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FORECASTING LABOUR PRODUCTIVITY IN THE EUROPEAN UNION MEMBER STATES: IS LABOUR PRODUCTIVITY CHANGING AS EXPECTED?

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ABSTRACT

The aim of the article is to propose different ways of forecasting labour productivity developments by using different statistical forecasting methods and applying different approaches to the most appropriate statistical forecasting method selection. This article examines labour productivity in the European Union member states, measured per employee and per hour worked, in the period from 1990 to 2016. In the forecasting analysis, seven statistical forecasting methods are used to forecast labour productivity for each European Union member state separately and for the European Union as a whole. Overall, three approaches to determine the forecast values of labour productivity have been used in the analysis. The impact of each statistical forecasting method was determined by using the MSE approach. The results are suggesting that the differences in labour productivity between countries should be smaller. In the future research, the level of labour productivity convergence in the European Union should be investigated.

KEY WORDS

European Union member states, labour productivity, statistical forecasting methods

CLASSIFICATION

JEL: C53, E24, J24

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INTRODUCTION

The brief definition of labour productivity is that it shows the amount of certain output per unit of certain labour input [1]. In other words, labour productivity is a ratio of certain output and certain labour input. It can be measured as total factor productivity, what refers to rate of change in technology which is calculated as Solow residual [2]. However, in order to calculate total factor productivity, level of capital is needed. Since capital data are not available directly and capital is not estimated straightforwardly, labour productivity presents plausible approximation of labour productivity. In that sense gross domestic product (GDP) or gross value added (GVA) are often used as the measure of output, whereas total number of working hours achieved by or total number of employees are used as the measure of labour input [3]. In that sense, productivity can be regarded as efficiency. In line with [4], when factors are used more efficiently, value added labour increases what leads to productivity growth. Efficient use of inputs might refer to better skilled and faster working force, but also with superior equipment, better input materials management or technological innovations. Moreover, [4] outlines that labour productivity provides a credible measure of economic conditions and competitiveness of a country.

According to [5] and [6], the productivity is thought to be one of key measures which describe competitiveness of countries. Not only productivity is important as a competitiveness measure but it is also a measure of economic growth [7]. Krugman [8] emphasizes that the labour productivity and the living standards are in strong relationship. Furthermore, he claims that labour productivity is especially important in the long run. Because of the positive impact of labour productivity on wellbeing of the population, it is fully justified to take care and investigate labour productivity more closely. So, [9] investigated the sources of labour productivity growth by using different economic theories. Sala and Silva [10] examined the impact of vocational training on the productivity growth in Europe. They have shown that one additional training hour per employee increases the rate of productivity growth by 0,55 percentage points. Ingason [11] was interested in the relationship between labour flexibility and labour productivity growth. On the one hand, [12] and [13] claim that there is a negative relationship between productivity, employment and output. However, on the other hand, [14] concluded that the labour productivity growth has positive impact on economic results and developments. Mentioned results motivated [15] to investigate labour productivity even more closely and his research posed 10 big questions about labour productivity at micro level. The research of [16] has shown that there are country-wide characteristics among the Europan Union member states which prevents some countries from catching up with the remaining member states.

The topic of labour productivity and its impact on the economy is interesting research area. There are many possible determinants which impact the labour productivity level both at the micro and macro level of the economy. Impact of all determinants on the labour productivity is almost impossible to investigate because of different practical and technical reasons which are connected with missing data needed for proper analyses. On the other hand, the importance of labour productivity is too high and it has to be monitored. Not only the labour productivity must be observed in present time but the projections of future trends and its developments must be conducted. Consequently, the aim of the article is to propose different ways of forecasting labour productivity developments by using different statistical forecasting methods and by applying different approaches of the most appropriate statistical forecasting method selection. Furthermore, the labour productivity will be examined in the case of the European Union member states. It is expected that statistical forecasting methods will show that the labour productivity level in the European Union member states is going to

increase in the future. However, because of different economic and political situations in the European Union member states, the expectations are a little bit relaxed and the research hypothesis of the article is that the labour productivity level in the majority of European Union member states is going to increase in the future.

The article is organized as follows. After the brief introduction, in the second chapter data and methods of analysis, which are going to be applied, are presented. In the third chapter, labour productivity level in the European Union member states is described by using descriptive statistics methods. The European Union member states are classified into groups according their historical labour productivity level values from 1990 to 2016 by using statistical clustering approach. In the fourth chapter, labour productivity in the European Union member states is forecasted by using three different forecasting approaches. In the final chapter, conclusions, limitations and suggestions for further research are given.

DATA AND METHODS

The labour productivity can be measured using different approaches and measures [17]. In order to estimate labour productivity, in this research, the focus is given to the following two measures: labour productivity per employee and labour productivity per hour.

As it was mentioned earlier in the article, labour productivity is calculated as the ratio of output and labour input. For both mentioned measures, the output is measured as the total annual value of GDP. In the analysis the values of GDP given in millions of 2015 US$ are used. These values are converted to 2015 price level with updated 2011 purchasing power parities (PPPs) [18]. In that way, the values of GDP are comparable across different years. The number of persons engaged in some activity that is included in the production area in the national accounts system is used [18] as labour input or as denominator for calculation of labour productivity per employee measure. It has to be emphasized that the domestic concept of employment is used which means that only workers that are employed domestically have been taken into account.

For the second labour productivity measure, labour productivity per hour worked, the number of working hours which have achieved all employed persons in a country during a year was used as a labour input. However, it has to be emphasized that only regular and overtime hours, which are actually worked and paid have been included in the number of working hours [18].

In order to calculate the two labour productivity measures data from [19] Total Economy Database have been used. The focus is given to labour productivity analysis in the European Union member states (EU-28). Unfortunately, the data for the number of working hours in Croatia are not available for the whole observed period. Consequently, it is not possible to calculate labour productivity per hour worked for Croatia for the observed period. The labour productivity is observed for period from 1990 to 2016. It has been decided to observe labour productivity from 1990 because until then many of the European Union state members had another economic system which could mean that the labour productivity results are not directly comparable with previous periods. In order to avoid seasonal effects on the labour productivity, the analysis is made by using yearly data. Furthermore, because the same approaches and methods were used to obtain the data, the labour productivity measures are comparable through the time and between the countries. Consequently, no additional statistical standardisation of the labour productivity measures is needed to be done.

In the first step, the two labour productivity measures have been calculated. After that, they have been inspected and compared by using basic descriptive statistics methods. Furthermore, the outlier analysis was conducted to see if there are some countries with remarkable high or low labour productivity levels. After that, the countries were grouped

according their labour productivity levels by using non-hierarchical clustering approach. It is assumed that countries with lower labour productivity levels should have higher rates of labour productivity increase in the future because they can learn from the countries with higher labour productivity levels [20].

