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**Article**

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# The Measurement of Real Convergence in the EU-28 by Using the Entropy Method[1]

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**Abstract**

*A convergence process, defined as the process of the economic indicators harmonization within the European Union, can be observed from the nominal and the real point of view. Real convergence is a quite interesting issue since it has a long-term influence on the growth and development of this regional integration as a whole and its competitive position in the global market. Therefore, the topic of this paper refers to the measurement of real convergence in the EU during the period from 2004 to 2016, using the entropy method. The entropy method is a fairly suitable method for investigation of real convergence since it measures the divergence across the sub-systems of a certain system (in this case, the EU member countries) by the level of entropy. In this paper, the real convergence is measured by the PPP-based GDP per capita, the unemployment rate, the GDP per worker and the gross capital formation (as % of the GDP). The obtained results pointed out that the most pronounced differences among EU economies exist in labor productivity, represented by GDP per worker, while the differences in domestic investment, expressed by gross capital formation, were the lowest.*

**Keywords**: *real convergence, the EU, European integration, the entropy method*

**JEL Classification**: O47, O52, F15

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## Introduction

One of the major goals of the European Union formation is uniform growth across the Member States. The necessity of reaching a similar degree of development among the EU economies puts the concept of convergence in the forefront. The process of convergence implies the leveling of the development among the Member States primarily by boosting the development of its underdeveloped economies so that they could reach the performance of the developed ones over time. The process of convergence in the EU is usually viewed in the light of meeting Maastricht criteria, or the so-called nominal convergence. The nominal convergence refers to predefined requirements for accessing a Monetary Union, which are related to inflation, long-term interest rates, the exchange rate, a budget deficit, and the public debt. However, the concept of real convergence is equally important and has become even more important after the financial and debt crisis that the EU members have been faced in the past decade. The real convergence implies a reduction in the difference among EU economies in the so-called real economic indicators, primarily those related to production and employment.

The Member States that have not joined EMU yet should compliance with a convergence program, which clearly defines the goals to be met. Also, these countries have an obligation to incorporate these goals into their national convergence programs and they are related to the capital expenditure, real growth rate, employment and inflation (EC, 1997). These goals largely coincide with the goals of the Lisbon Strategy, which is aimed at improvement of competitiveness and achieving sustainable growth, through the increasing economic growth, stimulating knowledge and innovation, providing better jobs within the EU and increasing the employment (Bongardt et al., 2013). Reducing the regional differences in the level of development is persistently gaining in importance, especially taking into account the fact that the number of EU members is not final yet. Although economic and other differences among countries and regions have existed since its very inception, with every new enlargement, the issue of the differences in development becomes more and more popular.

Hence, the European Commission has developed *The Policy of Economic, Social and Territorial Cohesion*. The objectives of the cohesion policy in the period from 2007 to 2020 (which include two programming periods: first, from 2007 to 2013 and second from 2014 to 2020) relate to (EU, 2011): 1. the convergence process, which tends to promote growth and lead to the real convergence of the Member States whose GDP is lower than 90% of the EU average, 2. the process of enhancing regional competitiveness and employment, aimed at reducing unemployment, and 3. European territorial cooperation, which refers to the

strengthening of cross-border and regional cooperation. The key instrument of this policy is an investment in less developed countries and regions in order to accelerate their development, using the three Funds: the Cohesion Fund, the European Regional Development Fund, and the European Social Fund. The implementation of cohesion policy has boosted development in underdeveloped EU economies in the previous period, but this policy continues to promote growth and employment through its support programs aimed at achieving uniform growth and development. However, although a lot of measures and funds are aimed at reducing the development gap between the Member States, there are still significant differences in some key real sector indicators.

In that sense, the main goal of this paper is to measure the real convergence in the EU in the period 2004 – 2016 using the entropy method. Until now, this method has been used for investigation of regional development in a single country, but in this paper, it is used for analysis of real convergence across European Union, as a regional integration in which leveling of economic development of Member States represents very important goal to be met.

## 1. Real Convergence Indicators through Literature Review

During the last decade, the EU has been facing serious challenges, before all global economic crisis and sovereign debt crisis. In the next decade, it will face even more pronounced challenges in the light of Brexit, migrant crisis and strengthening the competitive pressures in the global market. In order to access those challenges, the EU should pay special attention to achieving real convergence across the Member States, which should result in productivity growth and improvement of the EU competitive position in the global market. The issue of real convergence is specific and it has been discussed by economic researchers, policymakers, and the wider public. The literature on real convergence is very comprehensive and multidimensional and research results are mixed, depending on a number of countries, time horizon, methodology, and type of convergence.

The theorists of the neoclassical growth model have set the theoretical basis of convergence (Solow, 1956; Mankiw, Romer and Weil, 1992; Sala-i-Martin, 1996) – β (beta) convergence and σ (sigma) convergence. β convergence exists if the underdeveloped countries record faster growth than the developed ones, while σ convergence exists if the income dispersion among the economies within the observed group of countries is being reduced over time. The very important question arising from the investigation of this phenomenon is choosing the most appropriate indicators. Until now, there is no wider consensus about a set of real convergence indicators. However, Marelli and Signorelli (2010) emphasized that

real convergence analysis implies the evaluation of the real economic variables such as production, income, employment, and productivity.

The general conclusion of the increasing number of authors is that the real convergence in the EU has not been achieved yet (Borsi and Metiu, 2015; Becker, Egger and von Ehrlich, 2018; Alcidi, 2019; Monfort, Ordóñez and Sala, 2018; Cuestas Monfort and Ordóñez, 2012). However, there are some group of countries within EU-28 where convergence exists. Most authors have found evidence for convergence within group of the New Member States which recorded faster development then old ones in terms of GDP per capita, labour productivity, Gini coefficients, unemployment and employment (Deichmann et al., 2017; Grzelak and Kujaczyńska, 2013; Alcidi, 2019; Monfort, Ordóñez and Sala, 2018; Simuț, 2015; Bucur, 2012; Borsi and Metiu, 2015). Deichmann et al. (2017) used self-organizing maps to examine convergence between European economies and, according to obtained results, they find evidence of β-convergence in the eleven New Member States that had been part of the eastern bloc toward the EU-15, but at various paces. The Baltic states of Lithuania and Latvia experience some of the greatest observable convergence, followed by Estonia, the Visegrad countries, Croatia and Slovenia. Also, they pointed out that Ireland has experienced nominal and real divergence during the period 2011 – 2013.

Grzelak and Kujaczyńska (2013) stated that some progress in terms of real convergence has been recorded since 2007, but the differences between EU countries are still significant. On the basis of their research results, the issue of the EU regional policy efficiency has arisen. They stated that funds allocated to underdeveloped economies according to regional policy cannot give expected results in the short-term. On the other hand, Becker, Egger and von Ehrlich (2018) also have analyzed the effects of EU regional policy over the four program periods 1989 – 1993, 1994 – 1999, 2000 – 2006, 2007 – 2013 and came to a contrary conclusion – that convergence exists in the short-term and that similarities between countries have been reduced drastically during the crisis.

Alcidi (2019) pointed out that the inequalities between the richest and the poorest Member States are greater after the introduction of the euro, despite the high growth during the pre-crisis period. Although the idea of EU integration has been based on the argument that deeper economic integration would lead to income convergence, this argument seems wrong and there two evidences for that. The first one is theoretical and it implies that economic integration leads to agglomeration of production and concentration of income and the second one is empirical and it is based on the experience of the US, which is often taken as a benchmark for the EU integration process. The empirical result has proven that although US nations have been integrated for a very long time they do not

progress anymore in terms of GDP per capita convergence. So there is the divergence in this indicator across states similar to the one that exists in the EU.

Having in mind that the introduction of euro and, in that sense, meeting the nominal convergence criteria are very important prerequisite for achieving real convergence, some authors emphasized the importance of real convergence across EMU countries (Franks et al., 2018; Borsi and Metiu, 2015; Diaz del Hoyo et al., 2017). Franks et al. (2018) examined economic convergence among euro area countries and came to the conclusion that real convergence among the original EMU members has not occurred. They identified a lack of convergence in GDP per capita PPP and productivity in the first decade of the euro adoption and divergence since the crisis. Although there was some convergence of unemployment rates in the pre-crisis period, it has been partially reversed since the emergence of the global economic crisis. On the other hand, they identified significant convergence of GDP per capita PPP among those countries who have joined the EMU in 2007 or later and according to that concluded that monetary union successfully established a credible monetary policy framework with low inflation and a stable exchange rate contributed to convergence among those countries. In order to obtain the real convergence among all EMU countries, and ultimately at the EU level, the completion of the Banking Union, Capital Markets Union, and greater use of macro-prudential regulations should be obtained.

