DE GRUYTER OPEN

Folia Oeconomica Stetinensia
DOI: 10.1515/foli-2015-0043

WYDZIAŁ NAUK EKONOMICZNYCH I ZARZĄDZANIA
UNIWERSYTET SZCZECIŃSKI

DYNAMICS OF PRODUCING RENEWABLE ENERGY IN POLAND AND EU-28 COUNTRIES WITHIN THE PERIOD OF 2004–2012

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Received 3 June 2015, Accepted 5 November 2015

Abstract

The paper presents the estimation of trends describing the level of renewable energy resources in Poland and in EU-28 countries within the years 2004–2012. The process of the increase of the percentage of renewable energy in total production of energy was also presented. Comparative statistical analysis was carried out within the dynamics of the phenomena discussed in the paper with respect both to Poland and EU countries. It follows from the investigation that both in Poland and in the EU countries the increase in renewable energy resources has been observed. However, the rate of the increase of the level of renewable energy in Poland is not enough to catch up with the leading EU countries in near future.

Keywords: renewable energy sources, dynamics of changes, model, bioeconomy, trend

JEL classification: C21, O13, Q42, Q47

Introduction

The problem of acquiring energy from renewable sources is related to various issues, such as: environmental protection, environmentally-friendly undertakings, the preservation of fossil fuel deposits, alongside limiting greenhouse gas emissions which generate elevated costs to be paid by the state. The process also involves the competent reusing of pre-segregated waste and sewage. All these endeavours are customarily associated with the term bio-economy. Bio-economy is a sphere of human activity, in which natural resources are used in a well thought-out manner, best serving both the welfare of the human race and the natural environment. A broader look at the problems facing bio-economy and its significance, can be found in the following works Adamowicz (2014, p. 6), Chyłek (2014, p. 45), Lechwar and Kuźniar (2014, pp. 65–66).

Renewable energy sources (RSE) are a better alternative to the non-renewable ones. They are to be regarded as inexhaustible, as their reserves are continuously being replenished in a natural way. In addition, their extraction and consumption remain environmentally neutral. For Poland renewable energy sources include: wind, solar, geothermal, and hydro energy, resources acquired from biomass, as well as waste landfill and sewage treatment plant biogas. Renewable Energy Resources also include ambient energy acquired through heat pumps. It is worth mentioning the fact, that both in Poland and most EU countries there is a steady increase in the percentage of energy acquired from renewable sources, with an accompanying decrease in fossil fuel consumption across the continent.

It is universally recognized that Poland is a relative newcomer in utilizing renewable energy when put alongside such European states as Germany, France, Sweden, or Italy. It is therefore, in the scope of our interest to examine the pace of change regarding the use of renewable energy in both Poland and the rest of the 28 countries comprising the European Union, and answering the question whether or not Poland is closing the gap in renewable energy use.

The primary focus of this work is to conduct a comparative analysis of the changes in dynamics in the field of the production of renewable energy in Poland and the EU. Broader studies of the production dynamics of renewable energy in particular EU countries were conducted in (Kukuła, 2015, p. 52). The author would also like to separately showcase the changes in the percentage of renewable energy in the total production of primary energy in Poland and the EU. For the purpose of completing the formulated tasks, theoretical models for analyzing the upward trend of the following variables between 2004 and 2012 were built:

- renewable energy production volume in Poland – X_t,
- production volume of renewable energy in the EU-Y_t,

– renewable energy percentage in total primary energy produced in Poland-X_t,
– renewable energy percentage in total primary energy produced in the EU Y_t.

Variables marked with X_t, Y_t, W_t, Z_t are timelines constituting up to 9 elements. The base data for the tests was acquired from publications of the Central Statistical Office entitled: *Energia ze źródeł odnawialnych w 2013 r.* (2014) (Power from renewable sources ca. 2013).

1. Method used

Upward trend models are part of a broad group of econometric models with practical applications. We shall limit our analysis to a narrow group of upward trend models, considering only the trend and randomized variables. Such models were applied to research on energy dynamics by (Karmowska, Barczak, 2014, pp. 54–55). Since conducted studies do not include any short-term fluctuations, reduced versions of upward trend models have been adopted. The first two variables X_t and Y_t were described using an exponential expressed by the equation:

$$X_t = e^{\alpha+\beta t+\varepsilon_t} \tag{1}$$

where: α and β are the structural parameters of the model, t is the temporal variable, ε_t is the random component, while X_t and Y_t are response variables expressed by an exponential trend. Variations of the next two factors W_t and Z_t are described using a linear trend expressed by the equation:

$$W_t = \alpha + \beta t + \varepsilon_t \tag{2}$$

where W_t and Z_t are the variables explained within these models. The next stage after estimating the structural parameters of models labelled (1) and (2), is their verification, the positive results of which sanction the interpreting and usage of said estimation models for the purpose of analyses comparisons and predictions. The statistical verification includes the analysis of stochastic parameter structure values:

