Zeszyty Naukowe UNIWERSYTETU PRZYRODNICZO-HUMANISTYCZNEGO w SIEDLCACH Nr 117
Seria: Administracja i Zarządzanie (44) 2018
ISSN 2082-5501

REGRESSION AND CORRELATION ANALYSIS OF ENERGY PRODUCTIVITY INDICATORS COMPARED WITHIN SELECTED COUNTRIES OF THE EU

ANALIZA REGRESJI I KORELACJI WSKAŹNIKÓW EFEKTYWNOŚCI ENERGETYCZNEJ W PORÓWNANIU DO WYBRANYCH KRAJÓW UE

Eva Jílková, Veronika Říhová ✉

Czech Republic, Moravian University College Olomouc

Abstract. The paper is focused on the evaluation of energy productivity compared within selected countries of the European Union in the time period 1996-2016. To compare, we used the indicator, which results from the division of the gross domestic product (GDP) by the gross inland consumption of energy for a given calendar year. It measures the productivity of energy consumption and provides a picture of the degree of decoupling of energy use from growth in GDP. The aim of the research is to identify relations and trends of the indicators of energy productivity and compare them in the selected countries. The authors use the methods of the correlation and regression analysis and development trends, time series analysis.
Keywords: correlation analysis, energy productivity, development trends, comparative analysis, EU countries

Streszczenie. Artykuł koncentruje się na ocenie wydajności energetycznej w porównaniu do wybranych krajów Unii Europejskiej w latach 1996-2016. Do porównania wykorzystano wskaźnik, który wynika z podzielenia produktu krajowego brutto (PKB) przez ogólne zużycie energii w kraju w danym roku kalendarzowym. Mierzy on produktywność zużycia energii i obrazuje stopień oddzielenia zużycia energii od wzrostu PKB. Celem badania jest identyfikacja zależności i trendów wskaźników wydajności energetycznej i porównanie ich w wybranych krajach. Autorzy wykorzystują metody analizy korelacji i regresji oraz trendy rozwojowe, analizę szeregów czasowych.
Słowa kluczowe: analiza korelacji, wydajność energetyczna, trendy rozwojowe, analiza porównawcza, kraje UE

Introduction

Energy productivity (or efficiency) represents an important aspect of economic sustainability. Energy productivity has increased unprecedentedly and steadily in recent decades. Great attention is paid to raising this important indicator, but also to its development (Parker & Liddle, 2017). Some authors pursue energy efficiency only in certain sectors, such as horticulture (Meyerding, Stephan G.H. Schoettler & Hardeweg, 2017), other articles compare total-factor energy productivity growth among countries in the world (Du & Lin, 2017).

We used an indicator of energy productivity in our paper to compare 6 selected countries: V4 countries (Czech Republic, Slovakia, Poland, Hungary), Germany and Austria. The indicator results

✉ e-mail: eva.jilkova@mvso.cz; veronika.rihova@mvso.cz

from the division of the gross domestic product (GDP) by the gross inland consumption of energy for a given calendar year. It measures the productivity of energy consumption and provides a picture of the degree of decoupling of energy use from growth in GDP.

For the calculation of energy productivity Eurostat uses the GDP either in the unit of million euro in chain-linked volumes to the reference year 2010 (at 2010 exchange rates) or in the unit purchasing power standard (PPS). The unit euro in chain linked volumes allows observing the energy productivity trends over time in a single geographic area, whereas the unit PPS allows comparison between countries for the same year. The gross inland consumption of energy is calculated as the sum of the gross inland consumption of five energy types: coal, electricity, oil, natural gas and renewable energy sources. Since GDP is measured in million euro or million PPS and gross inland consumption in thousand tonnes of oil equivalent, energy productivity is available both in euro per kg of oil equivalent and PPS per kg of oil equivalent.

Material and methods

The main goal of this research is to compare the development of energy productivity in selected EU countries and provide critical information for prognosis values in the timeline for the future using timeline analysis. The aim is to identify trends of these indicators and compare them in the selected countries. As objects of comparison, we chose the neighbouring states of the Czech Republic, i.e. V4 countries plus Germany and Austria.

The authors use the methods of the correlation and regression analysis and development trends, time series analysis.

The method of correlation and regression analysis

Since correlation and regression analysis represents the basic research method and method for reaching the assumed goal in the paper, the authors consider it suitable to include at least a brief note on this method.