In order to forecast future development of labour productivity in the European Union member states, overall seven statistical forecasting methods are applied: the status quo naïve model, the difference naïve model, the rate of change naïve model, geometric mean forecasting model, simple average forecasting model, single exponential smoothing model, and linear trend model [21]. Overall three approaches to determine the forecast values of labour productivity are used in the analysis. In the first approach, the forecasted values are determined by using statistical forecasting method with the lowest Mean Squared Error (MSE) [22]. In the second approach, the forecasting is conducted based on data from 1990 to 2015. The statistical forecasting method with the closest forecasted value from 2016 to the real value from 2016 is used to determine labour productivity changes in the future. In the third approach, all seven statistical forecasting methods are used together to estimate forecasted values. The impact of each statistical forecasting method is determined by using MSE approach. The lower MSE of a statistical forecasting method is, the statistical forecasting method will have the higher impact or the higher weight on the forecasts.

STATISTICAL OVERVIEW OF LABOUR PRODUCTIVITY IN THE EUROPEAN UNION MEMBER STATES

DESCRIPTIVE STATISTICS ANALYSIS OF LABOUR PRODUCTIVITY PER EMPLOYEE

The labour productivity per employee is calculated as the ratio of GDP and number of employees. The ratio will for sure increase if GDP rises and number of employees decreases. On the other side, if GDP decreases and number of employees increases, the labour productivity per employee is going to fall. Also, if the effect of GDP increase is higher than the effect of number of employees increase, the labour productivity per employee is expected to rise. Obviously, there are many combinations and reasons when and why the labour productivity per employee is going to fall or rise. In this article the focus is given to analysing trends of labour productivity. However, for the sake of understanding the topic it is good to keep on mind how labour productivity measures or ratios are working.

The highest and the lowest labour productivity per employee values in the European Union member states in period from 1990 to 2016 are shown in Figure 1. Additionally, the average labour productivity per employee for all 28 European Union member states is also given. In the whole period, the highest labour productivity per employee is recorded for Luxembourg. There are oscillations of the highest labour productivity per employee, where the most pronounced decrease is recorded from 2007 to 2009. That coincides with the global financial crisis which originated in 2007. On the other side, Romania had the lowest labour productivity per employee in periods from 1990 to 1995 and from 1997 to 2002, whereas Bulgaria had the lowest labour productivity per employee in 1996 and from 2003 to 2016.

The difference between the European Union member states with the highest and the lowest labour productivity per employee ranged from 92 to 118 thousand US$ in the observed period. The highest difference between the highest and the lowest labour productivity per employee was achieved in 2000, whereas the lowest difference was in 2012. The difference was above 100 thousand US$ in period from 1991 to 2008. Since 2008 the difference is under 100 thousand US$. However, since 2012 the difference between the European Union member states with the highest and the lowest labour productivity per employee is starting to increase again.

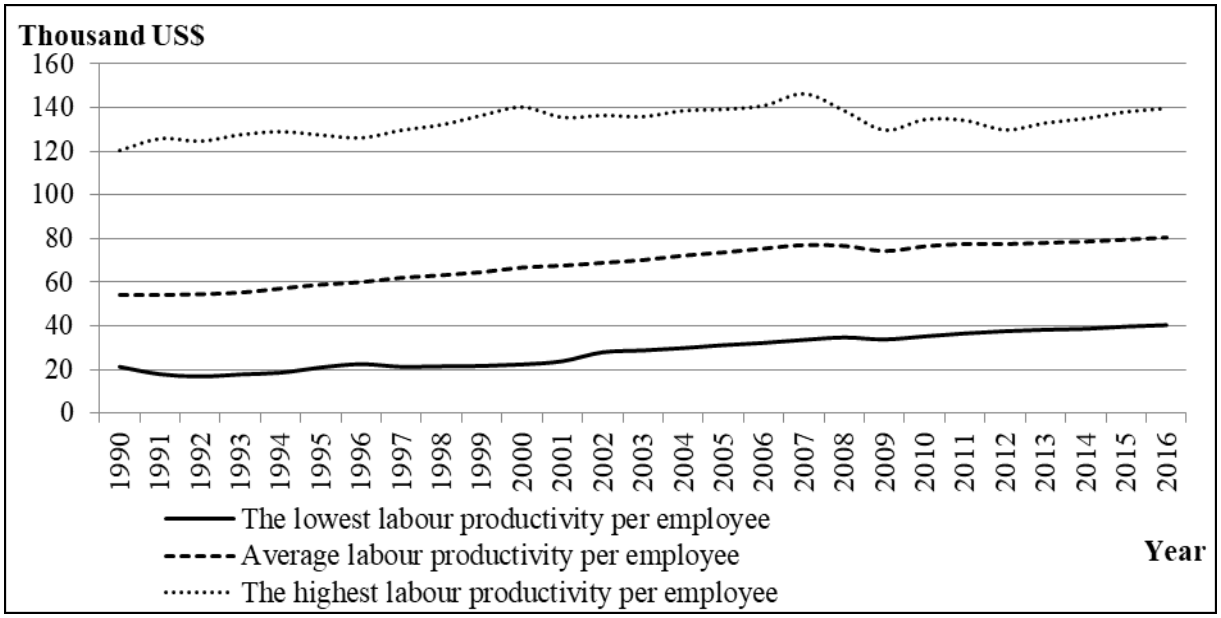

Figure 1. The highest, average and the lowest labour productivity per employee in the European Union member states, in thousand US$, period from 1990 to 2016 (authors' creation).

With so huge differences between the European Union member states, along with the highest and the lowest labour productivity per employee, it is worthy to check if there are countries with extremely high or low labour productivities values in comparison to the other countries. Consequently, the outlier analysis based on z-score calculation was conducted and the results are given in Table 1.

According to Table 1, the labour productivity per employee average for 28 European Union member states has increased from 54 thousand US$ in 1990 to 81 thousand US$ in 2016. The average labour productivity per employee was lower than in previous year only in 2009. So, in general, it can be concluded that the labour productivity per employee on average in the European Union member states has shown the constant increase, but of different values. On the other hand, standard deviations from the labour productivity per employee average of the European Union member states can be observed almost as a constant because of small changes between years. In the observed period, the standard deviations were between 22 and 27 thousand US$. These two trends, of the average and of the standard deviations, resulted in decreasing coefficient of variation in the period from 1994 to 2016. Consequently, it can be concluded that level of data variation is decreasing what, in the same time, means that the representativeness of the average is increasing. So, the use of the z-score calculation to determine presence of outliers is justified.

