Convergence of energy security level in the EU member countries

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Abstract

The purpose of the article is to assess convergence of energy security level in the EU member countries in the period 2000-2010. Because energy security is not directly measurable, a special synthetic indicator for measuring its level was developed. Synthetic variables describing energy security level obtained in the study indicate that dispersion of energy security level between the EU member countries decreases (σ-convergence), and that those countries aim at achieving an identical level of energy security (β-convergence).

Keywords**:** *energy security indicator, convergence, EU energy policy*

JEL Classification**:** O43, Q50

AMS Classification**:** 91B76

1. Introduction

Fossil fuels form the foundation of energy balance in the European Union member countries. Their share in the total primary energy supply in 2010 amounted to respectively: oil (33.3%), gas (25.5%) and coal (16.2%). Nuclear energy constituted 13.7% of the total primary energy supply and renewable energy – 11.3%. In 2010 the total primary energy supply in the EU member countries equalled to 1714 Mtoe. Net import constituted 55.5% of the total primary energy supply in 2010 and increased in comparison with 2000, when it constituted 49%. A growing dependence of the EU on imported energy, diminishing deposits of its own resources as well as the necessity to provide energy at acceptable prices make the issues connected with energy security and energy policy of the EU important themes. The Treaty of Lisbon from 2007 contains one the latest amendments regarding energy policy of the EU; article 176A states that 'in the context of the establishment and functioning of the internal market and with regard for the need to preserve and improve the environment, Union policy on energy shall aim, in a spirit of solidarity between Member States, to: (a) ensure the functioning of the energy market; (b) ensure security of energy supply in the Union; (c) promote energy efficiency and energy saving and the development of new and renewable forms of energy; and (d) promote the interconnection of energy networks'.

On the other hand, energy balance of the EU does not correspond to energy balance of its particular member countries due to their diversification, which results in difficulties with

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developing a single energy policy. The EU member countries differ in their energy balance structure, the level of dependence on import and the level of diversification of energy suppliers. Those aspects make energy security of the EU and the EU member countries worth considering.

The aim of the paper is to assess convergence of energy security level in the EU member countries in the period 2000-2010. The study was conducted within the framework of σ-convergence and absolute β-convergence. Because energy security is not directly measurable, a special synthetic indicator for measuring energy security level was developed. The analysis of its values indicated whether the dispersion of energy security level between the EU countries changes, and whether the EU member countries aim at achieving an identical level of energy security.

The paper is structured in the following way: Section 2 presents the concept of energy security and energy security indicators. Data, the discussion of the methods and results are given in Section 3, and Section 4 contains the main conclusions.

2. Energy security: definitions and indicators

According to the International Energy Agency, the definition of energy security understood as access to adequate, affordable and reliable supplies of energy has evolved over time, with changes in the global energy system and new perceptions about the risks and potential costs of supply disruptions[2]. About the conceptualizing and measuring energy security have written e.g Chester [7], Sovacool and Brown [16], Sovacool and Mukherjee [17], and Winzer [21]. The activities of the EU regarding energy security focus on three areas: developing common energy market, ensuring secure energy supplies and promoting sustainable development.

In order to evaluate energy security in quantitative terms the author has developed indicators describing the relations between energy consumption and economic development, natural environment and social issues. The indicators listed by international institutions or organisations and described in literature can be divided into two groups: disaggregated (a set of individual indicators) and aggregated[3] (Kruyt et al. [10], Löschel et al. [11]).

An example of a set of individual indicators is the Energy Indicators for Sustainable Development (EISD), compiled by the International Atomic Energy Agency (IAEA), the International Energy Agency (IEA), the United Nations Department of Economic and Social

[2] Relations between fossil fuel prices should be taken into account Papież and Śmiech [14], Śmiech and Papież [18].
[3] Other aggregate formula indices described by e.g. Białek [4].

