countries based on the ESI.

The economic sentiment indicator delivered by the European Commission reflects the monthly changes in economic activity in a given country. Despite notable similarities of the tendency of changes throughout the EU, temporary discrepancies between individual countries can also be found. The values of the ESI from January 1996 to December 2017

[1] In Poland, this type of research is conducted, among others, by the Central Statistical Office and the Research Institute of Economic Development of the SGH Warsaw School of Economics.

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

for Germany, Poland and Italy are shown in Figure 2. A significant deterioration of sentiments in 2008-2010 related to the global crisis, as well as an upward trend from 2013 on are just ones of the many common national indicators' behaviors. However, some deviations from the common pattern can also be found - for example, much better economic sentiments in Poland in the mid-nineties or in Germany in 2011 than in other countries can be found.

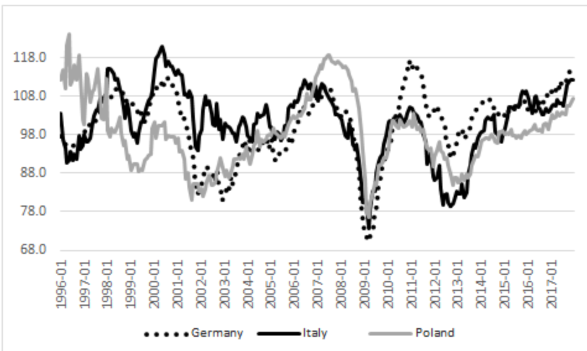

FIGURE 2. Economic sentiment indicator during 1996-2017 in Germany, Poland and Italy.

Monthly indicators offer the possibility of fast diagnose of the changes in economic activity and, as a result, allow for immediate reaction of politicians, for example in order to counteract the approaching recession or economic stagnation. In the case of the ESI, its suitability to assess monthly changes in the economic situation in a given country during the year can be determined by comparing its monthly values with its hypothetical values obtained by interpolating from data covering one observation per year. Such a comparison for Germany and Poland is presented in Figures 3 and 4 . In the process of interpolation, it is assumed that observations for January correspond to the real data, while observations in the remaining months are obtained with the use of linear interpolation of January values.

While the German economy seems to be quite stable, and deviations within particular years are not large, the Polish economy is characterized by higher monthly volatility of the business climate. This can be clearly seen in the example of data from the end of the 20th century, when fluctuations in economic activity in monthly data were significantly higher than the annual data indicated. Similarly, the crisis in 2009 affected much more the sentiments of Poles than the annual data could suggest. Such strong changes in the production volume would not be visible if the analysis took into account only the January data.

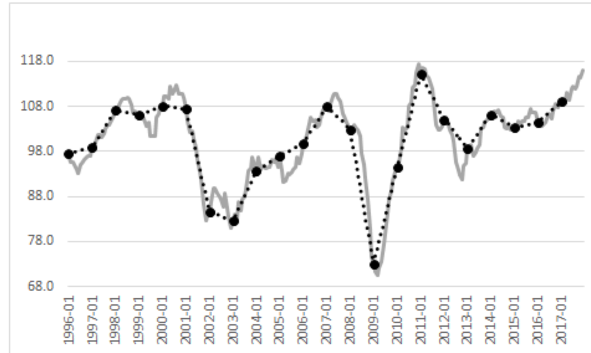

FIGURE 3. ESI in 1996-2017 in Germany: Monthly indications (solid line) and interpolated data (dotted line; the observations from January are marked).

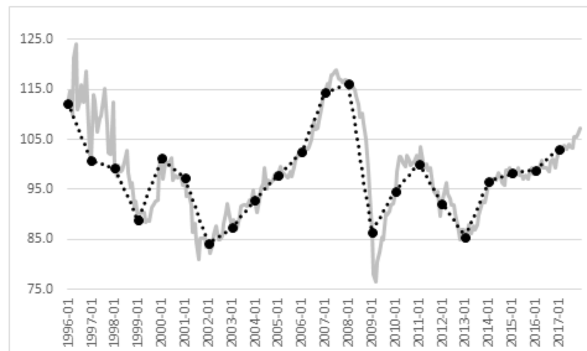

FIGURE 4. ESI in 1996-2017 in Poland: monthly indications (solid line) and interpolated data (dotted line; the observations from January are marked)

An even better picture of the differences between the averaged annual data and the values for individual months gives the comparison of the situation in which the values of the economic sentiment indicator from different months would be used as those for the whole year. Figure 5 shows the interpolated values of the time series, where the different months of the year (January, May or September) were adopted as the reference point.