The number of the European Union member states which have the labour productivity per employee below the European Union member states average or above it is shown in Table 1. It can be concluded that the number of the European Union member states below and above the labour productivity per employee average is almost the same in the whole observed period.

In order to determine if there are outliers, the standard deviations' ranges are observed. The standard deviations' ranges are calculated by adding and subtracting standard deviations' values from the average value. The number of the European Union member states in each standard deviation range is given in the last three columns of the Table 1. The vast majority of the European Union member states can be found in +/– 1 standard deviation range. Furthermore, almost all the European Union member states can be found inside of +/– 2 standard deviation interval. Only Luxembourg has more than 2 standard deviations higher labour productivity

Table 1. Basic descriptive statistics results and outlier analysis, labour productivity per employee, 28 European Union member states, from 1990 to 2016 (authors' creation).

Year	Statistics (in thousands US$ or %)			No. of countries		No. of countries inside the range of:		
	Mean	Std. dev.	Coeff. of var.	Below mean	Above mean	+/– 1 std. dev.	+/– 2 std. dev.	+/– 3 std. dev.
1990	54	23	42	13	15	18	27	28
1991	54	24	45	13	15	19	27	28
1992	55	25	46	13	15	18	27	28
1993	55	26	47	13	15	19	27	28
1994	57	26	46	13	15	19	27	28
1995	59	26	44	14	14	19	27	28
1996	60	26	43	13	15	19	27	28
1997	62	26	42	13	15	19	27	28
1998	63	26	41	12	16	19	27	28
1999	65	27	41	12	16	20	27	28
2000	67	27	40	12	16	19	27	28
2001	68	26	38	12	16	19	27	28
2002	69	25	37	12	16	20	27	28
2003	70	25	35	12	16	21	27	28
2004	72	25	34	12	16	21	27	28
2005	74	24	33	12	16	20	27	28
2006	76	24	32	12	16	20	27	28
2007	77	24	31	13	15	21	27	28
2008	77	23	29	12	16	21	27	28
2009	74	22	29	12	16	21	27	28
2010	77	23	29	14	14	22	27	28
2011	78	22	29	15	13	22	27	28
2012	78	22	28	14	14	22	26	28
2013	78	22	28	15	13	22	27	28
2014	79	22	28	15	13	22	26	28
2015	80	23	28	15	13	21	26	28
2016	81	23	28	15	13	21	26	28

per employee values than the European Union member states average in the whole period. In addition, Ireland has more than 2 standard deviations higher labour productivity per employee values than the European Union member states average in 2012 and in the period from 2014 to 2016. However, what is more important, the outlier analysis has shown that there are no European Union member states that are having labour productivity per employee values outside the +/– 3 standard deviations range. Because of that, there is no need for omitting any of the European Union member state from the further statistical analysis.

The descriptive statistics analysis is conducted by observing each year separately. However, the more detailed descriptive statistic of labour productivity per employee according to the countries is given in [23].

DESCRIPTIVE STATISTICS ANALYSIS OF LABOUR PRODUCTIVITY PER HOUR WORKED

The descriptive statistics analysis of labour productivity per hour worked is conducted in the same way as it was conducted in the previous chapter for labour productivity per employee.

In that way, the results of these two analyses can be compared and better insight into the labour productivity in the European Union member states is provided. However, it is kept in mind that the value of labour productivity per hour worked is changing in dependence of GDP and the number of working hours change.

In Figure 2 the highest, average and the lowest labour productivity per hour worked in the 27 European Union member states (without Croatia) in period from 1990 to 2016 is shown. Again the highest labour productivity level is achieved by Luxembourg in the whole period. Again, even more emphasized decrease in the highest labour productivity level is recorded from 2007 due to the global financial crisis. On the other hand, the lowest labour productivity per hour worked is recorded for Romania and Bulgaria. Romania had the lowest labour productivity per hour worked in comparison to the other European Union member states in periods from 1990 to 2005 and in 2011, whereas Bulgaria had the lowest labour productivity per hour worked in periods from 2006 to 2010 and from 2012 to 2016.

The difference between the highest and the lowest labour productivity per hour worked has been in range from 60 to 75 US$ in the observed period. The highest difference was recorded in 2000, whereas the lowest difference was recorded in 1990. The most recent difference between the highest and the lowest labour productivity per hour worked is 67 US$ in 2016.

The labour productivity per hour worked average of the European Union member states, without Croatia, increased from 31 US$ in 1990 to 49 US$ in 2016. On the other hand, the standard deviation was quite constant, ranging from 15 to 18 US$, in the observed period. Consequently, the coefficients of variation are showing the decrease in the labour productivity per hour worked variability level since 1994. The number of the European Union member states with labour productivity per hour worked below and above the average remained the same in the whole observed period. Almost all observed European Union member states have the labour productivity per hour worked value in range of +/– 2 standard deviations from the labour productivity per hour worked average of the European Union member states. In the observed period, only Luxembourg can be found outside that range, but inside the +/– 3 standard deviations range. Consequently, it can be concluded that there are no countries with extremely low or high labour productivity per hour worked level in comparison to the labour productivity per hour worked average of the European Union member states.

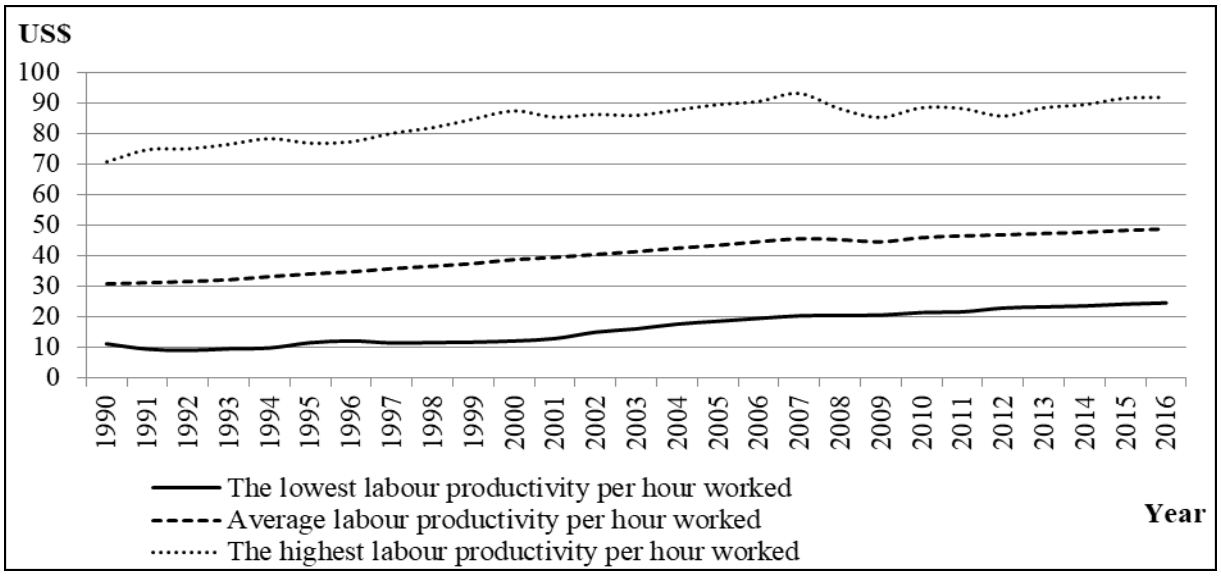

Figure 2. The highest, average and the lowest labour productivity per hour worked in the European Union member states without Croatia, in US$, period from 1990 to 2016 (authors' creation).

