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MODELLING THE TREND OF ENERGY PRODUCTIVITY IN THE SERBIAN ECONOMY

Modeliranje trenda energetske produktivnosti u privredi Srbije

Abstract

Energy productivity indicates the efficiency of energy use in production. Investment in energy efficient solutions, technologies and practices lead to increased energy productivity. It is often used as a suitable measure to compare the results of economic, energy and climate policies. In 2006, the Republic of Serbia became a member of the Energy Community, thus taking on the obligation to accept the energy acquis of the European Union. By this move, it also accepted the obligation to increase the use of renewables, its final energy consumption and energy services' efficiency. Energy productivity in Serbia has increased by 66.94%, in the period from 2000 to 2019. This growth was primarily driven by the national GDP high growth rate, but not by the reduction of energy consumption. Given the still extremely high Serbian energy intensity levels compared to the European and world average, the aim of this paper is to examine the expected future trends of this indicator. The inverse function econometric model best describes the energy productivity trend in Serbia. The paper concludes that its trend will most likely continue to move upwards, primarily because no significant changes in the Serbian economic and energy policy are expected and because, at least according to official statistics, the country's economy has not been largely affected by the global coronavirus pandemic COVID-19. Since the energy productivity improvement determines the competitiveness and performance of the economy, it is extremely important for Serbia to apply energy efficient technologies, and to implement its further structural changes.

Keywords: *energy productivity, energy efficiency, energy intensity, economic growth, renewable energy sources, energy policy, energy dependence, trend modelling.*

Sažetak

Energetska produktivnost meri efikasnost korišćenja energije u proizvodnji. Ulaganja u energetski efikasna rešenja, tehnologije i prakse dovode do povećanja energetske produktivnosti. Ovaj pokazatelj se često koristi i kao pogodna mera za poređenje rezultata sprovedenih ekonomskih, energetskih i klimatskih politika. Republika Srbija je 2006. godine postala članica Energetske zajednice, čime je preuzela na sebe obavezu prihvatanja energetskih pravnih tekovina Evropske unije. Ona je ovim potezom takođe prihvatila i obavezu da poveća korišćenje obnovljivih izvora energije, energetsku efikasnost svoje finalne potrošnje energije i sektora energetskih usluga. Energetska produktivnost u Srbiji je u periodu od 2000. do 2019. godine porasla za čak 66,94%. Ovoliki rast ovog pokazatelja je, pre svega, bio uslovljen visokom stopom rasta domaćeg BDP-a, a ne smanjenjem potrošnje energije. Cilj ovog rada je da, s obzirom na još uvek izuzetno visoke nivoe energetskog intenziteta Srbije u odnosu na evropski i svetski prosek, ispita očekivane trendove budućeg kretanja ovog pokazatelja. Trend kretanja energetske produktivnosti u Srbiji na početku ovog veka najbolje opisuje ekonometrijski model inverzne funkcije. U radu se zaključuje da će se trend kretanja ovog pokazatelja i dalje najverovatnije kretati uzlaznom putanjom, pre svega jer se ne očekuju značajnije promene u ekonomskoj i energetskoj politici Srbije i jer, barem prema zvaničnim statističkim podacima, privreda zemlje do sada nije bila u većoj meri pogođena globalnom pandemijom koronavirusa kovid-19. Pošto poboljšanje energetske produktivnosti opredeljuje rast konkurentnosti i performansi privrede, za privredu Srbije je od izuzetnog značaja da primenjuje energetski efikasne tehnologije, kao i da dalje sprovodi svoje strukturne promene.

Ključne reči: *energetska produktivnost, energetska efikasnost, energetski intenzitet, privredni rast, obnovljivi izvori energije, energetska politika, energetska zavisnost, modeliranje trenda.*

Introduction

In the most general sense, productivity is an aspect of production efficiency and is defined as the ratio between the value of output and a particular input. In other words, productivity measures the efficiency of the production factors' use such as labour, capital, land, electricity, natural resources, and other inputs consumed in the economy at a given production level, i.e., a given output or gross value added (GVA). In its broadest sense, productivity is the requirement to minimize input costs for a given production level, as well as to produce in an economically rational way. As such, productivity is one of the key determinants of economic growth and competitiveness and it often represents the basis for assessing and comparing the economic performance indicators of contemporary countries [19].

The Global Alliance for Energy Productivity defines energy productivity as a measure of the economic benefits derived from each unit of energy used. We can usually obtain this indicator by dividing total economic output (gross domestic product – GDP, national income or total gross value added) with the total energy consumption. Energy productivity also points to the economic results of energy efficient investments [2, p. 3]. By measuring this indicator, it is possible to determine the extent to which a given country more or less efficiently uses the energy it pays for. Investments in energy efficient solutions, technologies, and energy efficient practices lead to increased energy productivity. However, energy efficiency, as important as it is, is not an indicator of the economy's overall efficiency, but it is a measure of one of its aspects. Namely, it is possible to increase or decrease energy efficiency without concluding anything about the change in general efficiency, since other partial efficiency indicators may change in opposite direction in relation to general efficiency.