On the other hand, there are authors that proved evidence for the existence of real convergence across EU economies (Sorić, 2017; Młynarzewska-Borowiec, 2017; 2018; Bolea, Duarte and Chóliz, 2018; Dreyer and Schmid, 2017). Using the unit root test with up to two structural breaks, pointed out that the global economic crisis has not stopped the long-run real convergence within the EU. In addition, their research was focused on the identification of relevant macroeconomic variables, which coincide with up and down breaks in the convergence process. According to obtained results, they pointed out that downward breaks were followed by significant declines in investments and depreciation, while the growth of unit labor cost and appreciation coincide with upward breaks. The importance of external trade in explaining structural breaks is also pointed out.

Młynarzewska-Borowiec (2017) investigated the β-convergence process between the EU Member States in the period 2000 – 2014 and identify the existence of real convergence of GDP per capita PPP and total labor force in the considered period in the analyzed group of 27 Member States. They also tried to identify channels of convergence and their results pointed out that the speed of convergence was much stronger among the New Member States than in EU-27. On the other hand, in the EU-15 group, the relatively underdeveloped countries did not manage to catch up with the advanced ones. They also tried to identify

the channels of convergence. One of them is neoclassical catching-up which refers to the Solow-Swan growth model, implying that richer economies grow slower than poorer ones. In contrast, the technological catching-up approach implies that a catching-up process occurs due to greater capabilities of poorer countries (followers) to imitate and adopt the technology of richer ones. The obtained results proved that in the considered period, both channels of convergence (neoclassical and technological) existed in the group of EU-27, the technological mechanism was more important than the neoclassical one, especially among New Member States, while in the group of Old Member States there is no evidence for technological channel of convergence and β-convergence process. In the next research, the same author (Młynarzewska-Borowiec, 2018) identify the existence of convergence across EU-28 during the period 2004 – 2015 and came to the same results as in the previous study. In addition, usage of panel growth regression model enabled identification of the particular determinants that had the most pronounced impact on the pace of economic growth and real convergence process in the EU. The results have shown that the greatest influence on the convergence rate in the EU was exerted by positive institutional changes related to the transparency of law and the efficiency of its application in society and in EU-13 group these institutional factors were related on improvement of the institutional environment quality, the gradual liberalization of trade and technology transfer.

Cabral and Castellanos-Sosa (2019) examined the effects of the global economic crisis on economic growth and convergence across EU economies during the period 1973 – 2012. The results of cross-sectional and dynamic panel data techniques pointed out that the crisis has resulted in the convergence rather than divergence. The effects of the crisis were more pronounced in advanced economies and, accordingly, such outcome allowed less developed Member States to recover more quickly. Moreover, the obtained results pointed out that the establishment of the European Union has contributed toward economic growth and convergence, while there is no similar evidence regarding the European Monetary Union.

## 2. Data and Methodology

### 2.1. Data

The literature in the field of real convergence is very extensive and the authors used different indicators to evaluate the level of convergence in the EU (Soukiazis and Castro, 2005; Alexe, 2012; Stanišić, 2016; Simionescu, 2017;

López-Bazo et al., 1999; Monfort, Cuestas and Ordóñez, 2013; Barry, 2003; Hein and Truger, 2005; Marelli and Signorelli, 2010; Martin and Sanz, 2003; Borys, Polgár and Zlate, 2008). According to that, the first step in real convergence analysis is the identification of the appropriate set of indicators that will show the level of real convergence in the most accurate manner. In this paper, the following indicators of real convergence are used:

1. GDP per capita (PPP-based) as a measure of the total economic activity of a country,
2. GDP per worker as an indicator of productivity,
3. The unemployment rate as an indicator of the labor market inequalities,
4. Gross capital formation (as a % of the GDP) as an indicator of domestic investments.

All data were collected from the Eurostat official statistics for the period 2004 – 2016 (Eurostat, 2018). The reason for choosing this period lies in the fact that this is the period from the biggest enlargement of the European Union to the present state that represented by data for 2016, as the last available data.

### 2.2. Entropy Method – the Concept and Application

There are different definitions of entropy, but it can be generally defined as a measure of chaos or disorder of the system (Downarowicz and Frej, 2001). This concept is closely related to the laws of thermodynamics since the entropy was first applied in thermodynamics, and then Shannon introduced it into the information theory (Shannon, 1948). The great success of Shannon's (1948) information entropy theory has given impetus for development of many applications of entropy in economics – in economic modeling (Caticha and Golan, 2014; Sequeira, Gil and Afonso, 2018), structural change analysis (Hilbert, 2016; Joya, 2015), finance (He, Shang, and Xiong, 2018; Zhou, Cai and Tong, 2013; Yu, Lee and Chiou, 2014) and like. Especially interesting are papers with application of entropy in regional analysis (Bouvet, 2010; Villas-Boas, Fu and Judge, 2019; Salois, 2013; Liang, Si and Zhang, 2017; Czyz and Hauke, 2015) that are most similar with research topic of this paper.

Measuring the real convergence in the EU in this paper is applied according to the methodology used by Czyz and Hauke (2015). They analyzed the differences in the development of regions in Poland over the years 2005 – 2012 using the Shannon entropy Index. Taking into account that the EU represents regional integration aiming to obtain harmonized development and cohesion, the authors concluded that the same approach can be applied at the EU level. Analogously to the national economy, where national authorities have appropriate instru ments and funds to obtain balanced regional development, European Union has

appropriate policies and funds aimed at narrowing the development gap among the Member States. In addition, it should be noted that achieving harmonized development is much more difficult to coordinate and achieve in such a wider area. In that sense, the authors propose a new approach for assessment to diversity that can improve the information basis for a redefinition of policy framework and redirection of funds aimed at achieving the real convergence in new programming period 2014 – 2020.

Introduction of the entropy concept in the regional analysis is result of a growing number of economists that were using a system approach in the analysis of economic phenomena. Namely, the economic phenomena are usually viewed as systems, in the sense of entities consisting of interdependent sub-systems, and the concept of entropy is frequently being used by economists to take an insight into the uncertainty of systems. So, the concept of entropy has found applications in regional systems, which are overloaded with uncertainties. In regional science, the entropy approach attempts to identify the most probable spatial structure of a system, which is capable to adapt to numerous uncertain spatial states. Having that in mind, it can be concluded that the entropy in the regional analysis is a probability concept, illustrating the outcome of a stochastic process (Nijkamp and Paelinck, 1974).

There are various entropy statistics for analysis of regional disparities, but one of the most commonly used is the Shannon entropy index. In accordance with the approach of Czyz and Hauke (2015), the Shannon entropy index is calculated as follows.

The Shannon entropy measures the amount of uncertainty about the event associated with an appropriate probability distribution. In this case, those „events" are the real convergence indicators and they can be marked by $x$. The information obtained from the appearance of a certain event is determined by the monotonically decreasing function with probability $p$, which can be displayed in the form $\log 1/p = -\log p$. For a series of events $x_i$ with probabilities $p_i$ it can be defined that

$$0 \le p(x_i) \le 1, \ \sum_{i=1}^{n} p(x_i) = 1 \tag{1}$$

where $x_i$ is appropriate real convergence indicator for country $i$, where $i = 1, 2 \ldots n$ (in this case $i = 1, 2, \ldots 28$).

The measure of entropy $H(x)$, defined by Shannon (1948), is the expected value of this series that can be presented as:

$$H(x) = -\sum_{i=1}^{n} p(x_i) \log p(x_i) \tag{2}$$

or

$$H(x) = \sum_{i=1}^{n} p(x_i) \log_2 \frac{1}{p(x_i)} \tag{3}$$

The use of the logarithm function with base 2 implies the measurement of information in bits.

The presented Shannon entropy function has the following characteristics (Czyz and Hauke, 2015):

1. $H(x) \geq 0$, i.e. it is a positive value,
2. $H(x)$ assumes the value of 0 with $p(x_i) = 1$ for certain i, which means the absence of uncertainty among indicators,
3. $H(x)$ assumes the highest value equal to $\log_2 n$ when all values of $p(x_i)$ are equal for $i = 1, 2, \ldots n$. The maximum value $H(x)$ implies a complete uncertainty or disorder.