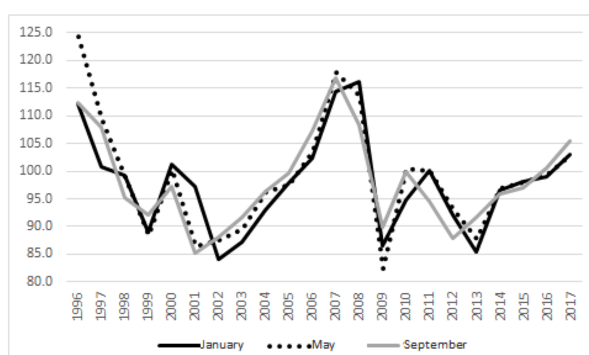

FIGURE 5. Economic sentiment indicator during 1996-2017 in Poland–values interpolated for different reference points: January, May or September.

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

Notable differences between sentiments in selected months provide empirical evidence for the legitimacy of the use of monthly data, if available. The problem arises if these are not available. The next part of the article presents a proposal on how to extrapolate missing data in a way which would allow for their use in the convergence model.

RESEARCH METHODOLOGY

Empirical analysis consists of two stages. The first one is the extrapolation of time series from annual to monthly data. This is necessary for the implementation of the second stage, in which the hypothesis of β convergence with structural breaks is verified based on the basis of monthly data.

Neoclassical models of economic growth (Solow, 1956); Mankiw, Romer, and Weil (1992); Nonneman and Vanhoudt (1996) confirm the hypothesis of conditional convergence, which means that it takes place as long as all the economies converge to the same steady state. The EU countries are relatively homogeneous in terms of economic, political and social factors, and one could assume that they have a common steady state, however, such an assumption would be highly simplifying. Therefore, in this study, we use the multiple regression model to analyze convergence. The latter also allows distinguishing the impact of factors other than the initial income level on the GDP growth rate.

Most empirical studies on economic growth, including the real convergence, are based on annual data[2]–primarily due to the data availability. The purpose of this study is to attempt to estimate β convergence with the use of data with higher than the annual frequency. In order to achieve this target, the data used in the study was extrapolated to the monthly frequency. This applies to all variables: GDP per capita at PPP [GDP], inflation rate, investment rate and export dynamics. The monthly ESI was used as the scaling element. For each variable var ϵ *GDP,inf,inv,exp* and for years *t* ϵ 1998,1999...,2016 an extrapolation procedure was used, which can be described in the following steps:

1. Determination of the monthly scaling factor $c_{t,m}$ for $m = 1, 2, .., 12$. The $c_{t,m}$ factor is determined on the basis of the monthly economic sentiment indicator sentiment_ind. More specifically, for the months between February (*m* = 2) and December (*m* = 12) in a given year t the factor value is equal to

$$c_{t,m} = \frac{sentiment\_ind_{t,m}}{sentiment\_ind_{t-1,m}} \quad (1)$$

where sentiment_ind$_{t,m}$ stands for the value of the index in year t and month *m* > 1. We assume that for January (*m* = 1) the value of the scaling factor $c_{t,1}$ = 1 for *t* = 1998, 1999, ..., 2016. The scaling factor is therefore the ratio of the ESI between a given month and the corresponding month of the previous year. A value greater than 1 means that the economic sentiments in a given month in relation to the same month of the previous year have improved, while values below 1 indicate the worsening of a business climate.