In addition to measures aimed at achieving energy efficiency, energy productivity, as a tendency to achieve greater results with the same or lower energy consumption, often includes the need for fuel substitution, energy storage, increased use of renewable energy resources, decarbonisation of the economy, etc. Increasing energy productivity directly contributes to reducing energy and electricity costs, protecting the environment, increasing the productivity of the economy, increasing the energy market competitiveness, and better managing energy demand [4]. This phenomenon also influences the reduction of greenhouse gas (GHG) emissions, improving economic performance and economic growth, increasing energy systems' reliability and security, introduction and development of technological innovations, etc. [2, p. 3]. Energy productivity is often used as a valuable and suitable measure to compare economic, energy and climate issues and policies' results internationally.

Energy intensity represents the ratio between the consumed energy and the total realized output and, as such, this indicator appears as a reciprocal value of energy productivity. Although the energy intensity indicator is more often used in practice, energy productivity gives better results and reasoning grounds, since it implies a better intuitive framework and has a positive connotation. In other words, while desirable improvements in energy productivity are represented by an increase in its value, improvements in energy intensity are reflected in a decrease in its value, which means that they are measured in less perceptive units of consumption [11, p. 6]. Recently, the popularity of energy productivity indicator has increased, considering that many contemporary countries and organizations, such as the American Climate Group EP100, have started to include it, as one of the strategic goals, in their agendas and development policies [5].

Changes in energy productivity at the level of an economy can occur, first, because of sectorial energy productivity that represents a consequence of technological improvements, changes in the energy mix of production, and changes of producers' and consumers' behaviour, but also changes of the economic activities' structure. For example, if structural change of economic activities is shifted to energy-productive sectors such as financial services, there will be an increase in aggregate energy productivity, even if the energy productivity of each sector would remain the same [3, p. 218]. We should add to the mentioned determinants the growth of energy efficiency, increase of GDP per capita, i.e., economic growth, growth of energy prices, national income and investments, growth

of service sector, increased rate of urbanization, etc., as factors that directly contribute to the energy productivity growth. In any case, the growth of energy efficiency leads to an increase in productivity, especially by reducing maintenance costs and increasing the yield per unit of energy input [10]. On the other hand, while a favourable industrial structure, openness of the economy, and per capita growth of available capital have a mostly positive influence, some authors are highlighting that the intensity of research and development (R&D) and government regulations can have a negative impact on the growth of energy productivity [14. pp. 1-9].

The state of the Serbian energy sector

In July 2006, the Republic of Serbia became a member of the Energy Community, thus accepting the obligation to adopt the European Union's (EU) acquis communautaire in the field of energy policy. This membership implies the country's obligation to encourage the use of energy from renewable sources, as well as biofuels and other renewable fuels for the needs of transport. By the decision of the Energy Community Ministerial Council in October 2012, the country undertook the commitment to increase the renewable energy sources' share in its gross final energy consumption from 21.2% to 27%, as well as to raise the share of renewable fuels in the transport sector to at least 10% in 2020 [25]. Serbia is at least declaratively committed to these goals, because in 2013 it adopted its first National Renewable Energy Action Plan. Membership in the Energy Community also obligates the country to increase energy efficiency of final consumption and energy services, to inform about and to label energy-important products, as well as to meet the criteria of energy performance for buildings. However, although it has fully transposed the Third EU Energy Package into its legislation, Serbia is clearly lagging behind in its implementation in many areas such as the splitting of activities of the national gas company Srbijagas and excessive air pollution from thermal power plants. In addition, Serbia is still far from achieving the defined target for 2020 of 27% share of renewable energy in its gross final energy consumption.

Primary energy consumption in Serbia in 2018 amounted to 15.4 million tons of oil equivalent (mtoe). Serbia is characterised by a high share of coal in its primary energy consumption, mainly low-calorie lignite (about 49%), which is mostly used for electricity production. Such high consumption of lignite compared to other states allows the country relatively high-energy independence in electricity production, with relatively lower and stable costs. On the other hand, such intensive use of lignite contributes to the GHG emissions' growth, and thus increases the adverse impact of the electricity sector on the environment. In 2018, Serbia's net import energy dependence was 34.8%, which is lower than in the vast majority of the EU countries in which the average value of this indicator is around 55%. Until 2013, import dependency of Serbia decreased due to increased domestic production of crude oil and natural gas, and after that, it started to grow again [1, p. 5]. In the last 12 years, the share or renewables in its final energy consumption has not changed significantly. Although the National Renewable Energy Action Plan defined a goal of achieving their share in gross final energy consumption of 27% until 2020 [16, p. 4], the value of this indicator in the observed period ranged only from 19.1% to 22.9% [7]. The most significant renewable energy sources in Serbia are in the form of biomass and hydropower, which in the past mostly participated in electricity production, but also in energy consumption. Further, renewable energy sources and renewable electricity accounted for about 21% of gross final energy consumption in the country [20]. During 2018, most windfarms (the share of 69.19%), small hydropower plants up to 10 MW of power (the share of 13.33%), and biogas power plants (the share of 12.03%) were built. The available data also show a very uneven distribution of production from various forms of renewable energy sources in the country [17, p. 6].