Table 2. Basic descriptive statistics results and outlier analysis, labour productivity per hour worked, 27 European Union member states, without Croatia, from 1990 to 2016 (authors' creation).

Year	Statistics, in US$ or %			No. of countries		No. of countries inside the range of:		
	Mean	Std. dev.	Coeff. of var.	Below mean	Above Mean	+/– 1 std. dev.	+/– 2 std. dev.	+/– 3 std. dev.
1990	31	15	47	14	13	17	26	27
1991	31	16	50	14	13	17	26	27
1992	32	16	51	14	13	16	26	27
1993	32	17	52	14	13	17	26	27
1994	33	17	52	14	13	17	26	27
1995	34	17	49	14	13	16	26	27
1996	35	17	49	14	13	16	26	27
1997	36	17	48	14	13	16	26	27
1998	37	17	47	14	13	16	26	27
1999	37	18	47	14	13	17	26	27
2000	39	18	47	14	13	16	26	27
2001	39	18	45	14	13	15	26	27
2002	40	18	43	14	13	16	26	27
2003	41	17	42	14	13	15	26	27
2004	42	17	41	14	13	16	26	27
2005	43	17	40	14	13	17	26	27
2006	44	17	39	14	13	17	26	27
2007	45	17	38	14	13	19	26	27
2008	45	17	37	14	13	17	26	27
2009	44	16	37	14	13	16	26	27
2010	46	17	37	14	13	17	26	27
2011	46	17	36	14	13	16	26	27
2012	47	16	35	14	13	16	26	27
2013	47	16	35	14	13	17	26	27
2014	48	16	34	14	13	17	26	27
2015	48	17	35	14	13	17	26	27
2016	49	17	34	14	13	18	26	27

CLUSTER ANALYSIS OF THE EUROPEAN UNION MEMBER STATES ACCORDING TO THE LABOUR PRODUCTIVITY MEASURES

In order to sort the European Union member states with different labour productivity level groups into groups, statistical non-hierarchical clustering approach is used. Namely, k-means clustering approach with three clusters solution is going to be applied. The values of labour productivity per employee and labour productivity per hour worked will be used in the cluster analysis. These two labour productivity measures should give an insight into general labour productivity in each country. Furthermore, in order to take into account the development of labour productivity in the European Union member states during the period from 1990 to 2016, variables labour productivity per employee and labour productivity per hour worked have been averaged for each member state in the observed period. Furthermore, before conducting cluster analysis, calculated averages have been standardized by using z-score value for each variable separately. Unfortunately, for the whole observed period, there is no data available for variable labour productivity per hour worked values for Croatia. Because of that, Croatia was omitted from the cluster analysis but it has been classified according to labour productivity per employee average value later in the analysis.

Table 3. Clustering results and classification of the European Union member states in the clusters, k-means non-hierarchical clustering approach, three clusters solution, 27 European Union member states and 2 labour productivity variables used in the analysis (authors' creation).

Cluster A: Low level labour productivity countries		**Cluster B: Medium level labour productivity countries**		**Cluster C: High level labour productivity countries**	
Average labour productivity per employee z-score	–0,87	Average labour productivity per employee z-score	0,66	Average labour productivity per employee z-score	2,65
Average labour productivity per hour worked z-score	–0,90	Average labour productivity per hour worked z-score	0,69	Average labour productivity per hour worked z-score	2,62
Number of countries	13 + 1	Number of countries	13	Number of countries	1
Countries: Bulgaria, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovak Republic, Slovenia, Croatia*		Countries: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, United Kingdom		Countries: Luxembourg	

*Croatia was added after the clustering analysis according to the labour productivity per employee average value.

In the cluster analysis both used variables, labour productivity per employee and labour productivity per hour worked, are appeared to be highly statistically significant (p-values < 0,0001) in the clustering process. The cluster analysis resulted in three clusters of the European Union member states with different labour productivity levels. According to the Table 3, the cluster A is consisted of the European Union member states which have low labour productivity levels. The average z-scores of the European Union member states in that cluster reveal that these countries are below the average labour productivity level of all European Union member states together. That cluster consists of 13 countries. Only Greece is considered to be an old European Union member state, whereas all other countries in that cluster are new European Union member states. After conducting the cluster analysis, Croatia has been classified into the cluster with countries which have low labour productivity levels, due to the fact that the labour productivity per employee average value of Croatia (51 797 US$) is very close to the labour productivity per employee average values of the Czech Republic (51 667 US$) and the Slovak Republic (50 778 US$) which can be found in the cluster A.The cluster B also consists of 13 European Union member states and only old European Union member states comprise this cluster. According to average z-scores, the average labour productivity of those countries is about 0,7 standard deviations above the average labour productivity of all European Union member states. Consequently, it can be stated that the countries from the cluster B have medium labour productivity level.

The cluster C consists of one country. It appeared that Luxembourg has by far the highest labour productivity level in comparison to the other European Union member states. It can be estimated that the labour productivity level in Luxembourg is about 2.6 standard deviations above the European Union member states labour productivity average level. Consequently, Luxembourg is declared to be high level labour productivity country.

According to the cluster analysis, the new European Union member states and Greece have low labour productivity levels. That would mean that those countries have a lot space for improvements and developments of labour productivity. So, it is expected that they should

have higher rates of labour productivity increase in compare to, for example, Luxembourg, which needs to invest far more efforts to keep the labour productivity level so high in comparison to the other European Union member states. The forecasting analysis in the following chapter should show if the assumption of different magnitude of increase of labour productivity level between European Union member states in these three clusters is justified or not.