The entropy statistics $H(x)$ gives the basis for creating a Shannon entropy index $I(x)$ as a measure of differences among countries according to certain relative convergence indicator $x$. It is calculated as follows:

$$I(x) = H(x)_{max} - H(x) = \log_2 n - \sum_{i=1}^{n} p(x_i) \log_2 \frac{1}{p(x_i)}$$

$$= \sum_{i=1}^{n} p(x_i) \log_2 \left[ n\, p(x_i) \right] \tag{4}$$

$$\text{for } 0 \leq I(x) \leq \log_2 n$$

where $I(x) = 0$ shows the absence of inequality, while $I(x) = \log_2 n$ denotes maximum inequality.

In the end, some similarities and differences in this approach in comparison to traditional measures of real convergence (β-convergence, and σ-convergence) should be mentioned. Shannon entropy index can be viewed as one type of σ-convergence, having in mind that it calculate disparities among all Member States, unlike to β-convergence that relies on catch-up of New Member States (NMS) in relation to Old Member States (OMS). On the other hand, unlike to σ-convergence (which is usually measured by the coefficient of variation), Shannon entropy index is not sensitive to changes in the mean, but it calculates the level of divergence in certain real convergence indicator among the Member States. This is particularly important after the global economic crisis and a sovereign debt crisis that had a different impact on EU economies. For example, the

position of some Member States with an initially higher GDP per capita has deteriorated (especially in Greece, Cyprus, Spain, and Portugal) and they did not manage to keep pace with the EU average, which significantly lowered the mean. Such an outcome can have a significant influence on the measurement of real convergence. This is even more pronounced problem for calculating β-convergence.

## 3. Discussion of Results

Using the formula (4) from the previous section the Shannon entropy index is calculated for considered four real convergence indicators. The obtained results are presented by a curve representing the trend of Shannon entropy index during the period 2004 – 2016. During the analysis of the results, one should have in mind that, in the case of a convergence analysis, the higher entropy implies the process of divergence, while the lower entropy implies that there is convergence in the observed indicator (Simionescu, 2014). In the best case, if all countries have the same value of observed indicator Shannon entropy index will amount zero.

In order to take a deeper insight into the convergence process during the observed period, the Shannon entropy index is complemented with the level of EU average for certain indicator. Namely, the leveling of the gap in some indicator can be the result of improvements made by economies that were lagging behind in the previous period (that were catching-up with advanced ones) or deterioration in advanced economies (that were closing to underdeveloped ones). In order to identify which of these two possibilities is present in the case of each considered indicator, besides the entropy curve, the EU average curve is also presented in the same figure. Also, in the Appendix, there are tables where relative country positions (RCP) are presented. The RCP for certain indicator x was calculated using the formula:

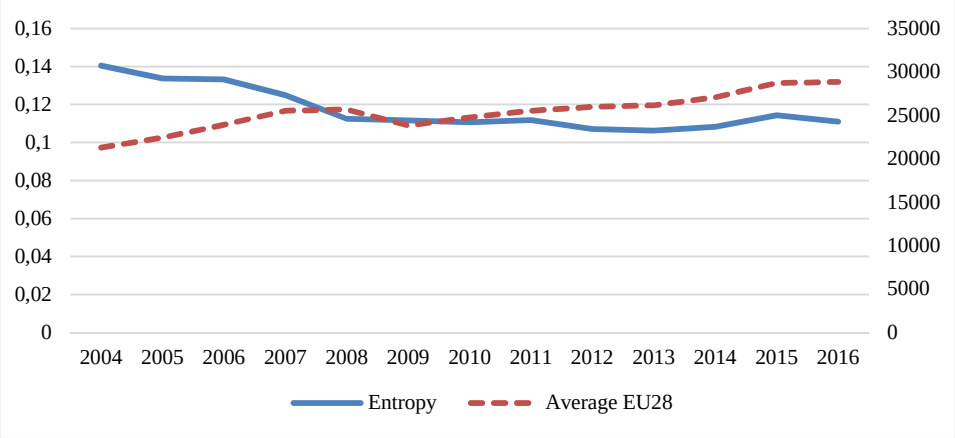
$$RCP\left(x_{ij}\right)=\frac{x_{ij}}{\bar{x}_j}*100 \tag{5}$$

where $x_{ij}$ is indicator for country $i$ ($i$ = 1, 2, 3, … $n$) in year $j$ ($j$ = 1, 2, … $m$) and $\bar{x}_j$ EU average in year $j$. The obtained results indicate the share of a certain indicator in the EU average for each year during the considered period. Usage of this additional indicator will indicate which economies are advanced and which are lagging behind in certain indicator, causing the divergence process in some period.

The first indicator for which mentioned indicators are calculated is GDP per capita PPP. By calculating entropy for this indicator, it can be drawn the conclusion of whether there is a convergence in economic development among EU economies (Figure 1).

F i g u r e 1

**The Trend of the Average GDP per capita PPP and the Calculated Entropy for this Indicator in the 2004 – 2016 Period**




*Source*: Author's calculation.

Based on the presented entropy trend in Figure 1, it can be concluded that the differences in the economic development among the EU countries had continuously been decreasing until the year 2010, indicating the convergence process. This decrease in differences among the Member States is the result of improvements in less developed economies, having in mind that the EU average was increased until 2008. Namely, the greatest enlargement of EU in 2004 led to the GDP growth (mostly through trade integration) in the pre-crisis period (Siljak, 2015). In 2009, there was a decrease in the average GDP per capita PPP, while the level of entropy was rather stable, i.e. it did not record significant variations. Such trends indicate the decrease of GDP per capita PPP in the majority of EU economies and the closing of advanced economies to less developed ones.

After 2010, there was a certain increase in inequality in 2011, which was the result of some changes in this indicator in 2011 compared to the year 2010. The majority of the countries (24 of them) increased their GDP per capita PPP in comparison with the previous year, with the largest increase being that in Luxembourg – by the amazing 3900 international dollars. Luxembourg is expected to have the highest GDP per capita PPP since it has a very high GDP PPP, a small population and a large inflow of cross-border workers (IMF, 2017).

Beside Luxembourg, the Baltic countries and Germany also recorded significant economic growth. The trend of this growth can also be seen in Appendix 1. The Baltic countries are small open economies, characterized by significant fluctuations in the economic activity. These countries found their way out of the crisis in the adequate measures of the fiscal policy or, to be more precise, fiscal consolidation. They recorded significant progress in catching-up, especially in the post--crisis period (Deichmann et al., 2017).

On the other hand, a slight increase in entropy in 2011 is also the result of GDP per capita PPP decrease in the rest four EU economies. Namely, Greece, Spain, Cyprus, and Portugal recorded a significant reduction in its GDP per capita, wherein the reduction was certainly the highest in Greece. This reduction in the GDP is confirmed through Appendix 1. Besides the high indebtedness and the generally poor fiscal positions, these countries were faced with a significant rigidity in the goods and services market, as well as in the labor market. During the crisis, the mentioned market rigidities increased the economic adjustment costs and led to a sharp GDP decline, which was higher than that in other countries (Zentralbank, 2015).

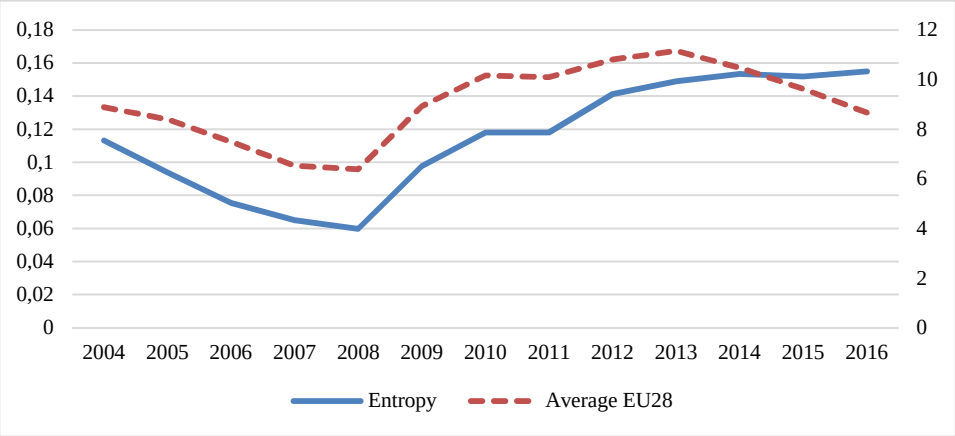
After this increase of inequality in the level of the GDP in 2011, the inequalities among the EU economies continued their decreasing trend until 2014. In that, as well as in the following year, inequalities increased, which can be explained by significant economic growth in Luxembourg and Ireland. Ireland achieved significant growth by the usage of the optimal combination of its own resources, foreign direct investments and structural instruments, which had a positive impact on the GDP (Pirvu and Budurnoiu, 2011; Deichmann et al., 2017). While entropy recorded some slight fluctuations after 2011, the EU average was continuously increasing until the end of the period, indicating that majority of EU economies recorded some growth in economic activity (even it was not so extensive like in Ireland and Luxemburg).