Generally, the correlation analysis is used to study mutual symmetric dependencies while the emphasis is put on the intensity of the mutual relationship. The task of the regression and correlation analysis is to mathematically describe systematic circumstances which accompany statistical dependencies. Our aim is to find out such an “idealizing” mathematical function which will best express the nature of the dependence and most faithfully depict the process of changes of conditioned averages of the dependent variable. This mathematical function (hypothetical in its nature) is called the regression function. The aim is to get the empirical (calculated) regression function as close to the hypothetical regression function as possible. Statistical dependencies connected to the process of dependence and its intensity will be examined in our paper. The description of dependence process is usually carried out by describing the particular dependence using a certain “balancing” analytical function. Some common mathematical functions represent these regression functions. The graphic form was chosen as the basic method of selecting the regression function. The graphic form depicts the process of dependence in the scatter plot, in which each observation pair x and y represents one point of this diagram. According to the characteristic course of the scatter plot, we try to decide which type of the particular regression function (line, parable, logarithmic function, etc.) would be the most suitable for the description of the monitored dependence. In order to determine the parameters of the regression function, the so-called method of least squares was used; it minimizes the sum of the squares of deviations of empirical values of the dependent variable from the theoretical values, see more in (Anderson, 2008).

The trend component is the most important component of the time series analysed, and therefore the trend description is one of the most important tasks of time series analysis. The Trend Component provides critical information for forecasting time series values for the future. We use two general approaches: analytical and synthetic to determine the trend component.

The analytical approach to trend determination is based on previously known types of trending functions characterized by the presence of parameters that need to be determined as best as possible with respect to the actual values of the time series indicator. From a large number of trending functions, we will focus on a linear trend that is especially important in economic applications (Kočenda & Černý, 2015).

The most common method of estimating unknown trend function parameters is the least squares method (MNC). Here we apply this method to a special type of simple regression for data in the form of an economic time series, i.e., when the independent variable is time and the dependent variable is the monitored economic indicator (in our case, energy productivity).

The synthetic approach to trend determination is to offset the deviations of a given pointer in the time series (so-called equalization) so that the obtained equilibrium values express the trend factor

The most commonly used trending function for an analytical approach is the linear trend function:

$$T_T = B_0 + B_1 \cdot t$$

where B_0, B_1 are unknown parameters and t = 1,2, ..., n is the time variable. Estimates of unknown parameters are obtained using the smallest squares method, which gives the best impartial estimates (Adamec, 2010). Therefore, it is necessary to solve 2 normal equations and to carry out time transformations. We get this solution of normal equations:

$$B_0 = \frac{\sum y_t}{n},\ B_1 = \frac{\sum t' \cdot y_t}{\sum (t')^2}$$

Parameter B_0 is interpreted as the arithmetic mean of the time series values, parameter B_1 indicates how the increment of the value T_t corresponds to the unit increment of the variable t.(Mendenhall, Beaver, & Beaver, 2009)

The expected quantity (in our case, energy productivity) in 2017, 2018 is calculated by assigning t', corresponding to the relevant year, to the specified trend equation.

A major problem of time series analysis is the problem of determining a particular type of trending function. The basis for deciding on the appropriate type of function should be substantive-economic criteria, i.e. the trend function should be chosen on the basis of a factual analysis of the examined economic phenomenon. During a factual analysis, it is usually possible to assess whether the function is increasing (or decreasing), with the growth trend above all the limits or a certain final value (asymptote).

The graphical representation of the time series will allow in rough lines to reveal the basic tendencies in the development of the analysed indicator. The risk of choice based on visual selection lies in its subjectivity. Different analysts can assess the situation differently and choose different types of trending features. The danger here arises from the fact that the shape of the graph is to a large extent dependent on the choice of the scale used.

We measure the adherence of the data to the trend curve with the R^2 determinant:

contained only in the time series, not the factor input from the outside. Therefore, we do not need to know in advance the type of trending function, which is a synthetic approach to the analytical approach. Its disadvantage is, on the contrary, more difficult to use for predicting time series values.

$$R^2 = \frac{St}{Sy}$$

Part of the overall variability explained by the regression model is characterized by the theoretical sum of squares of S_t.. Unexplained portion of total variability is the residual sum of squares S_r (Brockwell & Davis, 1991).