FORECASTING LABOUR PRODUCTIVITY IN THE EUROPEAN UNION MEMBER STATES

STANDARD FORECASTING APPROACH

In order to forecast labour productivity in the European Union member states, the standard forecasting approach is used. In other words, the data from the whole period is used to produce forecasts. In the observed case, in order to calculate labour productivity forecasts, the values of labour productivity per employee and labour productivity per hour worked in period from 1990 to 2016 are used. The forecasting analyses are conducted for each European Union member state separately. Furthermore, for each European Union member state, labour productivity forecasts were calculated by observing labour productivity per employee and labour productivity per hour worked separately. In that way, for each European Union member state, two forecast analyses have been conducted. Because of missing data, only one forecast analysis was conducted for Croatia. The forecast analyses have been conducted by applying seven different statistical forecasting methods. After all, observed statistical forecasting methods were applied and the best one was chosen by using the mean squared error (MSE) criteria. So, the statistical forecasting methods with the smallest MSE were selected to forecast the two labour productivity measures in European Union member states. The results of the standard forecasting approach are shown in Table 4.

The results from Table 4 are suggesting that, according to the labour productivity per hour worked measure, labour productivity should decrease in Spain and, according to labour productivity per employee measure, in Greece, in the next years. Furthermore, there are some countries at which no future change in the labour productivity level has been forecasted. If labour productivity per employee measure is observed, it can be concluded that in 13 European Union member states the labour productivity measured per employee will remain on the same level. The most countries, for which no change in the labour productivity measured per employee is forecasted, can be found in group of countries with medium level labour productivity. If labour productivity per hour worked measure is observed, the number of countries with forecasted no change in labour productivity in the future is smaller in comparison to the previous labour productivity measure and it is equal to 8 European Union member states. Again, the most countries with forecasted no change in labour productivity level in next year can be found in group of countries with medium level labour productivity.

It is obvious that labour productivity per employee and labour productivity per hour worked are taking into account different variables to estimate labour productivity. Because of that, it is not expected that the both measures are going to give the same forecasts about labour productivity. However, it is indicative that in 6 European Union member states both measures have forecasted no change of labour productivity level in the future. These 6 countries are: Belgium, Bulgaria, Denmark, Hungary, Italy, and Luxembourg.

Unfortunately, the magnitude of labour productivity level change in countries in each cluster cannot be directly measured and estimated. The reason for that is the fact that the change of labour productivity in a country is, due to different forecast methods, given as percentages or the US$. Consequently, the differences of the magnitude of labour productivity level change between the clusters cannot be examined. However, it seems that the magnitude of labour

Table 4. The most accurate forecasting methods for labour productivity in the European Union member states, mean squared error criteria (authors' creation).

Country	*Labour productivity per employee*		*Labour productivity per hour worked*	
	Forecasting method	**Change per year**	**Forecasting method**	**Change per year**
Low level labour productivity countries:				
Bulgaria	Status quo naïve model	0	Status quo naïve model	0
Croatia	Status quo naïve model	0	-	-
Czech Rep.	Rate of change naïve model	+1,72 %	Difference naïve model	+0,40 $
Estonia	Status quo naïve model	0	Difference naïve model	+1,00 $
Greece	Difference naïve model	–562,98 $	Status quo naïve model	0
Hungary	Status quo naïve model	0	Status quo naïve model	0
Latvia	Rate of change naïve model	+2,44 %	Rate of change naïve model	+2,44 %
Lithuania	Rate of change naïve model	+2,62 %	Difference naïve model	+0,84 $
Malta	Status quo naïve model	0	Difference naïve model	+0,68 $
Poland	Difference naïve model	+1884,98 $	Difference naïve model	+0,89 $
Portugal	Linear trend model	+683,74 $	Linear trend model	+0,36 $
Romania	Difference naïve model	+2 067,35 $	Difference naïve model	+1,10 $
Slovak Rep.	Linear trend model	+1840,44 $	Linear trend model	+1,07 $
Slovenia	Rate of change naïve model	+1,04 %	Rate of change naïve model	+0,94 %
Medium level labour productivity countries:				
Austria	Rate of change naïve model	+6,01 %	Difference naïve model	+0,41 $
Belgium	Status quo naïve model	0	Status quo naïve model	0
Cyprus	Difference naïve model	+591,49 $	Status quo naïve model	0
Denmark	Status quo naïve model	0	Status quo naïve model	0
Finland	Status quo naïve model	0	Rate of change naïve model	+0,28 %
France	Status quo naïve model	0	Difference naïve model	+0,37 $
Germany	Status quo naïve model	0	Difference naïve model	+0,11 $
Ireland	Difference naïve model	+4 037,17$	Difference naïve model	+2,14 $
Italy	Status quo naïve model	0	Status quo naïve model	0
Netherlands	Status quo naïve model	0	Difference naïve model	+0,23 $
Spain	Difference naïve model	+70,89 $	Difference naïve model	–0,01 $
Sweden	Difference naïve model	+1798,55 $	Difference naïve model	+1,05 $
United King.	Difference naïve model	+603,72 $	Difference naïve model	+0,00 $
High level labour productivity countries:				
Luxembourg	Status quo naïve model	0	Status quo naïve model	0
European Union member states productivity level:				
EU28 – mean	Rate of change naïve model	+1,17 %	-	-
EU27 – mean	Difference naïve model	+950,04 $	Difference naïve model	+0,47 $

productivity level change in a country is not related to the productivity level of a country. So, the reason of different magnitude of labour productivity level change between countries should be found in other economic variables. However, that is outside the scope of this article.

The main research hypothesis of the article is that the labour productivity level in the majority of European Union member states is going to increase in the future. According to the results given in Table 4, both labour productivity measures in 12 European Union member states are showing some increase in labour productivity level in the following periods. According to the labour productivity per employee measure, forecasted labour productivity will increase in 14 European Union member states in the future, whereas according to the labour productivity per hour worked measure, forecasted labour productivity will increase in 18 countries. Unfortunately, all these results are not speaking in favour of the research hypothesis. Consequently, by using standard forecasting approach the research hypothesis should be rejected.

BENCHMARK FORECASTING APPROACH

After the standard forecasting approach, in order to forecast labour productivity trends in the European Union member states, in this chapter the benchmark forecasting approach is applied. The difference between the standard and the benchmark forecasting approach is explained below. In order to produce forecasts, labour productivity data from 1990 to 2015 are used. The same seven different statistical forecasting methods are again applied and used to calculate the forecast value of the labour productivity in 2016. The statistical forecasting method, for which forecasted value was the closest to the real value from 2016, was declared the most appropriate for forecasting labour productivity in a country [22]. The forecasting analysis was conducted for labour productivity per employee and for labour productivity per hour worked separately. The results of the benchmark forecasting approach are given in Table 5.