Energy productivity was quite stable at the beginning of the observed period from 2000 to 2019, and from 2003, when it reached its lowest value of € 1.42 per kilogram of oil equivalent (kgoe), it began to grow gradually. This indicator experienced its highest values twice, in 2014 (the value of € 2.42 per kgoe) and at the very end of the observed period, i.e., in 2019 when it amounted to € 2.45 per kgoe. In this period, the value of energy productivity

increased by as much as 66.94% compared to the initial year 2000. This growth of energy productivity was above all driven by even higher growth of national GDP by as much as 88.04%. In contrast to the desirable GDP trend, gross available energy increased in the observed period by 13.75%, which indicates an obvious increase in Serbian energy consumption. Besides, Serbia has one of the lowest levels of energy efficiency in Europe. According to some calculations, Serbia consumes 2.5 times more energy per unit of its GDP than the world average and four times more than the EU average [13]. Since the country's available energy sources are far lower than the world and European average, and since its consumption is huge, Serbia is also very dependent on energy imports. According to another study, in the period from 2000 to 2014, the country lagged behind the EU-28 in terms of energy intensity, measured by gross energy consumption per unit of GDP. Although both EU countries and Serbia recorded energy intensity declining trends in this period, energy efficiency in EU countries amounted to 122 kgoe per € 1,000 in 2014, while in Serbia this indicator was more than 3.5 times higher and amounted to 442 kgoe per € 1,000 [22, p. 11]. Finally, in 2018, the energy intensity of Serbia was at the level of the Western Balkan countries, but 1.79 times higher than the European average [15, p. 123]. Higher energy intensity occurs partly because of inevitable technical losses in the transformation of lignite into electricity, but also due to inefficient energy consumption in households and industry, low capacity utilization, and to outdated technology.

Methodological explanations: Analysis of the energy productivity trend in Serbia

A time series is a range of observations arranged in relation to time, usually at equal time intervals. The main goal of time series is to predict the future value and/or development of a phenomenon based on historical data [12, p. 6]. Time series trends are the basic development components in the study of some economic phenomena or processes dynamics. In that sense, the trends of development are the result of important and permanent factors, as well as reasons that determine the direction of a certain economic phenomenon trend. Research on development trends contributes to the analysis of the following aspects [23, p. 34]:

- From a descriptive analysis viewpoint, such research clearly shows the regularity of phenomenon development, and
- From a prognostic analysis aspect, it can help to predict future levels of some phenomenon, i.e., in this case the level of energy productivity in the country.

Generally, energy productivity is the relationship between some monetary output and energy consumption. At the level of economy, energy productivity is usually defined as the ratio between gross domestic product (GDP) and primary energy consumption (PEC). This indicator shows how many monetary units of GDP primary energy consumption can generate. Energy intensity is a reciprocal value of energy productivity and it indicates how many units of primary energy consumption are needed to create each monetary unit of GDP [11, p. 6]. Thus, energy productivity is often obtained based on the following formula:

$$Energy\ productivity = \frac{Gross\ domestic\ product\ (GDP)}{Primary\ energy\ consumption\ (PEC)}$$

The Eurostat, on whose methodology this paper relies, defines energy productivity as the ratio between GDP and gross available energy for the following year. The Eurostat bases its calculations on the following formula [9]:

$$Energy\ productivity = \frac{Gross\ domestic\ product\ (GDP)}{Gross\ available\ energy\ (GAE)}$$

This indicator measures the productivity of energy consumption and gives a clear picture of the decoupling degree of energy consumption from GDP growth. To calculate energy productivity, the paper uses data on GDP in millions of euros in chain linked-volumes for the reference year 2010, at exchange rates from 2010. The paper traces the development of this phenomenon in the period from 2000 to 2019, while the data for its calculation are derived from the Eurostat database. The euro unit in chain-linked values makes it possible to observe the energy productivity trend over time in a country. Eurostat defines gross available energy as follows:

Gross available energy = Primary energy production + Renewable and recycled products + Energy imports – Energy exports + Stock changes

Gross available energy encompasses the overall energy supply for performing all activities on the territory of a certain country. This indicator also includes energy transformation, including generating electricity from combustible fuels, distribution losses, and use of fossil fuel products for non-energy purposes (for example in the chemical industry). It also covers fossil fuels' consumption in transport, including fuel purchased within the country that is used abroad (e.g., international aviation, international maritime bunkers, etc.). Energy productivity is expressed in euros per kilogram of oil equivalent, while its trend chart in Serbia in the period from 2000 to 2019 is presented in Figure 1.