It can be shown that there is a basic relationship between squares:

$$S_y = S_t + S_r.$$

We can use the Determination Coefficient to compare the suitability of the trend even now. In principle, an assessment can be made in which the most appropriate trend model gives the highest value to the determinant coefficient. Furthermore, we calculate a few simple indicators that are used as a **measure of dynamism** (Hindls, 2012):

absolute increment

$$\Delta y_t = y_t - y_{t-1}\ ,\ t = 2, 3, \cdots, n$$

average absolute increment

$$\overline{\Delta} = \frac{\sum \Delta y_t}{n-1} = \frac{(y_2 - y_1) + (y_3 - y_2) + \cdots + (y_n - y_{n-1})}{n-1} = \frac{y_n - y_1}{n-1}$$

relative increment

$$\delta_t = \frac{\Delta y_t}{y_{t-1}} = \frac{y_t - y_{t-1}}{y_{t-1}} = \frac{y_t}{y_{t-1}} - 1$$

average growth factor

$$\bar{k} = \sqrt[n-1]{k_1 k_2 \cdots k_n} = \sqrt[n-1]{\frac{y_2}{y_1}\frac{y_3}{y_2}\frac{y_4}{y_3}\cdots\frac{y_n}{y_{n-1}}} = \sqrt[n-1]{\frac{y_n}{y_1}}$$

Results and discussion

We used Eurostat data for countries of the Czech Republic, Slovakia, Poland, Hungary, Germany and Austria and assessed the nominal energy productivity figures in 1995-2016 (Eurostat, 2018). For the selected countries, the following calculated values are derived.

Czech Republic

The first figure shows the development of energy productivity in the Czech Republic including the linear development trend.

The linear trend function: y = 0,0773x - 151,85

The determination factor in this case is as follows:

$$R^2 = \frac{St}{Sy} = 0{,}9451 \rightarrow \mathbf{94{,}51\%}$$

Which means that 95% of total variability has been explained, 5% neglected. Average absolute increment: $\bar{\Delta}$ = **0,081** (this number will increase energy productivity each year). Average growth factor: $\bar{k}$ = **1,025** (annual energy productivity increases by 2,5%).

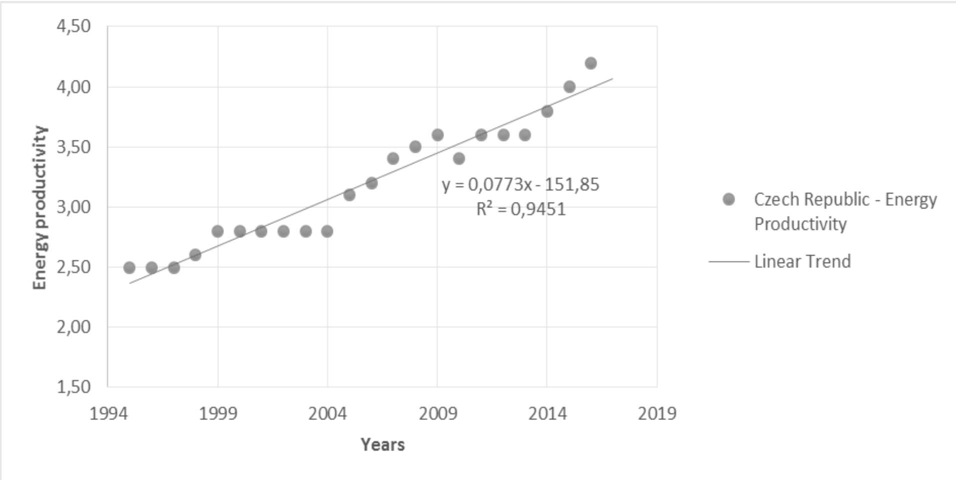

Figure 1. Development of energy productivity in the Czech Republic
Source: Own construction on the basis of research results.