The results from Table 5 are pointing out that there is no European Union member state in which labour productivity, measured as the labour productivity per employee or the labour productivity per hour worked, will decrease in the future. However, in some countries, no change in the labour productivity level has been forecasted. The number of such countries here is much smaller than at the standard forecasting approach. If the labour productivity per employee forecasts are observed, no change in labour productivity level is forecasted in 3 countries (Croatia, Greece, Spain) and if the labour productivity per hour worked forecasts are inspected, the same labour productivity level is forecasted in 8 countries (Finland, Germany, Greece, Italy, Luxembourg, Netherlands, Spain, United Kingdom).

The comparison of labour productivity changes between the clusters is not possible to conduct. The labour productivity changes given in different units are the main obstacle for conducting comparison analyses between the clusters.

In overall 18 European Union member states both used labour productivity measures are forecasting the increase in labour productivity level. These two labour productivity measures together point to the expectation that the labour productivity level in those 18 countries is going to increase. Furthermore, the labour productivity per employee measure forecasts are showing increase of labour productivity level in 25 countries whereas the labour productivity per hour worked measure is forecasting increase in 19 countries. In that way, the benchmark forecasting approach results are suggesting that the research hypothesis should be accepted.

WEIGHTED FORECASTING APPROACH

In the weighted forecasting approach, instead of using just one statistical forecasting method to calculate forecasts, all seven statistical forecasting methods together are combined and used

Table 5. The most accurate forecasting methods for labour productivity in the European Union member states, benchmark criteria. Authors' creation (continued on p.517).

Country	*Labour productivity per employee*			*Labour productivity per hour worked*		
	Forecasting method	**Diff. from 2016 value,$**	**Change per year**	**Forecasting method**	**Diff. from 2016 value, $**	**Change per year**
Low level labour productivity countries:						
Bulgaria	Geometric mean for. model	202,69	+2,17 %	Geometric mean for. model	0,17	+2,37 %
Croatia	Single exp. sm. model, α = 0,4	168,85	0	-	-	-
Czech Rep.	Geometric mean for. model	9,21	+1,70 %	Geometric mean for. model	0,30	+1,94 %
Estonia	Geometric mean for. model	211,14	+3,32 %	Geometric mean for. model	0,09	+3,37 %
Greece	Status quo naïve model	562,98	0	Single exp. sm. model, α = 0,1	0,34	0
Hungary	Geometric mean for. model	499,02	+1,92 %	Geometric mean for. model	0,24	+2,12 %
Latvia	Geometric mean for. model	21,21	+2,40 %	Geometric mean for. model	0,04	+2,60 %
Lithuania	Geometric mean for. model	19,07	+2,59 %	Geometric mean for. model	0,06	+2,33 %
Malta	Geometric mean for. model	714,48	+2,07 %	Geometric mean for. model	0,41	+2,68 %
Poland	Geometric mean for. model	458,86	+3,72 %	Rate of change naïve model	0,26	+2,05 %
Portugal	Rate of change naïve model	329,94	+0,07 %	Geometric mean for. model	0,21	+1,20 %
Romania	Difference naïve model	93,09	+2 160,44 $	Difference naïve model	0,02	+1,08 $
Slovak Rep.	Difference naïve model	80,81	+1109,21 $	Difference naïve model	0,38	+0,76 $
Slovenia	Difference naïve model	249,09	+953,65 $	Difference naïve model	0,21	+0,59 $
Medium level labour productivity countries:						
Austria	Rate of change naïve model	349,30	+0,23 %	Rate of change naïve model	0,11	+0,50 %
Belgium	Difference naïve model	80,00	+489,06 $	Difference naïve model	0,13	+0,39 $
Cyprus	Rate of change naïve model	36,43	+0,72 %	Difference naïve model	0,04	+0,37 $
Denmark	Rate of change naïve model	218,63	+0,06 %	Rate of change naïve model	0,10	+0,24 %
Finland	Difference naïve model	369,09	+805,43 $	Status quo naïve model	0,15	0
France	Difference naïve model	225,41	+774,15 $	Difference naïve model	0,13	+0,50 $
Germany	Difference naïve model	270,12	+754,45 $	Status quo naïve model	0,11	0
Ireland	Geometric mean for. model	555,20	+2,66 %	Linear trend model	0,30	+1,64 $

Table 5. The most accurate forecasting methods for labour productivity in the European Union member states, benchmark criteria. Authors' creation (continuation from p.516).

Italy	Difference naïve model	11,80	+180,81 $	Single exp. sm. model, α = 0,3	0,02	0
Netherlands	Geometric mean for. model	258,00	+0,91 %	Status quo naïve model	0,23	0
Spain	Status quo naïve model	70,89	0	Status quo naïve model	0,01	0
Sweden	Geometric mean for. model	84,23	+1,91 %	Geometric mean for. model	0,03	+1,78 %
United King.	Difference naïve model	67,81	+671,54 $	Status quo naïve model	0,00	0
High level labour productivity countries:						
Luxembourg	Linear trend model	10,02	+467,16 $	Status quo naïve model	0,25	0
European Union member states productivity level:						
EU28 – mean	Difference naïve model	16,74	+947,19 $	-	-	-
EU27 – mean	Difference naïve model	33,17	+983,22 $	Difference naïve model	0,12	+0,59 $

to obtain forecasts. In the first step, forecasts of all seven statistical forecasting methods, were calculated on the same way as at the standard forecasting approach. In the next step, the MSE values for each of seven statistical forecasting methods are calculated. With the standard forecasting approach, the best statistical forecasting method would be selected according to the smallest MSE criteria. In the weighted forecasting approach the MSE values are used to calculate weights for each statistical forecasting method. The weights are calculated in two steps as follows:

$$w_i = MSE_i \Big/ \sum_{i=1}^{k} MSE_i \,, \tag{1}$$

$$w_{fi} = w_i \Big/ \sum_{i=1}^{k} w_i \,, \tag{2}$$

where w_i is the preliminary weight of the i-th statistical forecasting method, MSE_i is the MSE of the i-th statistical forecasting method, and w_{fi} is the final weight of the i-th statistical forecasting method.

By using equations (1) and (2), the statistical forecasting method with the lowest MSE will get the highest weight. On the other hand, the statistical forecasting methods with the largest MSE will get the least importance in calculating forecasts and so that methods will get the lowest weight. The values of final weights are shown in Appendix in Tables A1 and A2.

After the calculation of weights for all statistical forecasting methods, the weights of a statistical forecasting method are multiplied with forecasts of that statistical forecasting method. The final forecasts are calculated by summing up the values of the products across all seven statistical forecasting methods. The future trends in labour productivity changes in the European Union member states given in Table 6 are calculated as differences between forecasted labour productivity in 2017 and the real labour productivity in 2016.