Figure 1: Trend chart of energy productivity in Serbia, in the period from 2000 to 2019 (in euros per kgoe)

Energy productivity (in € per kg of oil equivalent)
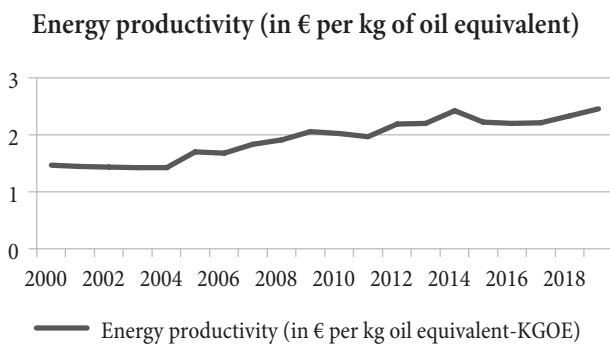
Source: Author's calculation based on the Eurostat data.

The diagram clearly shows that the development of energy productivity in Serbia in the period from 2000 to 2019 reveals a growing trend. There are numerous factors that determined this development path, including the growth of Serbia's GDP in the given period by 89.9%, the growth of gross available energy by 13.75%, but also better technological equipment of the national economy driven by foreign direct investment (FDI) inflows. These factors also include growth of energy efficient technologies' use in industry and households, restructuring of many large energy consumers, growth in the FDI volume, and growth in the share of services in the economy, etc. Thus, in this case, there was a relative separation of GDP from energy consumption because the economy grew much faster than energy consumption.

In addition to simple visual tracking of time series data, various statistical prediction methods such as hypothesis testing can be applied in the field of energy. In theory, various tests help to detect whether there is a development trend suitable for a given dynamic data order. A dynamic data order is an order of primary or secondary data, arranged in time in chronical order that reflects changes in a particular phenomenon over time. First-order autocorrelation coefficients are among the most commonly used tests in practice. Autocorrelation is the correlation between the values of a time series at different time points. First-order autocorrelation is the correlation between successive values of a statistical data order. Time series are considered autocorrelated when they contain a development trend, i.e., when each member of the order is correlated with and when it depends on the previous member and/or members of the same time series [23, pp. 35-36]. The first order correlation coefficient can be obtained based on the following formula [24, p. 7]:

$$r_1 = \frac{\sum_{i=2}^{N} Y_i Y_{i-1} - \frac{1}{N-1} \sum_{i=1}^{N-1} Y_i \sum_{i=2}^{N} Y_i}{\sqrt{\left[\sum_{i=1}^{N-1} Y_i^2 - \frac{1}{N-1}\left(\sum_{i=1}^{N-1} Y_i\right)^2\right]\left[\sum_{i=2}^{N} Y_i^2 - \frac{1}{N-1}\left(\sum_{i=2}^{N} Y_i\right)^2\right]}}$$

Where:

r_1 is autocorrelation coefficient of first order,

Y_i are the values of the observed dynamic row,

Y_{i-1} are the first order lagged values of the dynamic row, and

N is the length, i.e., the number of dynamic order members.

To perform this test, it is necessary to first define the null (H_0) and the alternative (H_1) hypotheses. In this analysis, a time series data on energy productivity of the Serbian economy in the period from 2000 to 2019 is observed. The calculation of autocorrelation coefficient is performed in the IBM SPSS statistical software. The initial and alternative hypotheses are as follows:

H_0: There is no autocorrelation in the dynamic row we examine, i.e., the autocorrelation coefficient is not statistically significant, which indicates that there is no development trend in the observed data series.

H_1: There is an autocorrelation in the observed dynamic row, i.e., the autocorrelation coefficient is statistically significant, which indicates that there is a development trend in the observed data series.

The significance level of the test, i.e., the risk of type I error is 5% ($\alpha = 0.05$). Table 1 indicates the results of calculating the autocorrelation coefficient, as well as the corresponding levels of their statistical significance. In this analysis, the first order autocorrelation coefficient amounts to $r_1 = 0.838$, while its significance level is *Sig.* = 0.000 which is less than 0.05. According to the methodology defined by Velichkova [24, pp. 71-74], this means that we can reject the null hypothesis H_0 and decline to reject the alternative hypothesis H_1 of the presence of autocorrelation in the dynamic data series we are examining. Thus, we can assume that

there is a development trend in the observed data series on energy productivity in Serbia. In a specific case of this research, this further means that with a probability of 0.05 (5%), we can claim that energy productivity in Serbia in the first two decades of the 21st century was accompanied by a development trend.

The presence of autocorrelation in the dynamic data series we are examining is also indicated by the autocorrelogram of energy productivity data (Figure 2). The autocorrelogram shows the correlation of a data series with itself. While the number of lags, i.e., orders of correlation is presented on the x-axis, the y-axis represents

Table 1: Autocorrelation coefficients of energy productivity in Serbia
(for the first six orders, i.e., lags of correlation)

Lag	Autocorrelation coefficients	Standard errors	Ljung-Box test		
			Empirical values	Degrees of freedom	Significance
1	0.838	0.208	16.262	1	0.000
2	0.704	0.202	28.362	2	0.000
3	0.562	0.197	36.549	3	0.000
4	0.437	0.191	41.807	4	0.000
5	0.290	0.185	44.276	5	0.000
6	0.113	0.178	44.675	6	0.000

Source: Author's calculations.