2. Calculating the extrapolated value of the $var_{t,m}$ variable for subsequent months of year *t* based on the true annual value *var(t)*. For *m* = 1 (January) and *t* = 1996, 1997, ..., 2016 it was assumed that

$$\text{var}_{t,1} = \text{var}(t) \quad (2)$$

The values of var in the remaining months of the year are calculated in relation to the value from January and take into account the relative sentiment change in a given month in relation to the same month of the previous year, reflected by the scaling factor $c_{t,m}$. The process of extrapolation can therefore be described as:

$$var_{t,m} = c_{t,m} * var_{t,1} \quad (3)$$

or

$$\text{var}_{t,m} = \frac{1}{c_{t,m}} * var_{t,1} \quad (4)$$

for *m* > 1 and *t* = 1998, 1999,.., 2016.

The application of formula (3) or (4) depends on a specific variable: if we expect it to increase as the sentiment in a given country improves, then formula (3) should be used. However, if the variable is a decreasing function of the sentiment then formula (4) needs to be applied. In the case of variables used in this study, extrapolation was performed with the use of the formula (3) in the case of gdp, inv and exp variables, while formula (4) was used in the case of inflation (*inf*).

The presented procedure assumes that the January data are fixed (and correspond to data for the entire year) while data for the other months extrapolated. However, since the assumption of assigning annual data to a particular month is meaningless from the point of view of verification of the research hypothesis, the values of variables for the whole year might well be assigned to any other month.

The extrapolation series for 1998-2016 for Poland are presented in Figures 6, 7, 8, 9. It is clearly seen on the figures both the non-linear character of the extrapolation and the fact that the short-term fluctuations of economic sentiments are significant.

[2] Due to limited space we do not present a detailed review of literature devoted to convergence analysis. Detailed references include, among others, Malaga (2004)

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

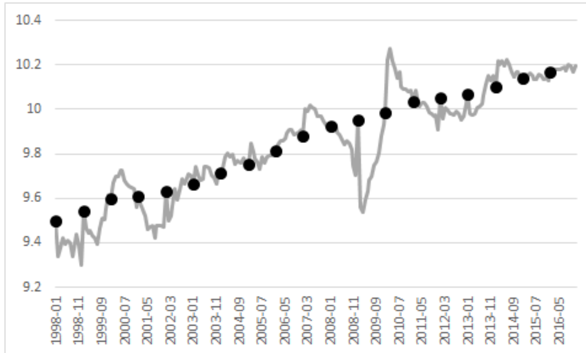

FIGURE 6. Results of extrapolation of log GDP per capita at PPP in Poland (solid line) against the observed values (dots).

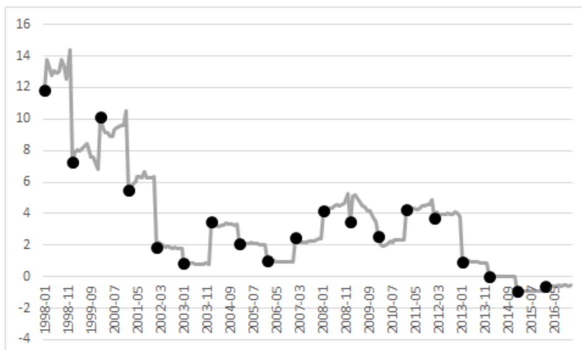

FIGURE 7. Results of extrapolation of inflation in Poland (solid line) against the observed values (dots).

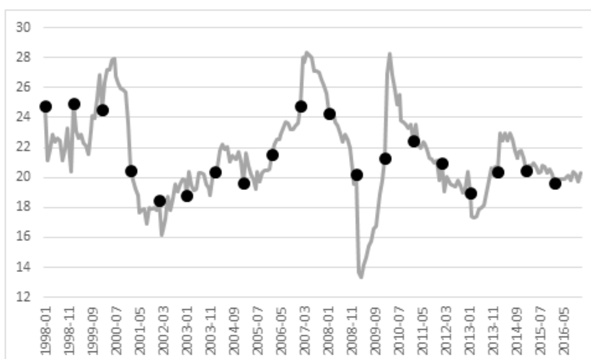

FIGURE 8. Results of extrapolation of the investment rate in Poland (solid line) against the observed values (dots).