The results in Table 6 show that, according to the labour productivity per employee measure, only in Luxembourg and, according to the labour productivity per hour worked measure, in Spain, the decrease of labour productivity is forecasted. In all other European Union member states both labour productivity measures have forecasted the increase in labour productivity level. Consequently, by using weighted forecasting approach the main research hypothesis of

Table 6. The forecasted change of labour productivity in the European Union member states in 2017 in compare to 2016, weighted approach, in US$ (authors' creation).

Country	*Labour productivity per employee*	*Labour productivity per hour worked*
Low level labour productivity countries:		
Bulgaria	+170,03	+0,14
Croatia	+1481,15	-
Czech Republic	+1009,99	+0,53
Estonia	+2 023,94	+0,86
Greece	+1509,82	+0,86
Hungary	+1539,90	+0,56
Latvia	+995,66	+0,43
Lithuania	+1221,97	+0,58
Malta	+1863,52	+0,61
Poland	+1288,65	+0,58
Portugal	+572,69	+0,28
Romania	+878,77	+0,40
Slovak Republic	+1098,67	+0,50
Slovenia	+1439,72	+0,89
Medium level labour productivity countries:		
Austria	+1424,75	+0,61
Belgium	+1031,08	+0,67
Cyprus	+1170,02	+0,49
Denmark	+1063,41	+0,78
Finland	+1897,37	+1,05
France	+726,49	+0,70
Germany	+610,10	+0,54
Ireland	+1943,67	+1,29
Italy	+1029,87	+0,43
Netherlands	+760,95	+0,56
Spain	+33,88	–0,03
Sweden	+1575,20	+0,96
United Kingdom	+947,60	+0,42
High level labour productivity countries:		
Luxembourg	–7,36	+0,36
European Union member states productivity level:		
EU28 – mean	+1074,82	-
EU27 – mean	+1059,66	+0,54

the article, that the labour productivity level in the majority of European Union member states are going to increase in the future, can be accepted.

The trend values are given in the same units of measure. Because of that, the comparison between clusters of countries can be conducted. According to the Table 6, the trend value of average labour productivity per employee for low level labour productivity countries is 1221,03 US$, for medium level labour productivity countries it is 1093,41 US$, and for high level labour productivity countries it is –7,36 US$. These results suggest that countries with lower labour productivity level are going to have higher labour productivity increase per year than countries with higher labour productivity level. In that way, the differences in labour productivity between countries should be smaller. However, the trend value of average labour

productivity per hour worked for low level labour productivity countries is 0,56 US$, for medium level labour productivity countries it is 0,71 US$, and for high level labour productivity countries it is 0,36 US$. These results are not going in favour of achieving equal labour productivity in the European Union member states.

CONCLUSIONS

The importance of labour productivity for the economic development of a country is undoubted. The labour productivity is closely related to economic growth and competitiveness of a country. The positive impact of labour productivity on citizens' welfare should also not be neglected. These relations are showing that it is fully justified to observe and inspect the labour productivity in a country.

In this research, future trends and developments of labour productivity in the 28 European Union member states are analysed. In order to do that, seven different statistical forecasting methods are applied. Two measures were used to calculate labour productivity: labour productivity per employee and labour productivity per hour worked. In order to calculate labour productivity forecast values, three different approaches to forecasting are applied.

In the first forecasting approach, the standard forecasting approach, all data points are used and the statistical forecasting method with the smallest MSE is chosen to forecast labour productivity in a country. According to the standard forecasting approach, the main research hypothesis of the article can be rejected. Namely, it has been shown that only in 12 European Union member states both used labour productivity measures forecast the increase of labour productivity. The benchmark forecasting approach is the second approach which is used to calculate forecasts and to determine trends in labour productivity in the European Union member states. In the benchmark forecasting approach, the data from 2016 are omitted from the forecasting process. However, the data from 2016 is used later to select the best statistical forecasting method to perform forecasting. The forecasting results show that the research hypothesis of the article can be accepted. Both labour productivity measures have shown that the labour productivity should increase in 18 European Union member states.

In the third forecasting approach, the weighted forecasting approach, all seven statistical forecasting methods are used to calculate final forecasts. Depending on the MSE value, lower or higher weights or the importance to certain statistical forecasting methods are given. According to this approach, the research hypothesis can also be accepted. By using this approach to forecasting, in 25 European Union member states the increase of labour productivity by both labour productivity measures is forecasted.

Out of three used forecasting approaches, two of them confirm and forecast the further increase of labour productivity in the majority of European Union member states and therefore the research hypothesis of the article is accepted. Furthermore, all three forecasting approaches have shown that the labour productivity, measured as average labour productivity of all European Union member states, should increase in the future. These results are in favour of accepting the research hypothesis.

The comparison of labour productivity levels of countries with similar labour productivity levels with groups of countries with different labour productivity levels was additionally conducted. The labour productivity per employee measure has shown that group of countries with lower labour productivity level tend to have higher increase of labour productivity in the future in comparison to the groups of countries with higher labour productivity levels. In that way, differences in labour productivity levels between countries should become smaller in the following years. However, the labour productivity per hour worked measure does not support this convergence. The problem of labour productivity convergence should be more investigated in the future research.

There are two main limitations of the article which have to be emphasized. The first limitation is missing data for Croatia for variable labour productivity per hour worked for the whole observed period. Because of that, Croatia was omitted from analyses where labour productivity per hour worked measure was used. The recent economic crisis has had certain impact on labour productivity levels. That impact is the most obvious in 2008 and 2009. Consequently, that resulted in time series break. The limitation of the article is the fact that this break in the time series was not taken into account when forecasting analyses were conducted. In the future research, it would be interesting if the labour productivity forecasted trend based on the data before the crisis is compared with the labour productivity forecasted trend based on the data after the crisis. Also, it is recommended to use bivariate forecasting methods in the future research.

APPENDIX

Table A1. The final weights of statistical forecasting methods used to calculate forecasts and labour productivity per employee measure. Authors' creation (continued on p.521).