Slovakia

The coefficients B_0 and B_1 of the Slovak energy productivity linear trend are as follows:

$$B_0 = \frac{\sum y_t}{n} = \mathbf{0{,}143}$$

$$B_1 = \frac{\sum t' \cdot y_t}{\sum (t')^2} = \mathbf{-0{,}9536}$$

The determination factor in this case is 95%, which means that 95%% of total variability has been explained, 5 % neglected. Average absolute increment: $\bar{\Delta}$ = **0,133** and average growth factor: $\bar{k}$ = **1,043**

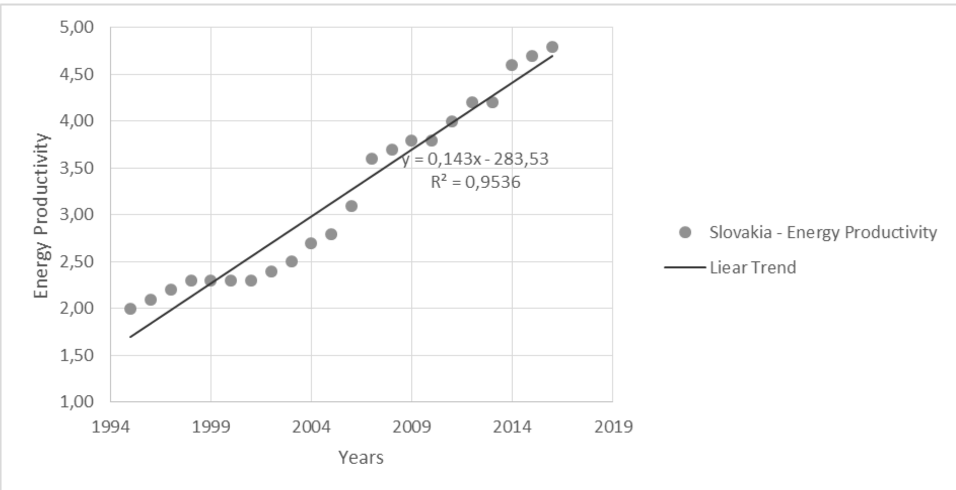

Figure 2. Development of energy productivity in Slovakia
Source: own construction on the basis of research results.

Poland

The Polish economy is set to continue growing with a near doubling of GDP between 2010 and 2030 (Blok, Hofheinz, & Kerkhoven, 2015). The coefficients B_0 and B_1 of the Poland labour productivity linear trend are as follows:

$$B_0 = \frac{\sum y_t}{n} = \mathbf{0{,}1157}$$

$$B_1 = \frac{\sum t' \cdot y_t}{\sum (t')^2} = \mathbf{-228{,}23}$$

In the case of Poland, 98% of total variability has been explained, 2% neglected. Average absolute increment: $\bar{\Delta}$ = **0,114** and average growth factor: $\bar{k}$ = **1,040.**

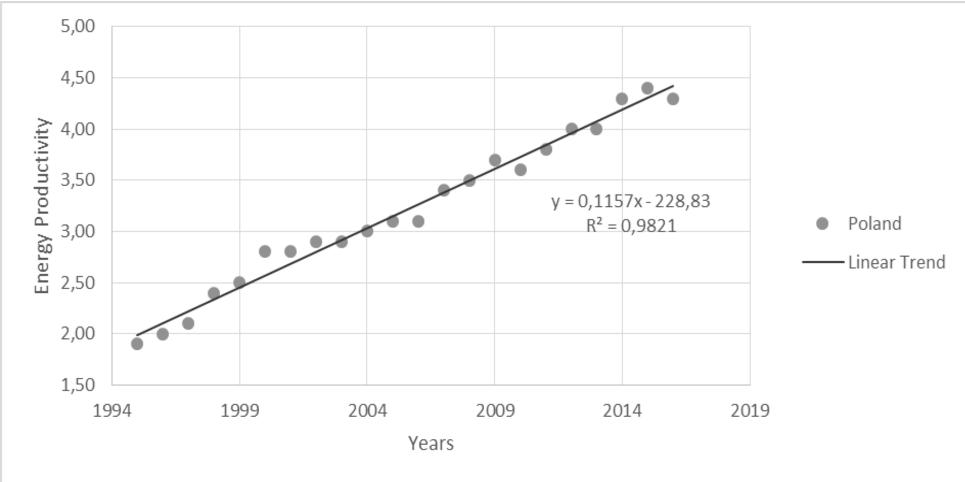

Figure 3. Development of energy productivity in Poland
Source: own construction on the basis of research results.