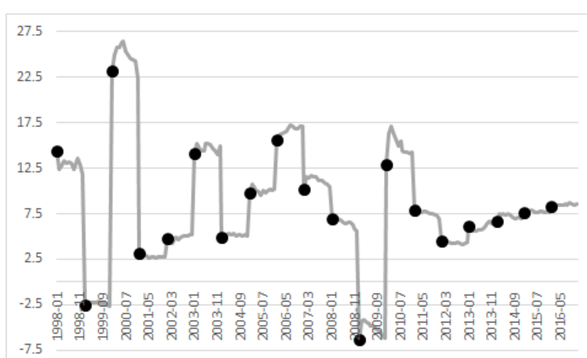

FIGURE 9. Results of extrapolation of the dynamics of exports of goods and services in Poland (solid line) against the observed values (dots).

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

The extrapolated data were used to construct a regression model to verify the β convergence in the EU28 countries. In the study, many models were estimated based on data from various time intervals. The details of the empirical study are presented in the next section. In this section, however, the models used in the econometric analysis are discussed.

The usual Barro regression for panel data–a typical model applied in the convergence analysis–is used (Barro & Sala-i Martin, 2003):

$$\Delta_{12} \ln GDP_{it} = \beta_0 + \beta_1 \ln GDP_{i,t-12} + x'_{it}\beta + \alpha_i + \gamma_t + \varepsilon_{it} \quad (5)$$

where $\Delta_{12} lnGDP_{it}$ is a change in the logarithm of real GDP per capita at PPP in *i*-th country in month t as compared to the same month of the previous year. β_0 is a constant, $lnGDP_{i,t-12}$ is the logarithm of the GDP per capita at PPP, delayed by one year (12 months), x_{it} is a vector of other GDP growth factors for i-th country in period t, α_i is the individual effect of *i*-th country, $_t$ is the individual effect of *t*-th period (time dummy), and ϵ_{it} is the error term. Due to the endogeneity of the explanatory variable $lnGDP_{i,t-12}$, it is necessary to transform the Equation (5) into:

$$\ln GDP_{it} = \beta_0 + (\beta_1 + 1) \ln GDP_{i,t-12} + x'_{it}\beta + \alpha_i + \gamma_t + \varepsilon_{it} \quad (6)$$

The latter enables proper instrumentalization of the explanatory variables and estimation of the above model with the use of the GMM estimator, such as the Blundell and Bond system GMM estimator used in this paper. Its application requires a small redefinition of the set of instruments used, taking into account that technically, it is the 12th order autoregressive model which is being estimated.

Various factors, both of demand and supply nature, usually play the role of regressors in the GDP growth analysis. In this paper we use three such variables: inflation rate, investment rate and export dynamics. Variables affecting the economic growth were mainly selected from the demand side, because in the study covering monthly output fluctuations, short-term dependencies between variables should be taken into account. Those variables, such as human capital or institutions, do not explain the short-term fluctuations in production dynamics, because the changes in the institutional environment take place smoothly over time. For example, the study by Rapacki and Próchniak (2014) suggests that some elements of the institutional environment have changed in a very limited way in the countries of Central and Eastern Europe over the last dozen or so years.

The set of explanatory variables used in the paper should be treated as an example. From the point of view of verification of research hypotheses, the set of control factors does not play a key role. Similar analysis could be repeated with the use of a different set of regressors, such as for example the one in Bernardelli et al. (2017). If more determinants are included, Bayesian model averaging is recently often used [3].