The general conclusion that can be drawn, according to obtained results, is that there is a convergence process in terms of GDP per capita PPP, due to faster growth in New Member states, as it was suggested by previous researches (Grzelak and Kujaczyńska, 2013; Sorić, 2017; Młynarzewska-Borowiec, 2017; 2018). This is particularly true for the pre-crisis period, where a decrease of entropy was followed by an increase of the EU average. Although the entropy was rather stable in the post-crisis period, the increase of EU average, improved relative country position of New Member States and deteriorate relative country position of Old Member States (Appendix 1) indicate the existence neoclassical catching-up in EU-15 and technological catching-up in the New Member States (Młynarzewska-Borowiec, 2017).

Apart from the economic activity trend, observing inequality in the level of unemployment in the EU member countries is also of huge importance for a real convergence analysis. According to that, the calculated entropy for this indicator is shown in Figure 2.

F i g u r e 2

**The Trend of the Average Unemployment Rate and the Calculated Entropy for this Indicator in the Period 2004 – 2016**




*Source*: Author's calculation.

It is obvious from Figure 2 that, unlike the GDP per capita PPP, in the case of the unemployment rate the trend of the inequality in the level of the unemployment rate and EU average had almost the same trend. The calculated entropy for the unemployment rate presented in Figure 2 indicates that the inequalities in the level of unemployment were continuously decreasing in the period from 2004 to 2008. In addition, the average EU unemployment rate had continuously been declining too, indicating that the unemployment rate was decreasing in almost all of the economies during this period as a result of the economic expansion and demand growth prior to the outbreak of the global economic crisis. So, reducing inequality in the unemployment rate in pre-crisis period was the result of an increase in employment in less developed member countries, especially in those that joined the Union in 2004 (Pirvu and Budurnoiu, 2011).

However, during 2009 and 2010, the differences were significantly increased as a result of both the application of different measures for overcoming the crisis and the different intensity of the crisis impact on the EU economies. Beside the Baltic economies, that were the most vulnerable to the crisis, a significant increase in the unemployment rate was also recorded in Spain and Ireland. After a certain reduction in inequality in 2011, there was a significant increase in inequality in the unemployment rate in 2012 and it lasted until the end of the period.

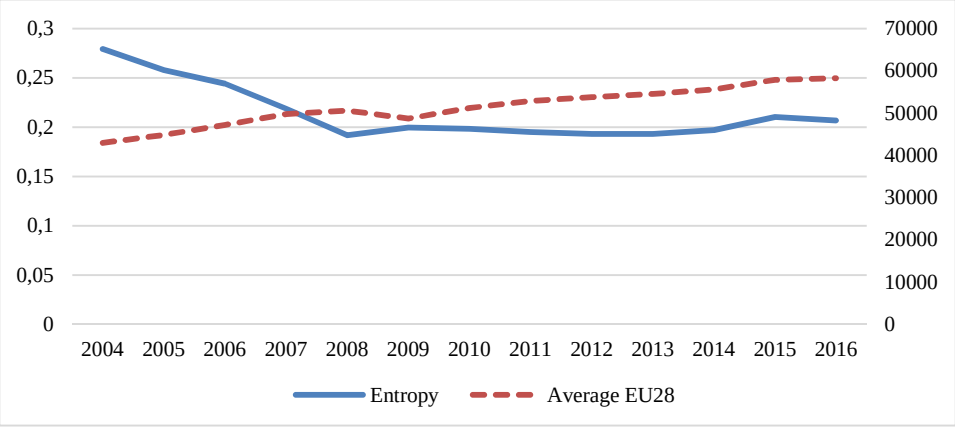
This was largely driven by a significant increase in unemployment in the countries most affected by the debt crisis – Greece, Spain, and Portugal. On the other hand, Belgium, Germany, Malta, Luxembourg, the Netherlands, and Romania recorded a slight increase or even a fall in the unemployment rate during the same period. However, it is interesting to note that after 2014, the increase in inequality was accompanied by a declining average unemployment rate, suggesting that a number of the Member States had significantly reduced the unemployment rate in comparison with the previous period (before all Spain and Slovakia).

Generally speaking, after the period of convergence until 2008 due to improvement of relative country position in most of New Member States (the exceptions are Cyprus, Hungary, and Malta) and deterioration of position in almost all EU-15 except in Denmark and the Netherlands (Appendix 2), there is the divergence in this indicator in the post-crisis period. The divergence process until 2014 is the result of further improvement of relative country position in almost all EU-15 (with exception of Denmark, Greece, Spain, and Ireland) and deterioration of relative country position in the majority of New Member States. The increase of inequalities after 2014 rather results in reversible processes in most of the countries, as it was suggested by Franks et al. (2018).

One of the most important factors of convergence is labor productivity, bearing in mind the fact that it shows how effectively an economy uses its production potentials or how efficiently the labor input is combined with the other factors of production and used in the production process. Hereof, Figure 3 presents the trend of entropy and the average unemployment rate in the period 2004 – 2016 for the GDP per worker.

F i g u r e 3

**The Trend of the Average GDP per Worker and the Calculated Entropy for this Indicator in the Period 2004 – 2016**




*Source*: Author's calculation.

Figure 3 indicates that the calculated entropy for the GDP per worker was continuously decreasing during the period 2004 – 2008. This trend is a result of a faster increase in the GDP than in employment growth in the majority of the Member States, as a result of overheated demand which had boosted the growth of the GDP.

The continuous decrease in inequalities until 2008 had been followed by an increase in the average GDP per worker, primarily as a result of the catching-up process in the CEE countries. After the emergence of the global economic crisis, a slight increase in entropy occurred in 2009. Namely, some countries, such as Latvia, Lithuania, Poland, Romania, and Hungary applied somewhat tougher austerity measures and, accordingly, recorded a lower level of productivity (which was decreased by over 20% in 2009 in comparison to 2008). Together with the remaining CEE countries, these countries recorded a very low level of productivity. On the other hand, there are countries such as Luxembourg, France, Finland, Sweden, Denmark, Netherlands, Austria, Ireland, and Belgium that managed to keep their productivity at a very high level, despite a certain decrease in this indicator because of the escalation of the crisis. The fact that the GDP per worker in Luxemburg, as a country with the highest level of productivity, was 10.5 times higher than that recorded in Bulgaria, as a country with the lowest productivity, may be the most obvious representation of the differences in this indicator among the Member States in 2009. This increase in inequalities was followed by a slight decrease in average GDP per employee because the majority of the EU economies recorded a faster decrease in the GDP than in employment.

After 2009, the period of relatively stable entropy was followed by a continuous increase in average productivity until the end of the period. Such trends indicated that the differences in productivity among the Member States remained relatively unchanged as a result of improving productivity in the EU member states that had not performed well in this field before the year 2009 (Diaz del Hoyo et al., 2017). It is interesting to note a slight increase in entropy occurred in 2015, which is, first of all, a result of the accelerated progress of Ireland that had achieved almost the same level of productivity as Luxembourg, which best performed in this field (Sorić, 2017).