Figure 2: Autocorrelogram graph of energy productivity in Serbia
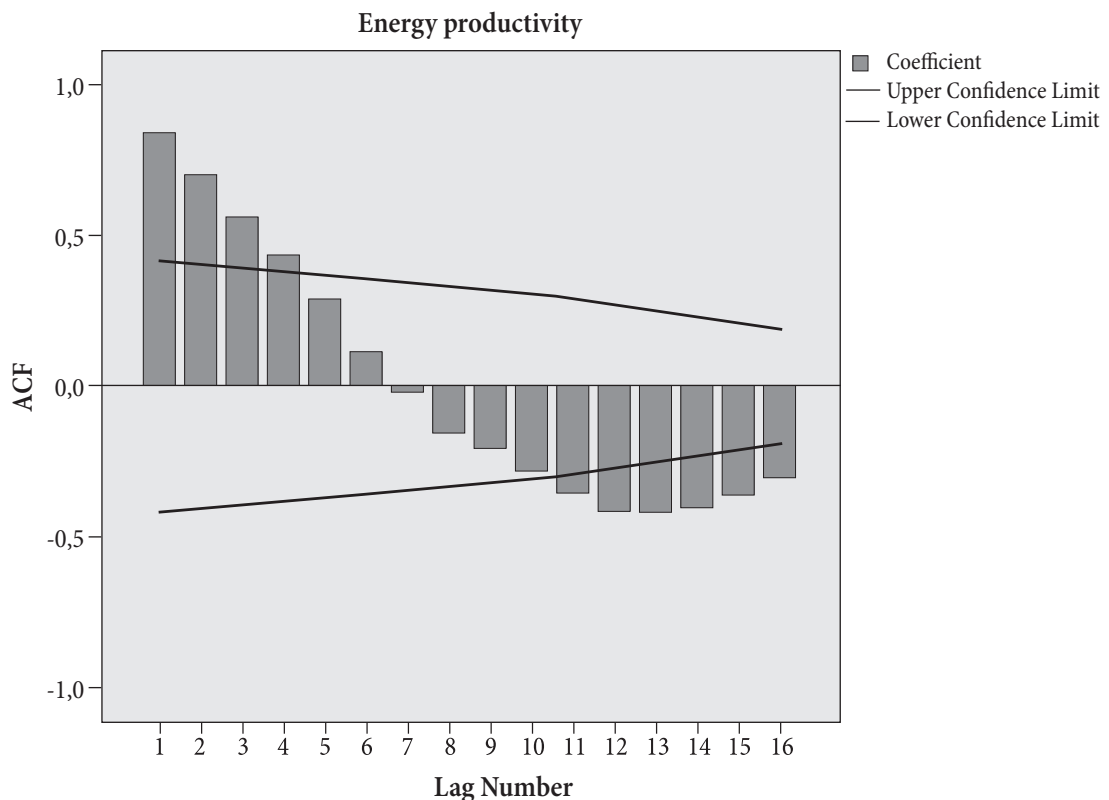
the calculated autocorrelation coefficient (ACF). We can see from Table 1 and Figure 2 that at lag 1 the autocorrelation coefficient is 0.838, at lag 2 the autocorrelation coefficient amounts to 0.704 etc., which indicates that it decreases with the growth of lags, becoming negative at the seventh lag.

Trend modelling

Modelling of development trends generates a specific analytical type of functions, in which the studied phenomenon features depend on its development. In these functions, Y is the symbol used to represent the energy productivity of Serbia, t is an artificial variable that indicates time, while ε_t is a random component of the model. In order to determine the development trend of energy productivity in Serbia, the paper applies 11 different econometric linear and nonlinear models, within which the appropriate trend is determined by the model that has the highest coefficient of determination R^2, and thus the highest power of explanation. The coefficient of determination R^2 highlights the percentage of variation in the observed data sample that the given model explains.

Table 2 shows the results of the energy productivity trend modelling with the aim of choosing the one that fits best.

The results of 11 tested competitive models indicate that with a probability of 95% we can assume that the **bolded** model of inverse function (3) is the best for describing the energy productivity trend in Serbia at the beginning of this century. Table 3 gives a brief description of the selected inverse function model basic statistical characteristics and estimated parameters.

The selected model of the inverse function is valid because it is statistically significant (*Sig.* = 0.000, which is lower than 0.05) and has a high coefficient of determination $R^2 = 0.911$. The chosen econometric model could be the most suitable because it explains 91.1% of the change in energy productivity in the country. Parameters' estimates of the chosen inverse function model indicate that the constant in this model is *Const.* = 117.473, while the curve slope is $b_1 = -232181.539$. Based on these data, it arises that the equation of this model is the following:

$$Y_t = 117.473 - \frac{232181.539}{t} + \varepsilon_t$$

Table 2: Results of 11 constructed econometric models

Models	Model characteristics				
	Coefficient of determination	F-statistic values	Degrees of freedom 1	Degrees of freedom 2	Level of significance
$Y_t = \beta_0 + \beta_1 t + \varepsilon_t$	0.910	182.424	1	18	0.000
$Y_t = \beta_0 + \beta_1 \ln t + \varepsilon_t$	0.910	183.002	1	18	0.000
$Y_t = \beta_0 + \dfrac{\beta_1}{t} + \varepsilon_t$	0.911	183.575	1	18	0.000
$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \varepsilon_t$	0.910	182.424	1	18	0.000
$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3$	0.910	182.424	1	18	0.000
$Y_t = \beta_0 t^{\beta_1} + \varepsilon_t$	0.898	158.576	1	18	0.000
$Y_t = \beta_0 \beta_1^{t} + \varepsilon_t$	0.898	157.918	1	18	0.000
$Y_t = e^{\beta_0 + \frac{\beta_1}{t}}$	0.898	159.233	1	18	0.000
$Y_t = \dfrac{1}{\dfrac{1}{u} + \beta_0 \beta_1^{t}} + \varepsilon_t$	0.898	157.918	1	18	0.000
$Y_t = e^{\beta_0 + \beta_1 t}$	0.898	157.918	1	18	0.000
$Y_t = \beta_0 e^{\beta_1 t}$	0.898	157.918	1	18	0.000

Source: Author's calculations.

Table 3: Model summary and parameter estimates

Equation	Model summary					Parameter estimates	
	Coefficient of determination	F value	*df*1	*df*2	Sig.	Constant	b_1
Inverse	0.911	183.575	1	18	0.000	117.473	-232181.539

Source: Author's calculations.

After estimating its parameters, this model takes the form of the inverse function presented in Figure 3. As Figure 3 shows, the trend of energy productivity in Serbia in the period from 2000 to 2019, which is shown by a continuous straight line, is growing. In this case, it is specific that Serbia's energy productivity has been gradually growing, primarily due to rapid GDP growth (by 89.9%), so that in recent years the value of this indicator has approached the trend line amounting around € 2.5 per kgoe.

## Forecasting the energy productivity trends in Serbia in the coming years

As already mentioned, modelling trends of energy productivity in Serbia could be used to describe its objective development laws, as well as to predict the further trends of this phenomenon in the forthcoming years. This analysis starts from the assumption that the energy productivity trend in Serbia until 2025 will follow the same patterns as in the analysed period (from 2000 to 2019). Table 4 and Figure 4 present the predicted values of this indicator in Serbia.

The dashed line in the middle refers to the observed and at the same time predicted trend of energy productivity in Serbia until 2025, while the upper and lower lines indicate the lowest and highest control limits of this phenomenon's development. As already mentioned, the starting point of this analysis is the assumption that energy productivity in Serbia will follow the same trend as in the previous period. In order to obtain a realistic and reliable statistical forecast, we need to consider the following key issues:

- The paper analyses 11 mutually competing econometric models, from which the modelled trend inverse function that gave the highest value of the coefficient of determination R^2 was selected.
- The calculated parameters can be accepted as stable ones, because we do not observe different trends of development in dynamic rows that have been examined for different time periods.

Figure 3: Dynamics of energy productivity in Serbia, in the period from 2000 to 2019
Energy productivity (in € per kg of oil equivalent)
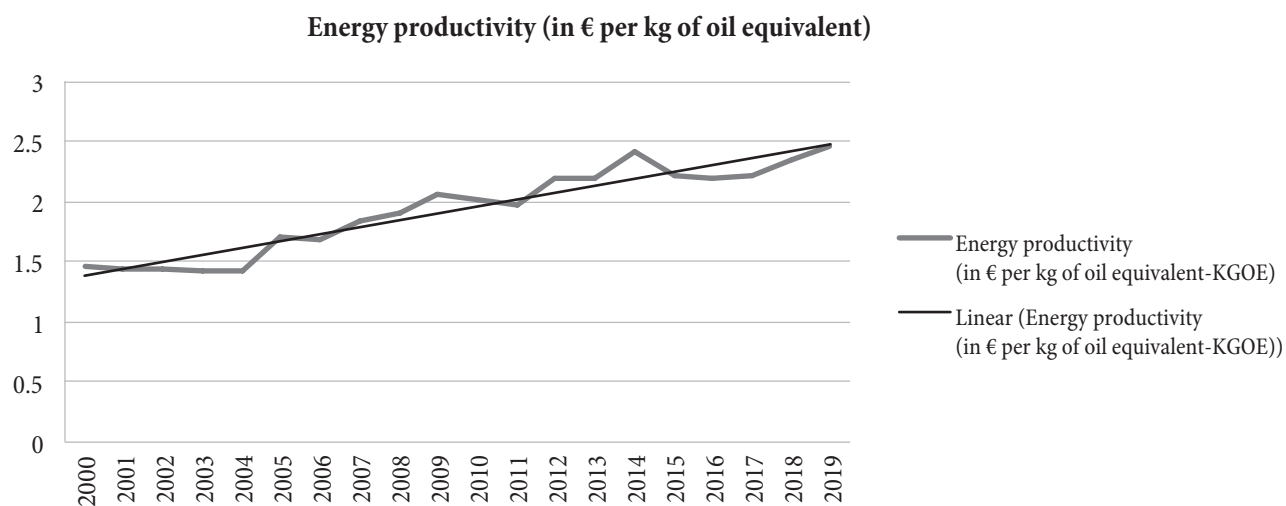
Source: Author's calculation based on the Eurostat data.