Hungary

The coefficients B_0 and B_1 of the linear trend of labour productivity in Hungary are as follows:

$$B_0 = \frac{\sum y_t}{n} = \mathbf{0{,}0817}$$

$$B_1 = \frac{\sum t' \cdot y_t}{\sum (t')^2} = \mathbf{-160{,}29}$$

The determination factor in this case is 94%, which means that 94% of total variability has been explained, 6% neglected. Average absolute increment: $\bar{\Delta}$ = **0,076** and average growth factor: $\bar{k}$ = **1,022.**

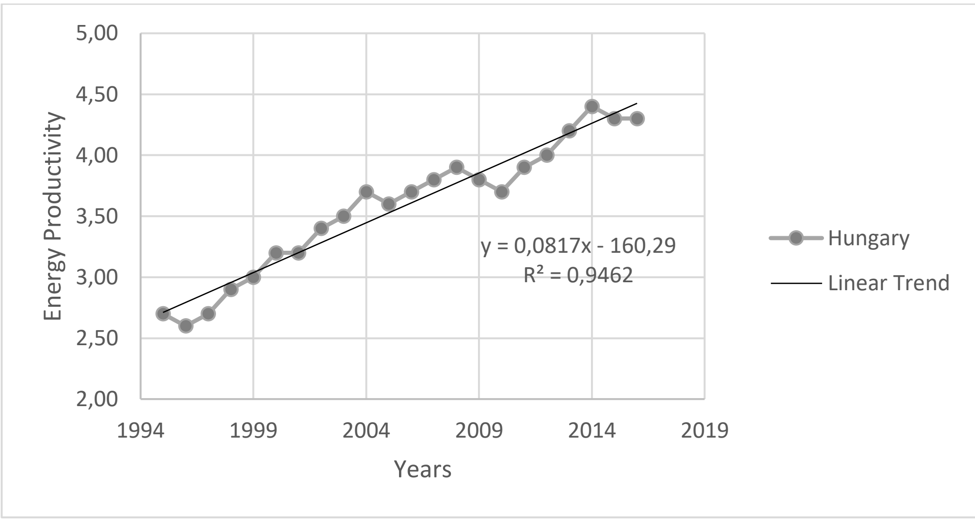

Figure 4. Development of energy productivity in Hungary
Source: own construction on the basis of research results.

Austria

Average absolute increment: $\bar{\Delta}$ = **0,062** and average growth factor: $\bar{k}$ = **1,007.**

Germany

Average absolute increment: $\bar{\Delta}$ = **0,129,** average growth factor: $\bar{k}$ = **1,017.**

The slower growth in energy productivity in Germany is due to high energy consumption. Therefore measures to reduce energy demand are needed. Germany could decrease its annual final energy consumption by as much as 32% by 2030 through more aggressive use of existing technology (Blok et al., 2015).

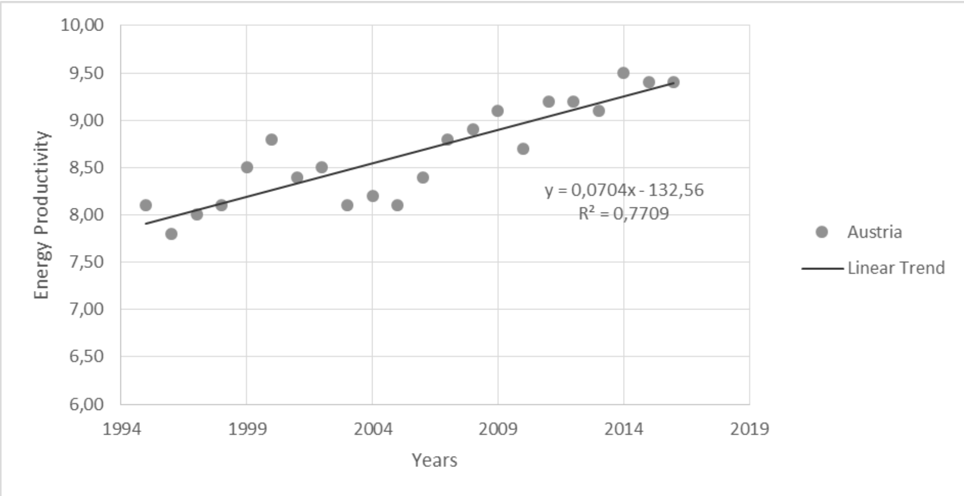

Figure 5. Development of energy productivity in Austria
Source: own construction on the basis of research results.