Affairs (UNDESA), Eurostat and the European Environment Agency (EEA). It contains a set of 30 indicators representing social, environmental and economy related issues, which reflects important issues within the context of sustainable development [8]. Other indicators include Energy Security Assessment developed by APERC (Asia Pacific Energy Research Centre) [1] and Energy Security Assessment developed by GNESD (Global Network on Energy and Sustainable Development) (Shrestha and Kumar [15]). Aggregated indicators include the Energy Security Indicator developed by Jansen et al. [9], the Geopolitical Energy Security (GES) developed by IEA (Blyth and Lefèvre [5]), the Assessment Index (AI) developed by WEC (the World Energy Council) [20], and the Aggregated Energy Security Performance Indicator (AESPI) using 25 individual indicators representing social, economic and environmental dimensions Martchamadol and Kumar [12].

3. Data and empirical results

The analysis of convergence of energy security level in the period 2000-2010 was based on the present member countries of the EU, apart from Luxembourg and Malta. The analysis used the variables from the Aggregated Energy Security Performance Indicator (AESPI) proposed in Martchamadol and Kumar [12]. As not all the values of the variables were accessible, only 11 out of 25 were selected for the analysis; those variables represent different aspects of energy security. The variables were further divided into groups focusing on particular aspects of energy security. The division was based on the criteria suggested in Martchamadol and Kumar [13]. There are 5 groups:

Group 1. Energy security indicators based on energy demand: *X1* - Total primary energy intensity (Total primary energy supply (TPES)/ GDP), *X2* - Total primary energy per capita (Total primary energy supply/Total population).

Group 2. Energy security indicators based on energy supply: *X3* - Diversity index - Shannon–Weiner index (SW).

Group 3. Energy security indicators based on environmental parameters: *X4* – CO 2 emission per capita, *X5* - CO 2 emission per GDP, *X6* - CO 2 emission per TPES, *X7* - Share of Renewable energy per TPES.

Group 4. Energy security indicators based on energy market: *X8* - Net Energy Import Dependency (NEID), *X9* - Net import per TPES.

Group 5. Energy security indicators based on energy expenditure: *X10* - Net import per GDP, *X11* - Net import per capita.

First, a synthetic indicator describing energy security level was developed, with the assumption that variables $\{X3, X7\}$ were stimulants and other variables were destimulants. Next, in order to obtain comparability of diagnostic variables, normalization through unitarization was performed. Minimum and maximum values from the year 2000 were taken as the point of reference (so called stable pattern). This pattern allowed comparing the changes with reference to the period at the beginning of the analysis. The results obtained indicated changes in energy security level in the EU member countries in comparison with the values at the beginning of the analysis. First, partial synthetic variables for each group were calculated on the basis of normalized variables, and then synthetic variable SE_{jt} was obtained, which describes energy security level (in country *j* at time *t*), as the arithmetic mean of partial variables.

Table 1 present the results obtained for the year 2000 and the year 2010. Additionally, the countries were divided into four groups according to their energy security level.

The groups were obtained in the following way:

G1. - countries with the highest level of energy security: $SE_{jt} \in \left\langle \overline{SE}_t + s_{SE_t}; \max_j SE_{jt} \right\rangle$

G2. - countries with energy security level above the average: $SE_{jt} \in \left\langle \overline{SE}_t; \overline{SE}_t + s_{SE_t} \right)$

G3. - countries with energy security level below the average: $SE_{jt} \in \left\langle \overline{SE}_t - s_{SE_t}; \overline{SE}_t \right)$,

G4. - countries with the lowest level of energy security: $SE_{jt} \in \left\langle \min_j SE_{jt}, \overline{SE}_t - s_{SE_t} \right)$.

Next, in accordance with the concept of σ-convergence, the author analysed the changes in energy security level in the EU member countries on the basis of the values of the synthetic indicator. Sigma-convergence is a measure of dispersion that provides information regarding how the gap between regions has narrowed over time. The rate of σ -convergence is measured by the change in the value of the standard deviation from period 1 to period *T*, i.e. $\hat{\sigma}_T - \hat{\sigma}_1$. A test statistic introduced by Carree and Klomp [6] was used to analyse convergence. The values of three tests are presented in Table 2.

The values of statistics T_2 and T_3 enable to reject the null hypothesis of non-σ- convergence. It can be concluded that in the period 2000-2010 statistically significant changes in the dispersion of energy security level in the EU member countries were observed. The results obtained indicate that in the period analysed the gap between regions narrowed over time.