Table 4: Estimated values of energy productivity of Serbia until 2025 (in € per kgoe)

Years	Estimated values of energy productivity	Lower limit	Upper limit
2020	2.531	2.278	2.785
2021	2.589	2.331	2.845
2022	2.645	2.385	2.905
2023	2.702	2.438	2.966
2024	2.759	2.490	3.027
2025	2.815	2.542	3.088

Source: Author's calculations.

- We can assume that in the coming years the trend of energy productivity in the country will remain relatively unchanged because no significant changes in the economic and energy policy of Serbia are expected. In addition, the COVID-19 coronavirus pandemic did not have a large impact on the country's GDP (a decrease of about 1% in 2020 compared to 2019), while no significant changes are expected in the level of gross available energy in 2021, nor in the next years.

- The modelled trends were extrapolated to 2025, providing a forecast for average expected values of energy productivity in the country.

- Prognostic confidence intervals were also calculated, showing the upper and lower limits within which energy productivity values can fluctuate in the coming years, with a probability of 95% ($p = 0.95$ and $\alpha = 0.05$).

Based on this prognostic analysis, assuming that the trend of energy productivity in Serbia will remain unchanged in the coming years, it is very likely that in 2025 this indicator will not be less than € 2.542 per kilogram of oil equivalent and will not be more than € 3.088 per kgoe.

Despite the fact that the energy productivity of Serbia depends on various factors, the paper attempts to forecast its development trend in Serbia in the coming years, with the use of econometric models. Based on the conducted research, it can be assumed that if the observed energy productivity trends in Serbia from the first two decades

of this century in the coming years remain the same, the expected value of energy productivity in 2025 could reach € 2.815 per kgoe. However, these results should still be taken with some caution given the adverse effects of the COVID-19 coronavirus pandemic on the country's economy. Despite all, it seems that the coronavirus global health crisis did not largely affect the Serbian economy until nowadays because, according to data from the Statistical Office of the Republic of Serbia, at the end of 2020 national GDP fell only by 1.1% compared to 2019. At the same time, this indicator in the fourth quarter of 2020 grew by 2.2% compared to the previous quarter [21, p. 1]. Finally, a massive wave of vaccination of the population is underway in the country, which is why we can expect that economic and social life of the country will slowly return to its regular course.

Conclusions from the statistical analysis

Studying and forecasting energy productivity trends is a complex and challenging process which, however, is crucial for the proper management of national energy policy, and also for the smooth functioning of all economic processes throughout the country. Such predictions are even more difficult to make in the context of a global or national economic crisis, as is the case with the current crisis caused by the COVID-19 coronavirus pandemic. This research followed the main trends in energy productivity in Serbia, as well as the expected trends of this indicator

Figure 4: Predicted values of energy productivity in Serbia until 2025 (in € per kgoe)
Energy productivity with fitted predicted levels
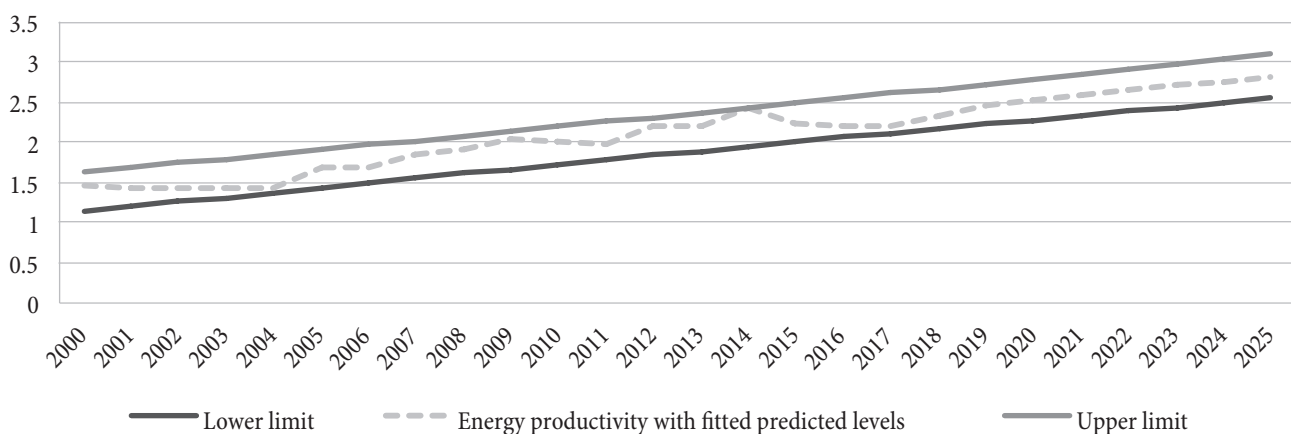
Source: Author's calculation based on the Eurostat data.

until 2025. Overall energy productivity in Serbia shows an upward trend in the last two decades, while it is expected that this trend will remain more or less unchanged. It is important to note that the country's energy productivity fluctuated in the observed period, as well as that in recent years (since 2016) we can observe its steady growth.