– $S^2(u)$ – residual variance,
– $S(u)$ – residuals standard deviation,
– $V(u)$ – random factor variability,
– R_w^2 – determinative factor,
– $\boldsymbol{D}^2\,(a, b)$ – estimators (a and b) variance and covariance matrix.

The average pace of changes of the first two factors came about from applying the estimated value b (the estimator parameter β in model (1)). The average chain index dynamics value (geometric average of chain indexes) is calculated by dividing Y_{t+1} by Y_t:

$$\frac{Y_{t+1}}{Y_t} = \frac{e^{a+b(t+1)}}{e^{a+b}} = e^b \tag{3}$$

When $b < 0$ phenomenon value goes down, when $b > 0$ the phenomenon value goes up, and when $b = 0$ the phenomenon remains at an unchanged level. Therefore the average index chain value of the phenomenon X_t and Y_t can be expressed as:

$$\bar{I}_x = e^b$$
$$\bar{I}_y = e^b \tag{4}$$

The value of these indexes is calculated by expanding the function e^b known as the Maclaurin model (Pawłowski, 1966, p. 215):

$$e^b = \sum_{n=0}^{\infty} \frac{b^n}{n!} = 1 + b + \frac{b^2}{2!} + \frac{b^3}{3!} + \frac{b^4}{4!} + \cdots \tag{5}$$

Calculations should conclude at a sum component (5), whence we shall obtain values below the assumed accuracy margin. In practice, the calculations are concluded after adding the third component of said sum.

The average pace of changes ($\bar{t}_x$ and $\bar{t}_y$) is obtained from the following equations:

$$\bar{t}_x = (\bar{I}_x - 1) \times 100\%$$
$$\bar{t}_y = (\bar{I}_y - 1) \times 100\% \tag{6}$$

The average changes chain indexes for two successive variables described by linear trends, are obtained by applying the following equations:

$$\bar{I}_w = \sqrt[n]{\frac{W_n}{W_o}}, \quad (t = 0, 1, \ldots, n) \tag{7}$$

and

$$\bar{I}_z = \sqrt[n]{\frac{Z_n}{Z_o}}.$$

As is the case with the first two variables, the average pace of changes $\bar{t}_w$ and $\bar{t}_z$ is calculated by applying the following equations:

$$\bar{t}_w = (\bar{I}_w - 1) \times 100\%$$
$$\bar{t}_z = (\bar{I}_z - 1) \times 100\% \quad (8)$$

The average pace of changes' value provides information on the average % increase or decrease of the examined phenomenon between two time periods considered.

2. Test results

Fluctuations in the dynamics of acquiring renewable energy in Poland and the EU are described using an exponential trend, and examined by means of average chain indexes and the average growth rate. Table 1 presents the volume of renewable energy output in Poland and the EU in 2004–2012.

Table 1. Renewable energy output in Poland and the EU in 2004–2012

No.	Specification	Years								
		2004	2005	2006	2007	2008	2009	2010	2011	2012
		in Mtoe								
1	Poland	4.3	4.5	4.8	4.9	5.4	6.1	6.9	7.5	8.5
2	EU	111.3	115.9	122.6	129.9	137.7	145.8	163.0	162.2	177.4

Source: Energy from renewable sources in 2013. Data and description, Central Statistical Office Warsaw (2014), p. 20.

The above data has been used for constructing exponential trends, which have been presented in Table 2. During the analyzed period 2004–2013, we can observe constant growth in renewable energy production in both Poland and the EU. Nonetheless, a difference in the rate of changes is readily discernible. The construction of trends and subsequent average growth rate calculation create a possibility to further specify the effect of such comparisons.