Country	Statistical forecasting methods						
	Status quo naïve model	**Difference naïve model**	**Rate of change naïve model**	**Simple average forecasting model**	**Geometric mean forecasting model**	**Single exponential smoothing model***	**Linear trend model**
Low level labour productivity countries:							
Bulgaria	0,2313	0,1787	0,1848	0,0858	0,0081	0,2127	0,0986
Croatia	0,2567	0,1397	0,1233	0,0797	0,0336	0,2512	0,1160
Czech Rep.	0,1822	0,2536	0,2574	0,0417	0,0054	0,1611	0,0986
Estonia	0,2190	0,2151	0,2064	0,0431	0,0061	0,1960	0,1143
Greece	0,2291	0,2561	0,2486	0,0132	0,0131	0,2042	0,0357
Hungary	0,2323	0,2180	0,2209	0,0285	0,0070	0,2095	0,0838
Latvia	0,1769	0,2591	0,2982	0,0224	0,0065	0,1550	0,0820
Lithuania	0,2199	0,2287	0,2294	0,0293	0,0077	0,1962	0,0888
Poland	0,0905	0,3015	0,2802	0,0214	0,0015	0,0758	0,2291
Portugal	0,2027	0,1754	0,1696	0,0520	0,0054	0,1834	0,2116
Romania	0,1929	0,2396	0,2252	0,0511	0,0061	0,1712	0,1138
Slovak Rep.	0,1646	0,2059	0,1993	0,0546	0,0035	0,1443	0,2278
Slovenia	0,2083	0,2459	0,2510	0,0205	0,0055	0,1830	0,0858
Medium level labour productivity countries:							
Austria	0,2259	0,2491	0,2512	0,0135	0,0070	0,2003	0,0529
Belgium	0,2509	0,1675	0,1648	0,0372	0,0087	0,2342	0,1367
Cyprus	0,2296	0,2478	0,2401	0,0152	0,0070	0,2025	0,0579
Denmark	0,2336	0,2229	0,2183	0,0197	0,0095	0,2096	0,0865
Finland	0,2547	0,2043	0,2087	0,0182	0,0111	0,2327	0,0704
France	0,2110	0,2025	0,2010	0,0385	0,0057	0,1888	0,1525
Germany	0,2267	0,1568	0,1584	0,0278	0,0213	0,2174	0,1915
Ireland	0,1297	0,2385	0,2291	0,0788	0,0033	0,1117	0,2091
Italy	0,2712	0,1873	0,1900	0,0159	0,0354	0,2527	0,0474
Malta	0,2513	0,2252	0,2143	0,0151	0,0075	0,2258	0,0608
Netherlands	0,2269	0,1863	0,1868	0,0584	0,0081	0,2068	0,1267
Spain	0,1120	0,3704	0,3583	0,0217	0,0047	0,0938	0,0391
Sweden	0,2081	0,2223	0,2173	0,0337	0,0061	0,1848	0,1278
United King.	0,1658	0,3075	0,3072	0,0138	0,0041	0,1419	0,0597

Table A1. The final weights of statistical forecasting methods used to calculate forecasts and labour productivity per employee measure. Authors' creation (continuation from p.520).

High level labour productivity countries:							
Luxembourg	0,2289	0,1149	0,1157	0,0799	0,0817	0,2277	0,1512
European Union member states productivity level:							
EU28 – mean	0,1920	0,2452	0,2452	0,0363	0,0043	0,1678	0,1091
EU27 – mean	0,1884	0,2456	0,2456	0,0365	0,0042	0,1644	0,1154

*α-s in steps of 0,1 from 0,1 to 0,9 were used and the model the smallest MSE was chosen.

Table A2. The final weights of statistical forecasting methods used to calculate forecasts, labour productivity per hour worked measure (authors' creation).

Country	**Statistical forecasting methods**						
	Status quo naïve model	**Difference naïve model**	**Rate of change naïve model**	**Simple average forecasting model**	**Geometric mean forecasting model**	**Single exponential smoothing model***	**Linear trend model**
Low level labour productivity countries:							
Bulgaria	0,2217	0,1674	0,1685	0,1166	0,0074	0,2043	0,1141
Croatia	-	-	-	-	-	-	-
Czech Rep.	0,1796	0,2669	0,2631	0,0404	0,0046	0,1573	0,0880
Estonia	0,2020	0,2032	0,1923	0,0552	0,0047	0,1800	0,1625
Greece	0,2692	0,1950	0,1918	0,0187	0,0162	0,2513	0,0578
Hungary	0,2149	0,1982	0,1959	0,0586	0,0058	0,1937	0,1330
Latvia	0,2092	0,2201	0,2378	0,0317	0,0084	0,1872	0,1058
Lithuania	0,2107	0,2489	0,2410	0,0240	0,0074	0,1861	0,0819
Poland	0,0822	0,2908	0,2692	0,0199	0,0014	0,0687	0,2679
Portugal	0,1332	0,1661	0,1593	0,0702	0,0037	0,1200	0,3475
Romania	0,1969	0,2227	0,2063	0,0627	0,0064	0,1757	0,1293
Slovak Rep.	0,1453	0,2294	0,2212	0,0456	0,0028	0,1255	0,2302
Slovenia	0,1980	0,2552	0,2578	0,0193	0,0054	0,1731	0,0912
Medium level labour productivity countries:							
Austria	0,1645	0,2689	0,2574	0,0207	0,0032	0,1414	0,1439
Belgium	0,2297	0,2040	0,1987	0,0197	0,0080	0,2088	0,1311
Cyprus	0,2226	0,2089	0,2018	0,0300	0,0059	0,1985	0,1324
Denmark	0,2525	0,1639	0,1574	0,0292	0,0125	0,2367	0,1477
Finland	0,2314	0,2330	0,2346	0,0158	0,0068	0,2061	0,0722
France	0,1980	0,2599	0,2512	0,0225	0,0043	0,1722	0,0918
Germany	0,1763	0,2731	0,2506	0,0126	0,0060	0,1578	0,1236
Ireland	0,1172	0,2774	0,2640	0,0327	0,0025	0,0997	0,2065
Italy	0,2615	0,2002	0,1975	0,0188	0,0188	0,2401	0,0632
Malta	0,1877	0,2518	0,2402	0,0264	0,0045	0,1637	0,1257
Netherlands	0,2102	0,2238	0,2232	0,0443	0,0053	0,1862	0,1070
Spain	0,1297	0,3388	0,3295	0,0375	0,0047	0,1092	0,0506
Sweden	0,1840	0,2642	0,2593	0,0357	0,0044	0,1598	0,0926
United King.	0,1432	0,3441	0,3359	0,0085	0,0031	0,1213	0,0439
High level labour productivity countries:							
Luxembourg	0,2460	0,1368	0,1355	0,0549	0,0311	0,2404	0,1553
European Union member states productivity level:							
EU28 – mean	-	-	-	-	-	-	-
EU27 – mean	0,1388	0,3007	0,2958	0,0267	0,0025	0,1176	0,1179

*α-s in steps of 0,1 from 0,1 to 0,9 were used and the model the smallest MSE was chosen.

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