While in the era of the COVID-19 coronavirus pandemic, and thus great uncertainties, it seems unwise to make forecasts of trends in economic phenomena, the following facts can be pointed out in favour of the assumption of moderate increase of energy productivity in Serbia in the coming years (by expected 14.72%):

- Further expected encouraging inflow of foreign direct investments (FDI) in Serbia, which the development of the national economy is largely based on. Although in 2020 the inflow of FDI decreased by 20% compared to 2019, this trend still presents an extremely good result since FDI globally fell by 42%, in developed countries they fell by 69%, while in European countries they experienced a decline of as much as 71% [18]. In addition, in recent years, Serbia has established itself as an attractive location for attracting foreign investments at the regional level, primarily due to its generous policy of subsidizing foreign investors, which has great effects on attracting those investors that are favoured by these measures [18]. These predictions are supported by the already mentioned fact that according to the calculations of the Statistical Office of the Republic of Serbia in 2020 the country's GDP fell by only 1.1% compared to the previous year [21, p. 1].

- Expected activities of multinational companies (MNCs) in the South-East Europe region. It can also be expected that MNCs will reallocate their production activities intended for the European markets in this region, due to competitive low wages and other production costs. In addition, unlike domestic companies, actual foreign investors in Serbia are protected from bureaucratic procedures and other obstacles to successful conducting of business, which gives them a privileged position at the domestic market. All the mentioned trends directly reflect on the Serbian growth and attractiveness of its investment destination [18].

- Expected stable levels of gross available energy in Serbia. Gross available energy in the observed period from 2000 to 2019 recorded its modest growth of 13.75%, while in recent years (from 2016) this indicator has remained quite stable. Therefore, we can expect its stability in the coming period. If, on the other hand, a possible decline in the country's economic activities should occur, this fall could be reflected in a reduction in energy consumption, and thus in an increase in its energy productivity.

- Further growth of final energy consumption efficiency in the country. According to available data, in the observed period, the energy efficiency in Serbia, measured by the ratio between the output (GDP) and final energy consumption, increased moderately by 10.43% compared to the base year 2000 [8]. This indicates the fact that the application of more energy efficient technological solutions in industry and households is ongoing, and thus that there is a decline in energy consumption in the country. Due to the slight growth of this indicator in the last years of the analysis (from 2015 onwards), it is possible to expect its further moderate growth, and thus the growth of the country's energy productivity.

- The obtained results of trend modelling. Finally, the high explanatory power of the econometric analysis presented earlier, with very high coefficients of determination ($R^2 = 0.898$, $R^2 = 0.910$ and $R^2 = 0.911$), makes this predictions quite reliable.

Conclusions

Improving energy productivity is the simplest and most efficient way to reduce GHG emissions, solve the problem of rising energy costs, and improve energy security. Energy is the basic economic input, which is why there is a need for its more productive use. Improving energy productivity and efficiency increases the overall competitiveness and performance of the economy, while at the same time reduces energy costs for consumers and GHG emissions. Therefore, it is extremely important to continue to insist on the energy efficient technologies' application, the introduction of appropriate innovations, as well as further

structural changes in the economy. Measures such as the use of energy efficient lighting, efficient heating and cooling systems, automation of some industrial processes, improvement of energy data systems management, transport electrification, etc., belong to only some of the steps that can directly contribute to the energy productivity growth in the country. These measures should be coupled with energy losses reduction in transformation and distribution processes, transition to more renewable energy sources, the energy transition process, etc. That is why it is important for Serbia to focus especially on further improvements in its more efficient energy consumption. This aim could also be achieved by developing more serious plans to improve energy efficiency and energy productivity. These efforts could include defining ambitious national commitments and supporting sectorial targets, further development of its energy market, and mobilizing adequate resources. They would help Serbia in addressing all identified barriers such as the need for additional incentives and market distortions removal, lack of motivation, steady inertia in addressing these issues, as well as the lack of ability and appropriate knowledge on its path to transform into an energy conscious society.

Although Serbia is trying to improve its energy policy by implementing the recommended measures for energy efficiency improvement, it should strengthen its commitment and administrative capacity at the state level so that it could implement a substantial energy transition process in the whole country. In addition, today there are great demands for national energy companies themselves in the direction of their restructuring, which could also lead to operations that are more efficient, to cleaner and more technologically advanced energy, and higher energy productivity. Finally, with the aim of fostering and achieving more effective implementation of the energy transition process itself, it is necessary to popularize a new energy culture that requires the dissemination of knowledge, information and environmental culture, but also a higher level of general, both material and spiritual culture of society [6, p. 44]. Only in that way could a better and more consistent process of energy transition give rise to a sustainable Serbian energy future.

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