RESULTS AND DISCUSSION

The Analysis of the β Convergence

The adopted procedure of the convergence analysis is the same for the entire considered period (1998-2016) and for sub-periods defined by structural breakdowns, that is 1998-2007, 2008-2012 and 2013-2016. Parameters of a number of regression models defined by Equation (6) for the EU28 group were estimated with the use of data from each of the considered sub-periods and the whole period. Specifically, models based on monthly data were estimated. In each of the four considered cases, all estimated model parameters have one common initial date of observation, which is the January of the first year from the selected range denoted by t_{begin}. These models, however, have different remaining observations in the sense, where–starting from some year chosen for the given sub-period, hereinafter referred to as the "initial year of extrapolation" – the input data covers all monthly data from the first year of the subsample till the initial year of extrapolation and adds in the subsequent models one extra data from the consecutive month of the following year. For instance, the model ending in October 2007 as the last observation takes into account the value from October 2007, and earlier observations are values from the first months of the previous years. The formal description of all considered models is given in the rest of this paper.

Let us use $M(t_{begin}, t_{end}, m)$ to denote the model given by the formula (6) whose parameters were estimated on the basis of data from the following months:

year t_{begin} , January

[3] The details are given, among others, in: (Próchniak & Witkowski, 2013, 2016).

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

year $t_{\text{begin}} + 1$, January
year $t_{\text{end}} - 1$, January
year t_{end}, month m
The following sets of models were therefore obtained in the four cases examined in the study: 1. period 1998-2016, initial extrapolation year: 2006
Number of the constructed models: 132 (11 years * 12 months) Models:
$\mathcal{M}(1998, 2006, 1), \ldots, \mathcal{M}(1998, 2006, 12)$
$\mathcal{M}(1998, 2007, 1), \ldots, \mathcal{M}(1998, 2007, 12)$
. . .
$\mathcal{M}(1998, 2016, 1), \ldots, \mathcal{M}(1998, 2016, 12)$
2. Sub-period 1998-2007, initial extrapolation year: 2004
Number of the constructed models: 48 (4 years * 12 months) Models:
$\mathcal{M}(1998, 2004, 1), \ldots, \mathcal{M}(1998, 2004, 12)$
. . .
$\mathcal{M}(1998, 2007, 1), \ldots, \mathcal{M}(1998, 2007, 12)$
3. Sub-period 2008-2012, initial extrapolation year: 2011
Number of the constructed models: 24 (2 years * 12 months) Models:
$\mathcal{M}(2008, 2011, 1), \ldots, \mathcal{M}(2008, 2011, 12)$
. . .
$\mathcal{M}(2008, 2012, 1), \ldots, \mathcal{M}(2008, 2012, 12)$
4. Sub-period 2013-2016, initial extrapolation year: 2015
Number of the constructed models: 24 (2 years * 12 months) Models:
$\mathcal{M}(2013, 2015, 1), \ldots, \mathcal{M}(2013, 2015, 12)$
. . .
$\mathcal{M}(2013, 2016, 1), \ldots, \mathcal{M}(2013, 2016, 12)$

Tables 12 present estimates of selected four out of 228 models, one from each considered period. Tables 1 summarizes the estimates and basic statistical properties of the exemplary model *M* (1998, 2016, 1). The adopted methodology requires that the dependent variable be the level of GDP per capita in the current year, instead of the growth rate (according to the formula (6)). This means that convergence should be considered confirmed if the parameter standing at the variable $\text{loggdp}_t - 1$ is less than 1 (and is statistically significant).

The results indicate that β convergence occurs both in the whole considered period (an exemplary model from this period is included in Table 1) and in each of the sub-periods (examples of models are described in Table 2).

TABLE 1. Estimates of the parameters of an exemplary β-convergence model for EU28 countries: *M* (1998, 2016, 1).

Variable	Coefficient	Standard Error	*p*-Value
loggdp_*t*-1	0.86356	0.01597	0.0000
Inf	-0.01228	0.00167	1.75E-13
Inv	0.01458	0.00141	0.0000
Exp	-0.00123	0.00050	0.0139

Source: Own calculations. Estimates of time dummies omitted.