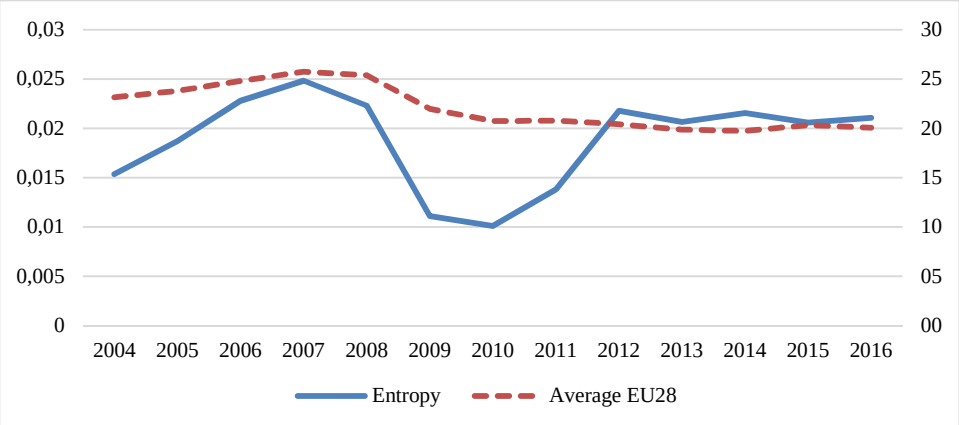
To summarize, there are some improvements made in obtaining convergence of labor productivity, especially in the pre-crisis period, like it was pointed out by Młynarzewska-Borowiec (2018) and contrary to results of Franks et al. (2018). The convergence process until 2008 is the result of relative country position improvements in most of the New Member States and deterioration of the relative country position of almost all Old Member states with the exception of

Luxemburg. Some divergence in the post-crisis period is a result of slight deterioration of relative country position in the Old Member States (Appendix 3).

The next important indicator of real convergence is the gross fixed capital formation, as an indicator of domestic investments in fixed assets. Since the level of domestic investments shows the capability of a particular economy to invest in expanding the production capacities, thus creating conditions for expanded reproduction in the future, its trend certainly has an important influence on convergence among EU economies. Figure 4 presents the average gross fixed capital formation (% of the GDP) and the calculated entropy for this indicator in the period 2004 – 2016.

F i g u r e 4

**The Trend of the Average Gross Fixed Capital Formation (% of the GDP) and the Calculated Entropy for this Indicator in the Period 2004 – 2016**




*Source*: Author's calculation.

It is obvious from Figure 4 that the significant variations in entropy were recorded during the period. The four periods characterized by the different trend of entropy can be derived from Figure 4. The first of them is the period of a continuous increase in entropy until 2007, which was primarily a result of the high share of domestic investments in the GDP in the Baltic States and the majority of the CEE countries, especially in the Czech Republic, Romania, Bulgaria, and Slovenia. Parallel with that, the higher share of domestic investments in the GDP in these countries caused the increase of EU average in the mentioned period.

After the emergence of the global economic crisis in 2008, the second period began. It was characterized by a decrease in entropy and lasted until 2010. Narrowing the discrepancy among the EU countries in this indicator was a result of a decrease in domestic investments in the CEE countries, particularly in the

Baltic States. The Baltic countries had the biggest drop in the share of the gross fixed capital formation in the GDP due to both the implementation of fiscal consolidation and insufficient accumulation in the conditions of the significant contraction of the economic activity. Only the Czech Republic and Romania retained a relatively high share of domestic investments in the GDP at the end of this period (see Appendix 4). The beginning of the second period is also characterized by a decrease of EU average, as the majority of the EU countries had recorded a lower level of domestic investments.

The third period, when entropy was increasing again, lasted during the years 2011 and 2012. The growth of the differences can mostly be explained by an increase in domestic investments in Estonia and in Latvia, on the one hand, and a decrease in Greece and Portugal, on the other. Estonia and Latvia increased their domestic investments due to the production growth and consequently the growth of accumulation in the post-crisis period. On the other hand, domestic investments in Greece and Portugal decreased as a result of the growing debt crisis. Both private and public domestic investments experienced a drop. During this period, average gross fixed capital formation was relatively stable, indicating that the increase of inequalities hasn't affected the EU average. This means that countries that have performed well in previous period manage to obtain a further increase of this indicator, while the low performers have even worsened their position, so the average remained almost the same.

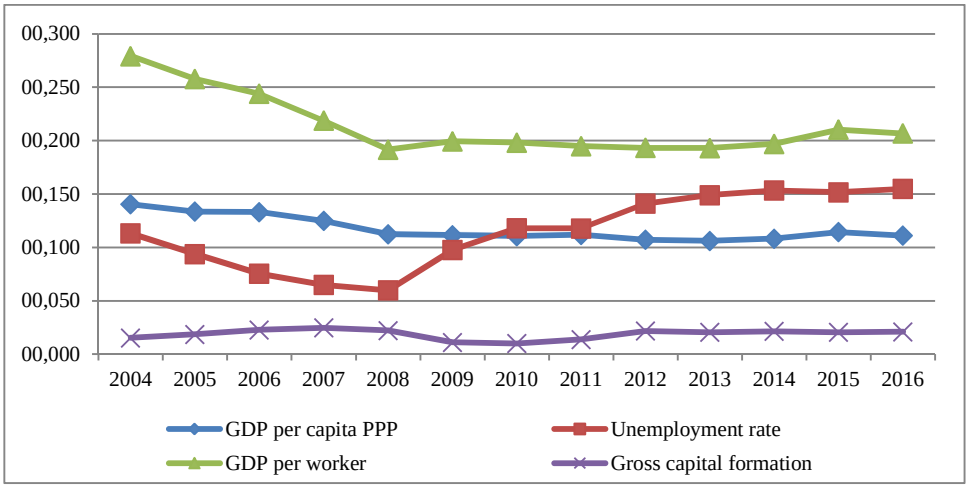
The fourth period, characterized by a high and relatively stable level of entropy, started in 2013 and lasted until the end of the observed period. Although the entropy recorded slight fluctuations, the EU countries alternated in the ranking order of the best performers and the worst performers during the time. The major shift was a continuous decrease in domestic investments in the CEE and the Baltic states in 2016 (Sorić, 2017), which is in accordance to Barry's argument (2003), stating that the European integration process encourages investment in peripheral countries. Such a trend of this indicator resulted in a relatively stable level of EU average.

Taking into account the trend of entropy and EU average for a considered indicator, some general conclusion can be drawn. Namely, although some improvements have been made during the period 2007 – 2010, the significant variation of entropy level and lowering of EU average in the post-crisis period indicate that EU was facing with some difficulties with ensuring convergence in gross fixed capital formation during the period.

In order to perform a comparative analysis of the measured inequalities in the observed indicators, Figure 5 shows the trend of entropy for all observed indicators.

Figure 5

**A Composite View of the Entropy Trend during the Period from 2004 to 2016**




*Source*: Author's calculation.

Figure 5 shows that the highest entropy was recorded in the labor productivity indicator during the entire considered period, although the significant decrease of inequalities was recorded in the pre-crisis period. Another relatively pronounced problem arising after the global economic crisis was an increase in the differences in the unemployment rate level. According to this indicator, entropy had been lower until the emergence of the global economic crisis in comparison with the entropy of the GDP per capita, whereas a different reaction to the crisis and the different measures for overcoming the crisis in the EU Member States had led to an increase in the inequalities. The entropy of the GDP per capita, however, recorded a slight decrease during the period, with a single less pronounced growth episode in 2015.

Finally, the gross fixed capital formation was the indicator in which entropy was at the lowest level, implying that the differences in the domestic investments level among the EU economies were relatively low.

## Conclusions

The empirical assessment of real convergence in this paper provided an important and additional contribution to the literature in this field. The application of the entropy method provided a clear insight into the level of inequalities among the EU member states in terms of real indicators and results are rather mixed across considered indicators.

The obtained results point out the fact that the highest differences among the EU-28 have been recorded in the level of labor productivity. Although these differences have been decreasing over time and they were lower at the end of the period in comparison to the beginning of the period, they are still high enough to threaten the future growth of the EU member states and the EU as a whole and to influence differences in the other indicators that have become increasingly pronounced over time. The highest entropy for this indicator suggests that this field of the economic policy should be the main focus of policymakers at both the national and the supranational levels. In that sense, it can be said that efforts of EU policymakers aimed at achieving convergence of labor productivity were not effective enough and the pace of implemented measures was weakened in the post-crisis period.

The entropy for the unemployment rate, as another very important indicator of real convergence, was increased at the end of the period in comparison to the beginning of the period, although some improvements were made in the pre-crisis period. Namely, the entropy for this indicator started its decreasing trend after the largest single enlargement of the EU in 2004, but in the post-crisis period the differences in this indicator started to grow, having in mind the fact that the EU countries had been affected by the crisis to a different degree and they had implemented different anti-crisis measures. The crisis indicated that there were still significant imbalances in the labor market, both in the New Member States and in some of the old ones. The New Member States, especially CEE economies, did not have the adequate capacities to formulate and implement an effective national labor policy due to their inheritance from the central planning period, while some EU-15 economies, before all Greece, Spain, Italy, and Portugal, were struggling to overcome the effects of global economic and sovereign debt crisis on their labor markets. So, according to obtained results, it can be concluded that EU authorities have significant difficulties in achieving the convergence of the unemployment rate after the global economic crisis.