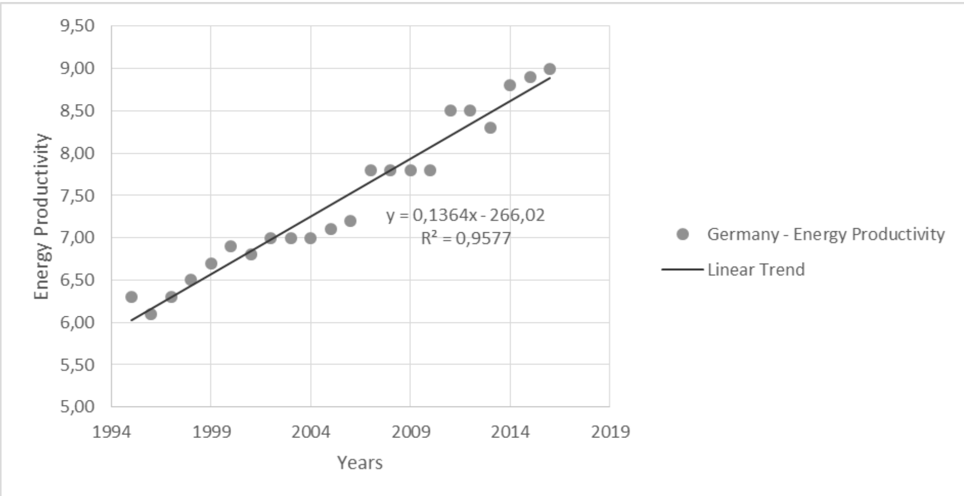

Figure 6. Development of energy productivity in Germany
Source: own construction on the basis of research results.

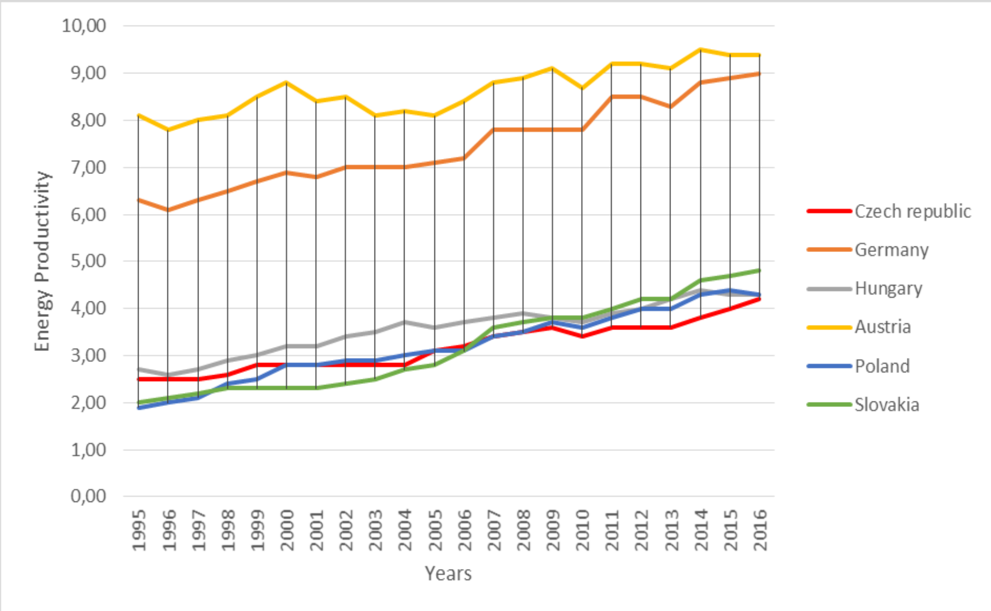

Figure 7. Development of energy productivity in selected countries EU
Source: own construction on the basis of research results.

The results of our analyses show that development of energy productivity is growing in all monitored countries. A very important and interesting finding is, that the energy productivity grows faster in V4 countries than in other monitored ones. There are researches (Atalla & Bean, 2017), they say that structural economic shifts away from industry and to- wards service-oriented sectors played a lesser role in aggregate energy productivity improvements. The countries whose performances are worth noting in this context are Singapore (No. 4 globally, at €329 billion of GDP per exajoule) and Switzerland (No. 5 globally, with €310 billion of GDP per exajoule). (Blok et al., 2015). They show that even advanced economies can perform at a high level of energy efficiency.