TABLE 2. Estimates of the parameters of exemplary β-convergence models for different sub-periods (EU28 countries)

Variable	Coefficient	Standard Error	*p*-Value
Sub-period: 1998-2007; model: *M* (1998,2007,1)			
loggdp_*t*-1	0.89810	0.02121	0.0000
Inf	-0.00644	0.00208	0.0020
Inv	0.01192	0.00199	2.2E-09
Exp	0.00032	0.00074	0.6715
Sub-period: 2008-2012; model: *M* (2008, 2012, 1)			
loggdp_*t*-1	0.87276	0.03744	0.0000
Inf	-0.01975	0.00354	2.4E-08
Inv	0.02061	0.00275	6.3E-14
Exp	-0.00387	0.00098	7.2E-05
Sub-period: 2013-2016; model: *M* (2013, 2016, 1)			
loggdp_*t*-1	0.90388	0.03172	0.0000
Inf	0.01938	0.00690	0.0005
Inv	0.01122	0.00309	0.0003
Exp	0.00300	0.00140	0.0322

Source: Own calculations. Estimates of time dummies omitted.

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It is better to present the monthly volatility of convergence on a graph. The parameter values for the variable log-gdp_t-1 in particular periods are shown in Figures 10, 11, 12, 13. These values were compared with the expected monthly parameter values determined by the linear interpolation.

Months shown on the horizontal axis of Figures 10, 11, 12, 13 indicate the last observation in a given model. For example, the value of 0.87 observed in Figure 10 in March 2014 suggests that in the model based on the period between January 1998 and March 2014 (estimated with the use of monthly data) the estimate of the parameter on the initial income level was 0.87, which means that convergence occurred in this period. In turn, the value of 0.85 for May 2014 suggests that in the model covering the period from January 1998 to May 2014, the estimate of the parameter on the initial income level was equal to 0.85, which suggests that between January 1998 and March 2014, the convergence was slower than between January 1998 and May 2014. The results shown in Figures 10, 11, 12, 13 confirm the occurrence of convergence in all the analysed periods. In the case of all the estimated models (after transformation, i.e., as in Equation (6) the estimates of the parameter on the initial level of GDP per capita are within the (0;1) range. Tables 1 and 2 also show that those parameters are statistically significant which corresponds to the negative estimate of the convergence parameter in pre-transformed classical convergence Equations (5) that further corresponds to the inverse relationship between the initial level of GDP per capita and the future rate of economic growth.

The character of convergence is conditional since the estimated equations also include other explanatory variables. The obtained results are consistent with most literature. Numerous empirical studies of convergence in the enlarged European Union exist and most of them confirm the occurrence of conditional convergence, although the rate of convergence and the conclusions regarding its time stability are different [4].

The estimated models are, in general, economically and statistically reliable considering the impact of other explanatory variables on the rate of economic growth. The averaged estimate of the inflation is negative (Table 1), which means the unfavourable effect of the price increase on the dynamics of output. The positive estimate of the inflation rate parameter in the period 2013-2016 (Table 2) suggests that deflation processes in Europe that have taken place recently had a negative effect on economic growth (although the reverse causal relationship cannot be excluded in this case). The models confirm the positive impact of investment on output growth (the estimate of the inv parameter in all the equations given in Tables 1 and 2 is statistically positive). The least clear and unambiguous are the results for the dynamics of exports.

Despite the occurrence of convergence in the entire period and in particular sub-periods, its rate proves different. In Table 3 the averaged estimates of parameters on the initial income level from all models estimated for a given period are provided. The estimates of the parameter in the transformed model, defined by Equation (6), are given in the second column, and the third column provides the corresponding estimate in the pre-transformed model (5). These were used to compute the coefficient of convergence rate and the so-called half-lives [5](half-life is defined as the number of years that must elapse, so that the considered countries halve the distance between the current level of income and the hypothetical steady state equilibrium provided that they maintain current development pattern). The steady state is in turn determined by explanatory variables included in the regression equation as control variables.

The data in Table 3 indicate that the rate of convergence was not constant over time. The fastest convergence occurred in 2008-2012, that is during the global crisis. This result is slightly different from the previous calculations based on annual data from official statistics Bernardelli et al. (2017) and from some other empirical studies suggesting the emergence of divergence tendencies in income levels during the crisis (see, for example,Borsi and Metiu (2015); Monfort, Cuestas, and Ordonez (2013) Mucha (2012); Stanišić (2012). This is probably due to the fact that consumer sentiments during the global crisis showed a strong tendency to become similar, which is manifested by the rapid convergence obtained on the basis of ESI-based data, even if data from official economic statistics suggested a slowdown in convergence processes.