The inequalities in the GDP per capita PPP were higher than those in the unemployment rate prior to the emergence of the global financial crisis, but they recorded slight decrease in the pre-crisis period, so inequalities in unemployment become more pronounced. Also, it should be pointed out that the entropy was slightly lower at the end of the period than at the beginning. The main reason for relatively high entropy in the pre-crisis period was the insufficient economic growth and development of the New Member States, especially the transition countries. The catching-up process in most of them was slow. After a great recession caused by the crisis some of them managed to reach a sufficient level of growth and development, and in that sense approached the Old Member States.

Some of them, however, including Bulgaria, Romania, and Croatia (which accessed later) are still lagging behind and convergence towards the advanced EU countries has lost the impetus. The economic model of the resource and debt intensive growth that they have applied in the past two decades has proven to be ineffective and unsustainable. However, obtained results give some evidence in the favor of conclusion pointed out in some previous studies that there is convergence across EU economies in terms of this indicator.

Although the differences in domestic investments were the lowest among considered real convergence indicators, there are still significant differences in this indicator across EU economies. The ineffective measures at the national level aimed at obtaining a satisfactory level of domestic investment resulted in very mixed results across countries. The policy makes in most of both new and old Member States failed to obtain a satisfactory level of investment expenditure, which in large extent affected the convergence of other indicators. Apart from the fact that considered period was characterized with significant volatility of entropy level and slightly higher entropy in 2016 in comparison to 2004, the obtained results suggest that the differences in this indicator were relatively low during the period, indicating rather a convergence among EU economies according to this indicator.

In general, the EU is a regional integration comprised of 28 heterogeneous countries with significant natural, economic, institutional and political differences. Having in mind that these differences it is not surprising that the real convergence is still an ongoing process, especially in terms of labor productivity and employment. In that sense, it can be concluded that achieving this very important goal of integration implies the proper management of the EU economic and regional policies. The effective coordination of monetary and fiscal policies and redirection of regional policy measures and funds seem to be a good solution for achieving both nominal convergence and sustainable real convergence.

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# Appendix 1

## GDP per capita PPP

0-25.9
26-50.9
51-75.9
76-100.9
101-125.9
126-150.9
151-175.9
176-200.9
>200

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | 128.2 | 126.2 | 122.5 | 119.0 | 117.2 | 121.2 | 124.0 | 122.6 | 124.0 | 122.7 | 121.9 | 119.1 |
| Bulgaria | 36.2 | 38.8 | 39.3 | 41.5 | 44.0 | 45.3 | 46.0 | 46.2 | 47.0 | 46.6 | 47.3 | 47.4 |
| Czech Republic | 82.7 | 83.0 | 82.0 | 83.8 | 85.3 | 87.6 | 84.8 | 85.0 | 84.3 | 85.6 | 87.9 | 87.8 |
| Denmark | 131.0 | 129.4 | 129.2 | 125.7 | 126.9 | 128.7 | 132.9 | 131.3 | 130.5 | 131.1 | 129.6 | 127.4 |
| Germany | 126.3 | 122.7 | 120.4 | 119.4 | 119.1 | 120.4 | 123.2 | 126.2 | 126.7 | 126.9 | 127.8 | 124.7 |
| Estonia | 57.3 | 62.5 | 66.5 | 70.9 | 69.7 | 65.4 | 66.6 | 72.5 | 75.5 | 76.8 | 77.2 | 75.2 |
| Ireland | 153.6 | 153.4 | 153.0 | 150.7 | 135.9 | 132.5 | 133.3 | 134.4 | 135.1 | 135.7 | 139.2 | 177.9 |
| Greece | 101.0 | 96.8 | 98.7 | 94.3 | 95.0 | 96.9 | 86.8 | 77.2 | 73.5 | 73.4 | 71.6 | 68.6 |
| Spain | 104.3 | 104.8 | 106.6 | 105.3 | 102.8 | 103.2 | 98.6 | 94.8 | 93.2 | 91.7 | 91.2 | 90.2 |
| France | 116.0 | 116.0 | 112.5 | 110.4 | 108.2 | 110.7 | 111.1 | 110.9 | 109.7 | 110.9 | 109.3 | 107.3 |
| Croatia | 57.8 | 58.0 | 60.2 | 62.2 | 64.2 | 63.7 | 61.0 | 61.1 | 61.6 | 60.8 | 59.4 | 58.2 |
| Italy | 116.5 | 113.3 | 111.2 | 109.2 | 108.2 | 109.0 | 107.0 | 106.2 | 104.0 | 100.9 | 98.2 | 96.8 |
| Cyprus | 102.9 | 105.3 | 103.7 | 106.1 | 107.1 | 108.2 | 102.6 | 98.0 | 92.8 | 86.0 | 82.7 | 81.8 |
| Latvia | 48.4 | 52.6 | 54.4 | 58.3 | 60.0 | 53.7 | 54.1 | 58.4 | 62.0 | 63.8 | 64.6 | 64.8 |
| Lithuania | 51.7 | 54.9 | 56.9 | 61.5 | 63.8 | 57.9 | 62.2 | 67.4 | 71.6 | 74.9 | 76.4 | 75.2 |
| Luxembourg | 254.1 | 258.3 | 269.7 | 270.5 | 266.3 | 262.1 | 264.2 | 271.5 | 266.4 | 267.6 | 275.1 | 270.9 |
| Hungary | 64.3 | 64.7 | 63.1 | 61.1 | 63.5 | 65.4 | 66.2 | 67.0 | 67.0 | 68.4 | 69.0 | 68.6 |
| Malta | 85.0 | 84.3 | 80.3 | 80.2 | 80.6 | 83.5 | 86.0 | 84.6 | 85.5 | 87.5 | 91.6 | 93.3 |
| Netherlands | 140.9 | 141.4 | 140.5 | 140.1 | 140.9 | 140.5 | 137.7 | 136.0 | 135.9 | 136.8 | 132.9 | 128.8 |
| Austria | 133.8 | 132.0 | 129.6 | 126.4 | 126.5 | 129.6 | 129.3 | 130.9 | 134.4 | 134.2 | 131.8 | 128.5 |
| Poland | 53.1 | 52.6 | 52.3 | 54.0 | 56.5 | 61.2 | 64.2 | 66.6 | 68.5 | 68.4 | 68.7 | 68.9 |
| Portugal | 85.5 | 86.1 | 85.3 | 83.0 | 81.8 | 84.3 | 84.4 | 79.1 | 77.0 | 78.4 | 78.3 | 77.3 |
| Romania | 36.2 | 37.0 | 40.6 | 43.5 | 50.2 | 51.2 | 52.9 | 53.3 | 55.1 | 55.8 | 56.5 | 57.5 |
| Slovenia | 90.6 | 90.6 | 89.1 | 88.9 | 91.1 | 87.6 | 85.6 | 85.0 | 83.9 | 82.9 | 84.2 | 83.2 |
| Slovakia | 60.1 | 62.9 | 65.2 | 68.1 | 72.4 | 73.0 | 76.7 | 76.4 | 77.4 | 78.4 | 78.6 | 77.7 |
| Finland | 123.5 | 121.3 | 118.8 | 121.7 | 123.0 | 120.8 | 119.6 | 120.3 | 118.2 | 115.8 | 112.6 | 110.0 |
| Sweden | 133.4 | 128.9 | 129.6 | 130.7 | 128.9 | 126.6 | 128.4 | 129.3 | 130.1 | 128.1 | 125.9 | 124.3 |
| United Kingdom | 125.9 | 122.2 | 118.8 | 113.5 | 111.0 | 109.9 | 110.3 | 107.8 | 109.0 | 109.7 | 110.4 | 108.6 |

*Source*: Author's calculation.