The verification of both models showcases the exponentially high level of their accordance with empirical data, indicated by high values of determination coefficients, close to complete uniformity, at the phenomenon trend values for Poland – $R_w^2 = 0.967,$ and even higher for the EU – $R_w^2 = 0.987.$ The variability coefficient value also remains relatively miniscule (Table 2). For the purpose of further supplementing the verification process of presented trends, a separate study of the statistical significance of structural parameters estimated within said models was conducted. As such each of the models has been subject to the estimators' variance and covariance matrix assessment. Average errors in score assessments, were listed in parentheses under scores for each model. Relations [scores/errors] remain high to an extent that requires estimator testing. Thus all structural parameter assessments in estimated models can be considered statistically significant. These determinations validate positive assessment of the models presented in Table 2. The high quality of said models warrants the possibility of using them in comparative studies and predictions.

Table 2. Trends for acquiring primary energy from RSE in Poland and the EU in 2004–2012

No.	Model	Stochastic structure model parameters			
		$S^2(u)$	$S(u)$	$V(u)$	R^2_w
1	Poland: $\ln \hat{X}_t = \underset{(0.0156)}{1.7446} + \underset{(0.0061)}{0.0867}t$	0.0022	0.0469	0.0269	0.9670
2	EU: $\ln \hat{Y}_t = \underset{(0.0067)}{4.9343} + \underset{(0.0026)}{0.0593}t$	0.0004	0.0201	0.0041	0.9870

Source: Prepared by the author based on Table 1.

Estimated exponential trends for the production of renewable energy create a basis for comparisons between Poland and the EU. Estimator *b* values in both trends (Poland and the EU), demonstrate a relatively small difference between them, with slight trend value advantage for Poland. The conclusion is that Poland, despite its relative infancy in the field of renewable energy, is narrowing the gap between itself and the EU, which is further reinforced by the average values of chain dynamics indexes and the average growth rate of the discussed phenomenon in Poland and the EU (Table 5). The estimator values *b* were used in calculating the average chain index and the average renewable energy production growth rate in both territories, with the aforementioned equations (3–6). The obtained results indicate that the average growth rate of renewable energy production is higher in Poland (9.1%), than the average growth rate in the EU, oscillating around the level of 6.1%. These results indicate that Poland, is narrowing the distance between itself and the EU, although attaining the level of renewable energy production, similar to the leaders in the field will take considerable time.

Supplementary to the renewable energy production dynamics in Poland and the EU comparative study is the modelling of changes of renewable energy production levels against the total production of primary energy. Primary energy shall be understood as energy obtained from primary power carriers, and extracted from both renewable sources and fossil fuels. As such, the sources of fossil fuels are: coal and lignite, oil, natural gas etc.

Table 3. The percentage of renewable energy in relation to the total amount of primary energy production in Poland and the EU in 2004–2012

No.	Specification	Years								
		2004	2005	2006	2007	2008	2009	2010	2011	2012
		%								
1	Poland	5.5	5.8	6.1	6.7	7.6	9.0	10.2	10.9	11.7
2	The EU	12.0	12.9	13.9	15.2	16.2	17.9	19.6	20.2	22.3

Source: Energy from renewable sources in 2013. Data and description, Central Statistical Office Warsaw (2014), p. 20.

The models of the upward trend of renewable energy percentage, as compared to the total primary energy production was based on the information presented in Table 3. The estimated trend models of the percentage of renewable energy in primary energy production are presented in Table 4. Models for both Poland and the EU assume the form of linear graphs. The analysis of stochastic structure parameter values indicates their close correlation with empirical data. This fact is further reinforced by the determination coefficient values, which for Poland assumes the value – $R_w^2 = 0.965$ and an even higher value for the EU – $R_w^2 \cong 0.990$. The relatively low random variability coefficients also strengthen the conducted approximation. Finally, the very low average errors of structural parameter assessments (high [assessment/error] ratio) lead to the conclusion that all the estimators for both models are statistically significant. A positive statistical verification result for the models allows their unrestricted use for the purpose of comparative analyses and predictions.

Table 4. Percentage trends of renewable energy in relation to the total amount of primary energy production in Poland and the EU in 2004–2012

No.	Model	Stochastic structure model parameters			
		S^2(u)	S(u)	V(u)	R_w^2
1	Poland: $\hat{Z}_t = \underset{0.157}{8.17} + \underset{(0.061)}{0.84}t$	0.2214	0.4705	0.0575	0.9650
2	EU: $\hat{W}_t = \underset{(0.127)}{16.69} + \underset{(0.049)}{1.29}t$	0.1443	0.3799	0.0228	0.9899

Source: Prepared by the author based on Table 3.

The first step of the analysis is the assessment values comparison for the variable *t*. These assessments present the annual average increases of renewable energy in primary energy production. And so, Poland’s average annual growth percentage amounted to little over 0.8%, while for the EU it was considerably higher reaching about 1.3% (Table 4). Although the average growth rates are inverted (Table 5), it has to be expressly stated that at the current rate it is impossible for Poland to reach levels comparable to other EU states.