It should be borne in mind that the different speed of the convergence process in individual periods is not only due to differences in the rate of economic growth, but also from different values of explanatory variables and the initial level of GDP per capita.

4 Recent studies that concern this problem include: Batóg (2013);Forgó and Jevcák (2015); Grzelak and Kujaczyńska (2013); Jóźwik (2017); Matkowski, Prochniak, and Rapacki (2016); Rapacki and Próchniak (2014).

5 Formulas used to attain the β estimates and the corresponding half-lives are provided in: Próchniak and Witkowski (2016).

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

FIGURE 10. Estimated coefficients for the variable loggdp_*t*-1 in the period 1998-2016 for models based on the extrapolated data (solid line) and real data (points). The predicted values of the coefficients determined on the basis of linear interpolation are denoted by the dotted line. The final month of the period for which the model was estimated is marked on the horizontal axis (in each case the data beginning in January 1998 are used).

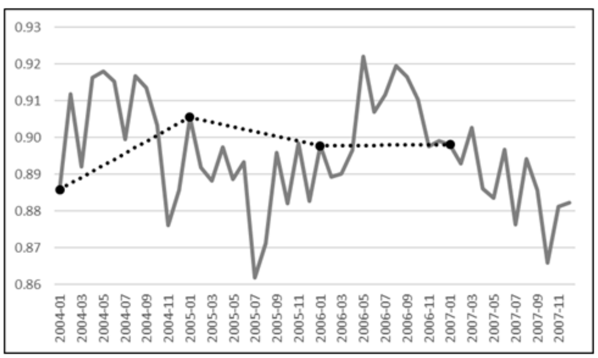

FIGURE 11. Estimated coefficients for the variable loggdp_*t*-1 in the period 1998-2007 for models based on the extrapolated data (solid line) and real data (points). The predicted values of the coefficients determined on the basis of linear interpolation are denoted by the dotted line. The final month of the period for which the model was estimated is marked on the horizontal axis (in each case the data beginning in January 1998 are used).

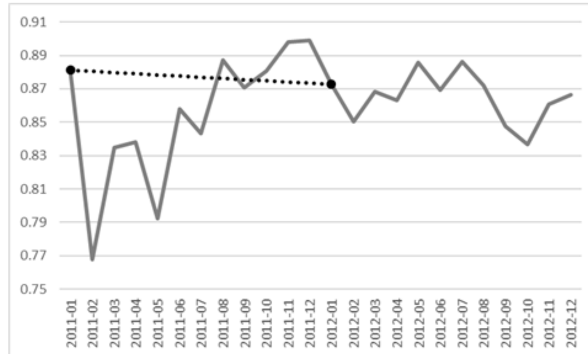

FIGURE 12. Estimated coefficients for the variable loggdp_*t*-1 in the period 2008-2012 for models based on the extrapolated data (solid line) and real data (points). The predicted values of the coefficients determined on the basis of linear interpolation are denoted by the dotted line. The final month of the period for which the model was estimated is marked on the horizontal axis (in each case the data beginning in January 2008 are used).

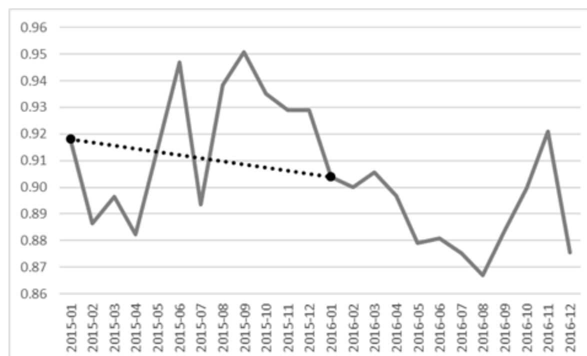

FIGURE 13. Estimated coefficients for the variable loggdp_*t*-1 in the period 2013-2016 for models based on the extrapolated data (solid line) and real data (points). The predicted values of the coefficients determined on the basis of linear interpolation are denoted by the dotted line. The final month of the period for which the model was estimated is marked on the horizontal axis (in each case the data beginning in January 2013 are used).