# Appendix 2

## Unemployment Rate

**0-25.9**
26-50.9
51-75.9
76-100.9
101-125.9
126-150.9
151-175.9
176-200.9
>200

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | 94.5 | 101.2 | 110.8 | 114.8 | 109.6 | 88.5 | 81.7 | 71.3 | 70.3 | 75.3 | 81.2 | 88.3 |
| Bulgaria | 136.2 | 120.3 | 120.1 | 105.6 | 87.6 | 76.2 | 101.4 | 111.8 | 113.8 | 116.5 | 108.9 | 95.6 |
| Czech Republic | 93.4 | 94.1 | 94.8 | 81.1 | 68.9 | 75.1 | 71.8 | 66.3 | 64.8 | 62.7 | 58.3 | 53.0 |
| Denmark | 61.9 | 57.2 | 52.0 | 58.2 | 53.2 | 67.2 | 73.8 | 75.2 | 69.4 | 62.7 | 63.1 | 64.4 |
| Germany | 117.0 | 133.4 | 134.8 | 130.1 | 115.8 | 85.2 | 68.9 | 57.4 | 50.0 | 46.6 | 47.8 | 47.8 |
| Estonia | 113.7 | 95.3 | 78.7 | 70.4 | 86.1 | 151.3 | 164.4 | 121.7 | 92.5 | 77.1 | 70.7 | 64.4 |
| Ireland | 50.6 | 52.4 | 60.1 | 72.0 | 100.2 | 134.5 | 136.8 | 145.5 | 136.0 | 117.4 | 107.9 | 97.7 |
| Greece | 119.3 | 119.1 | 120.1 | 128.6 | 122.1 | 107.6 | 125.0 | 177.2 | 226.6 | 246.5 | 253.2 | 258.8 |
| Spain | 123.8 | 109.6 | 113.4 | 125.5 | 176.9 | 200.6 | 195.9 | 211.8 | 229.4 | 233.9 | 234.0 | 229.7 |
| France | 100.2 | 106.0 | 117.4 | 122.5 | 115.8 | 102.0 | 91.5 | 91.1 | 90.7 | 92.3 | 98.4 | 108.1 |
| Croatia | 155.3 | 154.8 | 154.8 | 151.6 | 134.6 | 104.2 | 116.1 | 135.6 | 146.2 | 156.0 | 164.3 | 167.3 |
| Italy | 90.0 | 91.7 | 90.8 | 93.4 | 104.9 | 86.3 | 82.7 | 83.1 | 99.0 | 108.5 | 121.3 | 123.7 |
| Cyprus | 51.8 | 63.1 | 61.4 | 59.7 | 57.9 | 60.5 | 62.0 | 78.2 | 110.1 | 142.5 | 153.8 | 155.9 |
| Latvia | 131.7 | 119.1 | 93.4 | 93.4 | 120.5 | 196.1 | 191.9 | 160.3 | 138.8 | 106.7 | 103.2 | 102.9 |
| Lithuania | 122.7 | 98.9 | 77.4 | 65.8 | 90.8 | 154.6 | 175.2 | 152.4 | 124.0 | 105.8 | 102.2 | 94.6 |
| Luxembourg | 56.3 | 54.8 | 61.4 | 64.3 | 76.7 | 57.1 | 45.3 | 47.5 | 47.2 | 52.9 | 57.3 | 67.6 |
| Hungary | 68.6 | 85.8 | 100.1 | 113.3 | 122.1 | 112.0 | 110.2 | 108.9 | 101.8 | 91.4 | 73.6 | 70.7 |
| Malta | 81.0 | 82.2 | 90.8 | 99.5 | 93.9 | 77.3 | 67.9 | 63.3 | 58.3 | 57.4 | 55.4 | 56.1 |
| Netherlands | 64.1 | 70.3 | 66.7 | 64.3 | 57.9 | 49.3 | 49.2 | 49.5 | 53.7 | 65.4 | 70.7 | 71.7 |
| Austria | 61.9 | 66.7 | 70.7 | 75.0 | 64.2 | 59.4 | 47.2 | 45.5 | 45.3 | 48.4 | 53.5 | 59.2 |
| Poland | 215.0 | 213.2 | 185.5 | 147.0 | 111.1 | 90.8 | 95.5 | 96.0 | 93.4 | 92.3 | 86.0 | 78.0 |
| Portugal | 87.8 | 104.8 | 118.8 | 139.3 | 137.7 | 119.9 | 118.1 | 127.7 | 146.2 | 147.0 | 134.7 | 131.0 |
| Romania | 90.0 | 84.6 | 96.1 | 98.0 | 87.6 | 72.8 | 68.9 | 71.3 | 62.9 | 63.6 | 65.0 | 70.7 |
| Slovenia | 70.9 | 77.4 | 80.1 | 75.0 | 68.9 | 66.1 | 71.8 | 81.2 | 82.3 | 90.5 | 92.7 | 93.5 |
| Slovakia | 207.1 | 195.3 | 180.2 | 171.5 | 150.3 | 135.6 | 142.7 | 135.6 | 129.5 | 127.3 | 126.1 | 119.5 |
| Finland | 99.0 | 100.0 | 102.8 | 105.6 | 100.2 | 91.9 | 82.7 | 77.2 | 71.2 | 73.5 | 83.1 | 97.7 |
| Sweden | 83.3 | 91.7 | 94.8 | 93.4 | 97.0 | 93.0 | 84.6 | 77.2 | 74.0 | 71.7 | 75.5 | 76.9 |
| United Kingdom | 52.9 | 57.2 | 72.1 | 81.1 | 87.6 | 85.2 | 76.8 | 80.2 | 73.1 | 68.1 | 58.3 | 55.1 |

*Source*: Author's calculation.

# Appendix 3

## GDP per Worker

0-25.9
26-50.9
51-75.9
76-100.9
101-125.9
126-150.9
151-175.9
176-200.9
>200

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | 166.0 | 163.4 | 160.9 | 158.3 | 157.3 | 161.2 | 159.5 | 158.2 | 158.3 | 158.2 | 158.1 | 154.1 |
| Bulgaria | 14.3 | 15.2 | 16.0 | 17.5 | 19.3 | 20.5 | 20.7 | 22.2 | 22.7 | 22.5 | 22.4 | 22.7 |
| Czech Republic | 46.3 | 49.6 | 52.6 | 54.4 | 61.2 | 59.7 | 60.4 | 61.6 | 59.3 | 56.9 | 55.2 | 55.7 |
| Denmark | 172.0 | 170.7 | 167.9 | 161.0 | 162.2 | 166.5 | 170.5 | 168.4 | 171.2 | 171.5 | 170.8 | 166.0 |
| Germany | 134.6 | 130.6 | 127.9 | 125.2 | 124.0 | 123.6 | 122.9 | 123.1 | 122.0 | 122.4 | 123.3 | 121.7 |
| Estonia | 37.8 | 41.0 | 44.6 | 50.7 | 50.9 | 50.4 | 52.5 | 54.0 | 56.2 | 57.6 | 58.7 | 56.2 |
| Ireland | 194.6 | 193.6 | 191.0 | 185.0 | 174.4 | 177.7 | 173.5 | 175.0 | 175.7 | 173.2 | 179.1 | 222.2 |
| Greece | 98.1 | 95.7 | 97.6 | 97.5 | 98.6 | 101.1 | 93.9 | 89.4 | 86.7 | 82.9 | 80.0 | 75.5 |
| Spain | 105.9 | 105.0 | 103.6 | 102.0 | 103.6 | 111.0 | 107.6 | 106.0 | 105.5 | 105.3 | 103.5 | 100.6 |
| France | 152.2 | 149.9 | 147.3 | 144.6 | 145.3 | 148.4 | 145.3 | 143.9 | 142.8 | 142.3 | 141.1 | 138.2 |
| Croatia | 48.1 | 49.8 | 50.4 | 50.6 | 53.5 | 52.5 | 51.7 | 51.8 | 51.9 | 52.0 | 49.1 | 47.8 |
| Italy | 138.6 | 135.7 | 131.3 | 127.8 | 127.4 | 129.7 | 126.6 | 124.8 | 121.2 | 121.0 | 119.9 | 116.0 |
| Cyprus | 91.9 | 91.6 | 92.3 | 90.7 | 93.2 | 95.1 | 93.0 | 92.1 | 92.2 | 89.9 | 87.1 | 82.4 |
| Latvia | 28.3 | 31.6 | 35.7 | 42.8 | 45.7 | 42.6 | 41.2 | 44.7 | 47.2 | 47.1 | 48.5 | 47.4 |
| Lithuania | 30.1 | 33.0 | 36.0 | 40.4 | 45.4 | 42.0 | 43.9 | 47.3 | 48.7 | 49.7 | 49.9 | 48.3 |
| Luxembourg | 217.5 | 217.8 | 224.2 | 223.9 | 215.8 | 215.2 | 218.4 | 220.7 | 216.5 | 221.1 | 227.0 | 222.6 |
| Hungary | 46.5 | 48.4 | 46.2 | 48.7 | 51.7 | 48.0 | 48.4 | 48.1 | 46.4 | 46.3 | 44.8 | 44.0 |
| Malta | 76.0 | 75.9 | 74.3 | 73.7 | 75.3 | 78.4 | 78.8 | 76.7 | 77.0 | 78.0 | 80.6 | 81.8 |
| Netherlands | 147.4 | 146.0 | 144.1 | 140.5 | 141.8 | 143.6 | 140.6 | 137.5 | 135.8 | 137.1 | 136.7 | 134.1 |
| Austria | 147.1 | 145.8 | 143.3 | 141.3 | 141.2 | 144.4 | 140.4 | 140.2 | 140.1 | 140.0 | 139.4 | 136.9 |
| Poland | 34.9 | 39.1 | 40.1 | 41.6 | 46.0 | 41.3 | 46.0 | 46.6 | 46.8 | 46.8 | 47.0 | 46.5 |
| Portugal | 70.1 | 70.2 | 69.6 | 69.6 | 69.7 | 73.0 | 72.2 | 69.8 | 68.4 | 70.2 | 69.0 | 67.8 |
| Romania | 15.2 | 19.3 | 22.3 | 26.9 | 30.1 | 27.0 | 27.1 | 27.8 | 28.7 | 30.9 | 31.3 | 32.3 |
| Slovenia | 69.2 | 70.2 | 70.8 | 72.4 | 75.0 | 75.6 | 73.7 | 73.8 | 71.5 | 71.1 | 72.1 | 70.8 |
| Slovakia | 39.3 | 42.0 | 45.2 | 51.9 | 58.1 | 59.7 | 60.9 | 60.5 | 61.2 | 62.0 | 61.5 | 60.0 |
| Finland | 155.6 | 152.2 | 149.0 | 149.5 | 149.5 | 148.8 | 147.2 | 148.2 | 146.5 | 148.0 | 147.4 | 144.9 |
| Sweden | 165.2 | 160.7 | 160.4 | 158.3 | 152.7 | 142.9 | 160.4 | 166.9 | 170.2 | 171.0 | 164.3 | 160.6 |
| United Kingdom | 157.1 | 156.0 | 155.3 | 153.0 | 131.2 | 120.2 | 122.6 | 120.9 | 129.4 | 125.0 | 132.2 | 142.5 |