Table 5. Average index and growth values for *X*, *Y*, *W*, *Z* variables

No.	Specification	Average index dynamics value for 2004–2013	Average growth rate (in %) for 2004–2013
1	(X_t) Primary energy acquired from renewable sources in Poland	$\bar{I}_x \cong 1.091$	$\bar{t}_x \cong 9.1\%$
2	(Y_t), Primary energy acquired from renewable sources in the EU	$\bar{I}_y \cong 1.061$	$\bar{t}_y \cong 6.1\%$
3	(W_t), The percentage of renewable energy in the total primary energy production in Poland	$\bar{I}_w \cong 1.099$	$\bar{t}_w \cong 9.9\%$
4	(Z_t), The percentage of renewable energy in the primary energy in production in the EU	$\bar{I}_z \cong 1.081$	$\bar{t}_z \cong 8.1\%$

Source: Prepared by the author based on Tables 2 and 4.

It is worth noticing Figure 1, where we can clearly see almost parallel percentage increases of renewable energy in total primary energy produced in both Poland and the EU. The difference is that almost every year between 2004–2012 the total growth rates for Poland constitute roughly a half of the EU values.

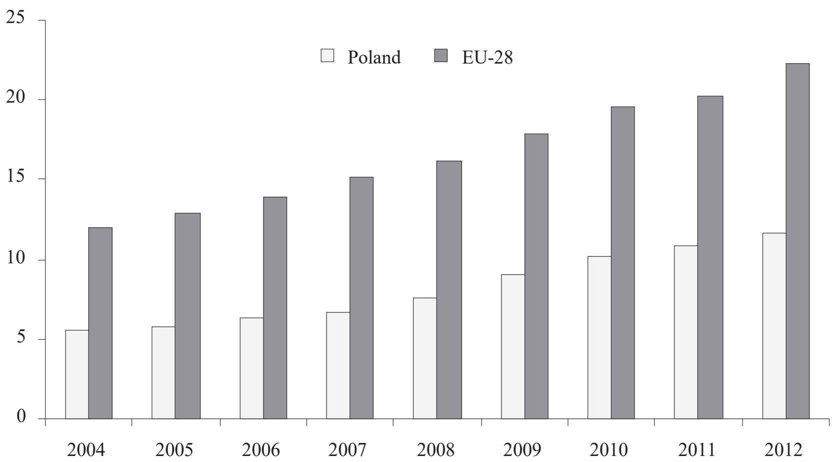

Figure 1. Percentage of renewable energy in the total primary energy production for the EU and Poland in 2004–2012

Source: prepared by the author based on Table 3.

However, the average growth rates of renewable energy percentage compare favourably for Poland at 9.9%, as compared to the EU's 8.1%. This situation can be seen as an optimistic symptom in Poland's renewable energy production development in comparison to other EU countries. Nonetheless, the urgent need for efforts to increase the percentage of renewable energy in primary energy production should be noted, as such actions tend to have a positive effect on both the economy and the natural environment.

Conclusions

1. Renewable energy production, both in Poland and globally, is now regarded as being of outmost importance, especially in the context of natural environment preservation and the rational use of sewage and waste, as well as the development of producing energy from inexhaustible sources i.e. solar radiation and wind farms (additional information about the use of solar energy can be found in (Us et al., 2014, p. 87).

2. Renewable energy production in Poland is relatively recent. In 2012 Poland, as one of the larger-sized and more populous states in Europe, was ranked at 9th place among EU countries in terms of renewable energy production. In 2005 it was at 10th place, which means that our country has only slightly improved its position.

3. The values of indicator dynamics for Poland, as compared to the EU, are not very favourable. Especially with regard to the renewable energy percentage of total primary energy production. Its average annual increase is marginally above 0.8 % in Poland, whereas in the EU these values remain steady at approximately 1.3%.

4. The recorded changes of said percentage compare favourably between 2004–2012, which creates a small chance for closing the gap between Poland and the leading EU states

5. A certain optimistic accent in comparative studies of the dynamics of growth in renewable energy production in Poland are its steady upward trends considered both independently relative to other EU countries.

6. Moreover, from the information in Table 2 it follows that in Poland the average rate of acquiring the original energy from renewable energy sources is slightly higher than the average level of this measure in EU-28 (in Poland 9.1% while in EU-28 – 6.1%).

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