TABLE 3. β coefficients and half-lives

Period	Initial Income Level Parameter in the Transformed Convergence Model (6)	Initial Income Level Parameter in the Non-Transformed Convergence Model (5)	β Convergence Parameter	Half-Life (Years)
1998-2016	0.86552	-0.13448	14.44%	4.8
1998-2007	0.89570	-0.10430	11.01%	6.3
2008-2012	0.85953	-0.14047	15.14%	4.6
2013-2016	0.90454	-0.09546	10.03%	6.9

Moreover it is necessary to emphasize that the application of the other control variables usually leads to different estimates of the speed of convergence. Such an outcome is economically justified because the concept of conditional con-

ISSN: 2414-309X
DOI: 10.20474/jabs-5.5.4

vergence is tested here. In such a case, the pace of convergence is counted toward a specified steady-state, defined by the set of explanatory variables. If another set is included, the steady-state will be different and the pace of conditional convergence will be different as well. This is also one of the reasons of the differences between these results and the results of the other studies on the subject.

The results given in Table 3 are averaged results for many models. Individual models are estimated in the form of multiple regression equations. Statistical and econometric methods included in the calculations are not additive and the results for the whole period do not have to be even approximately equal to the average for individual sub-periods. This takes place in the presented situation.

Looking at the above results, it should be emphasized that convergence is not an automatic process. The exact nature of the path of economic growth depends on many factors, such as economic policy, internal and external situation, institutional environment, political stability. There is, therefore, no guarantee that the convergence processes in Europe will continue. It cannot be excluded that the periods of income-level divergence will appear in the future.

Analysis of the fluctuations of the rate of convergence on a monthly basis suggests that annual data give an incomplete picture of convergence. Figures 10, 11, 12, 13 show that the convergence parameter exhibits strong monthly fluctuations, which result from the high volatility of economic growth paths and their irregular changes in particular months. Thus, annual data, which should be viewed as the averaged monthly data, distort the actual shape of the convergence path. This confirms the validity of the main research hypothesis, which states that the data with a frequency greater than annual (e.g., monthly data analyzed in this study) provide a more complete picture of convergence.

The obtained results show that continuous analyses of economic growth and convergence processes are necessary. Monthly volatility of the β convergence rate seems to confirm the need to use more frequent than annual series of macroeconomic indicators. Availability of the survey data enables monitoring of the economic situation on a monthly basis.

CONCLUSION

The aim of the paper was to validate the existence of β convergence in the whole EU28 group with the use of the monthly data. Following the main research hypothesis, estimating the path of income convergence with the use of data whose frequency is higher than annual (more specifically - the monthly data) allows to obtain a fuller picture of the convergence phenomenon. The analysis covers the period 1996-2017 and 28 EU countries. On the basis of turning points in the paths of economic growth identified with the use of hidden Markov models, the structural breaks in 2008 and 2013 were introduced to the regression model. As a result, convergence models for 1998-2016 and three sub-periods were estimated: 1998-2007, 2008-2012 and 2013-2016.

IMPLICATIONS

The main value added of the study is obtaining monthly estimates of the rate of convergence based on the data that are extrapolated with the use of monthly values of the economic sentiment indicator based on survey data. On the basis of monthly data, the β convergence hypothesis was positively verified, however (as expected) the convergence occurred at different rates between the different turning points.

In addition to this, large deviations in estimates based on extrapolated monthly data were observed compared to the results based on annual time series. The research on convergence on the monthly basis thus allows to get a more complete picture of the economic growth paths in EU countries.

ACKNOWLEDGEMENT

The research project has been financed by the National Science Centre, Poland (project number: 2015/19/B/HS4/00362).

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