*Source*: Author's calculation.

# Appendix 4

## Gross Fixed Capital Formation (%GDP)

**0-25.9**
26-50.9
51-75.9
76-100.9
101-125.9
126-150.9
151-175.9
176-200.9
>200

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | 92.5 | 93.3 | 89.9 | 90.1 | 94.6 | 102.8 | 105.2 | 108.8 | 110.8 | 111.8 | 116.1 | 113.3 |
| Bulgaria | 91.2 | 108.9 | 111.3 | 109.9 | 130.0 | 127.0 | 107.1 | 100.6 | 104.4 | 106.3 | 106.9 | 103.5 |
| Czech Republic | 121.4 | 118.6 | 112.9 | 114.6 | 114.3 | 123.3 | 129.8 | 127.6 | 127.0 | 126.4 | 127.2 | 130.6 |
| Denmark | 89.5 | 89.1 | 94.0 | 91.3 | 90.2 | 91.9 | 87.3 | 87.6 | 92.2 | 96.2 | 97.3 | 94.6 |
| Germany | 83.0 | 80.3 | 79.9 | 78.1 | 80.0 | 87.4 | 93.6 | 97.7 | 98.5 | 99.2 | 101.4 | 98.0 |
| Estonia | 137.4 | 138.3 | 148.0 | 142.2 | 122.9 | 103.3 | 102.3 | 126.2 | 140.2 | 139.0 | 123.7 | 116.8 |
| Ireland | 116.7 | 125.3 | 125.0 | 111.5 | 97.7 | 96.0 | 84.9 | 82.8 | 95.6 | 91.7 | 103.9 | 104.5 |
| Greece | 105.4 | 87.5 | 95.6 | 101.0 | 93.8 | 94.7 | 84.9 | 73.7 | 61.8 | 61.4 | 58.8 | 56.7 |
| Spain | 123.2 | 125.7 | 125.4 | 120.4 | 115.0 | 110.6 | 111.0 | 103.5 | 97.1 | 94.7 | 96.8 | 97.1 |
| France | 92.1 | 91.2 | 90.3 | 89.7 | 93.0 | 100.1 | 106.7 | 107.9 | 110.3 | 111.3 | 110.5 | 106.4 |
| Croatia | 111.1 | 106.8 | 107.3 | 104.1 | 110.7 | 114.7 | 102.8 | 97.7 | 96.1 | 99.7 | 98.3 | 97.6 |
| Italy | 89.9 | 89.1 | 86.7 | 83.9 | 83.5 | 91.0 | 96.0 | 94.9 | 90.2 | 86.6 | 84.6 | 82.8 |
| Cyprus | 89.0 | 90.4 | 101.2 | 99.0 | 107.2 | 106.5 | 107.6 | 91.0 | 74.0 | 71.0 | 59.3 | 65.5 |
| Latvia | 124.9 | 131.6 | 137.9 | 141.4 | 126.5 | 102.4 | 93.6 | 106.9 | 124.5 | 116.9 | 114.5 | 105.9 |
| Lithuania | 99.0 | 98.4 | 104.5 | 111.1 | 102.4 | 81.5 | 81.6 | 89.1 | 85.3 | 92.7 | 93.8 | 95.1 |
| Luxembourg | 87.7 | 80.3 | 71.0 | 71.5 | 80.0 | 83.7 | 84.9 | 92.5 | 99.0 | 96.2 | 95.8 | 89.7 |
| Hungary | 104.2 | 100.5 | 95.2 | 92.1 | 91.8 | 103.8 | 98.0 | 95.3 | 95.1 | 105.3 | 110.5 | 106.9 |
| Malta | 89.0 | 92.5 | 88.7 | 87.0 | 77.2 | 82.8 | 103.3 | 86.7 | 89.2 | 88.1 | 87.2 | 122.2 |
| Netherlands | 88.6 | 86.6 | 85.9 | 84.7 | 87.9 | 96.9 | 95.1 | 97.7 | 92.6 | 90.2 | 91.2 | 95.6 |
| Austria | 102.0 | 97.1 | 91.6 | 89.3 | 92.2 | 102.4 | 104.2 | 108.3 | 111.3 | 116.4 | 115.0 | 111.3 |
| Poland | 79.1 | 79.5 | 82.3 | 87.4 | 91.0 | 97.4 | 98.0 | 99.7 | 97.1 | 94.7 | 99.8 | 99.0 |
| Portugal | 101.1 | 97.1 | 90.8 | 87.4 | 89.8 | 96.0 | 98.9 | 88.6 | 77.5 | 74.5 | 76.0 | 75.4 |
| Romania | 96.8 | 102.2 | 106.5 | 139.8 | 151.3 | 118.3 | 125.0 | 130.5 | 133.8 | 124.4 | 123.1 | 122.2 |
| Slovenia | 113.2 | 111.8 | 112.1 | 111.9 | 116.6 | 110.6 | 102.8 | 97.3 | 94.6 | 100.7 | 99.3 | 96.1 |
| Slovakia | 108.0 | 114.8 | 110.1 | 104.1 | 100.5 | 98.7 | 106.7 | 115.6 | 103.9 | 104.3 | 103.4 | 113.3 |
| Finland | 96.4 | 96.7 | 92.0 | 94.0 | 96.1 | 103.8 | 105.7 | 106.9 | 109.3 | 106.8 | 104.4 | 100.5 |
| Sweden | 93.3 | 92.9 | 92.8 | 92.8 | 95.7 | 101.5 | 107.6 | 109.3 | 110.8 | 112.3 | 117.1 | 116.3 |
| United Kingdom | 74.3 | 73.2 | 71.0 | 69.9 | 68.2 | 71.0 | 75.3 | 75.6 | 77.9 | 81.1 | 84.1 | 83.3 |

*Source*: Author's calculation.