Conclusions

Many developing countries have an inbuilt advantage; if they are clever, they can leapfrog the long period of energy intensive economic development that characterized the Industrial Revolution and use new technologies to move immediately to cleaner, more efficient forms of energy consumption (Blok et al., 2015) and production as well. V4 countries have a similar advantage; if they use new technologies, they can be more efficient. Also it is clear, there are many possibilities and measures to save energy. Of course, these measures have advantages and disadvantages. Some of them can result in the loss of some professional jobs in energy inefficient areas. On the other hand, the reduced fuel bill can also mean that additional money is available to be spent in another sectors of the economy, e.g. in healthcare, which is more labour intensive.

Energy productivity is a very important point in the development of each economy and society, because it brings greater welfare.
Some studies (Parker & Liddle, 2017) show that some group of countries has distinctive dynamics and evidence that technology structure of production and investment are associated with higher relative energy productivity performance. Further, we have the same opinion that adjusting for energy quality is important.

If Germany and Austria do not reduce their energy consumption and the V4 countries will continue to increase their energy efficiency, it is possible that the V4 countries in the developed countries will come closer to their level of development of energy productivity.

Our proposals for producers of energy are the following: They can use, to a greater extent, renewable energy in the form of wind, solar, hydroelectric, biomass and geothermal which generates substantial benefits for our climate, health, and the global economy.

References

Adamec, V. (2010). Applied statistics. Statistics I : descriptive statistics : linear regression and correlation : categorical data : time series : statistical indices (1.). Brno: Mendelova univerzita.

Anderson, D.R. (David R. (2008). Statistics for decision making (2.). Cengage Learning.

Atalla, T., & Bean, P. (2017). Determinants of energy productivity in 39 countries: An empirical investigation. Energy Economics, 62, 217–229. https://doi.org/10.1016/J.ENECO.2016.12.003.

Blok, K., Hofheinz, P., & Kerkhoven, J. (2015). How Efficiency Will Drive Growth, Create Jobs and Spread Wellbeing Throughout Society THE 2015 ENERGY PRODUCTIVITY AND ECONOMIC PROSPERITY INDEX. ECOFYS, 9(1), 60. Retrieved from https://www.ecofys.com/files/files/the-2015-energy-productivity-and-economic-prosperity-index.pdf.

Brockwell, P.J., & Davis, R.A. (1991). Time series : theory and methods (2.). Springer-Verlag.

Du, K., & Lin, B. (2017). International comparison of total-factor energy productivity growth: A parametric Malmquist index approach. Energy, 118, 481–488. https://doi.org/10.1016/j.energy 2016.10.052.

Eurostat. (2018). Energy productivity - Datasets. Retrieved March 2, 2018, from https://data.europa.eu/euodp/data/dataset/xWiT1fbpF5q1ZCvLQc2upg.

Hindls, R. (2012). Statistika pro ekonomy (8.). Praha: Professional Publishing. Retrieved from https://www.cupress.cuni.cz/ink2_ext/index.jsp?include=podrobnosti&id=222218.

Kočenda, E., & Černý, A. (2015). Elements of time series econometrics: An applied approach. Prag: Karolinum Press, Charles University. Retrieved from http://press.uchicago.edu/ucp/books/book/distributed/E/bo26038158.html.

Mendenhall, W., Beaver, R.J., & Beaver, B.M. (2009). Introduction to Probability and Statistic (13.). Belmont, USA: Brooks/Cole, Cengage Learning. Retrieved from ftp://nozdr.ru/biblio/kolxo3/M/MV/Mendenhall W., Beaver R., Beaver B. Introduction to probability and statistics (13ed., Duxbury, 2008)(ISBN 0495389536)(O)(777s)_MV_.pdf

Meyerding, Stephan G.H. Schoettler, S., & Hardeweg, B. (2017). Development of energy productivity and energy intensity in German horticulture from 2000 to 2013. Berichte Über Landwirtschaft., 95(3). Retrieved from http://apps.webofknowledge.com.ezproxy.lib.cas.cz/full_record.do?product=WOS&search_mode=GeneralSearch&qid=3&SID=D2smJadhLqT43O5FoiN&page=1&doc=7.

Parker, S., & Liddle, B. (2017). Analysing energy productivity dynamics in the OECD manufacturing sector. Energy Economics, 67, 91–97. https://doi.org/10.1016/j.eneco.2017.07.016.