Group	**Country**	**Symbol**	SE_{j1} **in 2000**	**Group**	**Country**	**Symbol**	SE_{j11} **in 2010**
G1	Denmark	DK	0.802	G1	Denmark	DK	0.795
	United Kingdom	UK	0.748		Romania	RO	0.745
G2	Romania	RO	0.653	G2	Latvia	LV	0.668
	Sweden	SE	0.650		United Kingdom	UK	0.667
	Latvia	LV	0.636		Sweden	SE	0.642
	Slovenia	SL	0.630		Slovenia	SL	0.631
	Austria	AT	0.625		Hungary	HU	0.628
	Hungary	HU	0.612		Portugal	PT	0.620
	France	FR	0.598		France	FR	0.610
	Poland	PL	0.581		Austria	AT	0.594
	Spain	ES	0.569		Germany	DE	0.592
	Portugal	PT	0.567		Spain	ES	0.588
	Germany	DE	0.561	G3	Czech Republic	CZ	0.584
G3	Finland	FI	0.550		Poland	PL	0.578
	Lithuania	LT	0.550		Slovakia	SK	0.563
	Netherlands	NL	0.525		Bulgaria	BG	0.560
	Czech Republic	CZ	0.523		Lithuania	LT	0.553
	Italy	IT	0.519		Italy	IT	0.553
	Greece	GR	0.516		Greece	GR	0.544
	Slovakia	SK	0.479		Netherlands	NL	0.538
	Ireland	IE	0.467		Finland	FI	0.528
	Estonia	EE	0.461		Ireland	IE	0.509
G 4	Belgium	BE	0.420	G4	Estonia	EE	0.495
	Bulgaria	BG	0.419		Belgium	BE	0.443
	Cyprus	CY	0.335		Cyprus	CY	0.364

Table 1 The classification of the EU member countries in 2000 and 2010 according to their energy security level.

Statistics (T_i)	Estimate	*p*-value
T_1	1.455	0.1875
T_2	4.378	**0.0364**
T_3	2.701	**0.0069**

Table 2 Sigma convergence.

The further empirical analysis focused on the verification of the hypothesis of unconditional *β*-convergence. Traditional nonlinear cross-sectional Barro regression [2], Barro, Sala-and-Martin [3], was estimated, in which an average pace of changes in energy security level depends on its initial values. The analysis used the following form of the absolute convergence model:

$$\frac{1}{T}\ln\left(\frac{SE_{j1}}{SE_{jT}}\right) = \alpha + \beta\ln\left(SE_{j1}\right) + \xi_i \tag{1}$$

where: SE_{jt} - energy security level of the *j - th* - country in the period *t*, *T* is the end of the period of investigation, *β* – the coefficient of convergence (divergence). Obtaining a statistically significant, negative value of *β* rejects the null hypothesis of the lack of absolute convergence *β*. Parameter *λ* given by the formula: $\lambda = \frac{-\ln\left(1+T\hat{b}\right)}{T}$ is the speed of convergence.

Figure 1 presents the dependence of the average pace of changes in energy security level in the period 2000-2010 on the logarithm of the initial energy security level in 2000. The figure shows a negative dependence of the average pace of changes in energy security level on the logarithm of the initial energy security level in 2000.

The analysis of the regression (1) revealed a statistically significant negative value of the parameter *β*. The results obtained indicated absolute convergence in the EU member countries in the period 2000-2010. The estimated pace of convergence *λ* was 0.0278, which means that the speed of convergence with regard to energy security in a group of 25 countries was 2.78 % annually, that is it was not very high. In order to establish the influence of given countries on the convergence process, the author calculated the measures describing the influence of given observations on the evaluation of parameter *β* in model (1). Thanks to this, it was possible to establish which countries caused the decrease of the value of *β*, that is stimulated the convergence process, and which countries increased the value of β. The analysis indicated that Bulgaria and the United Kingdom positively influenced the convergence process, while Cyprus, Denmark and Romania slowed this process down.

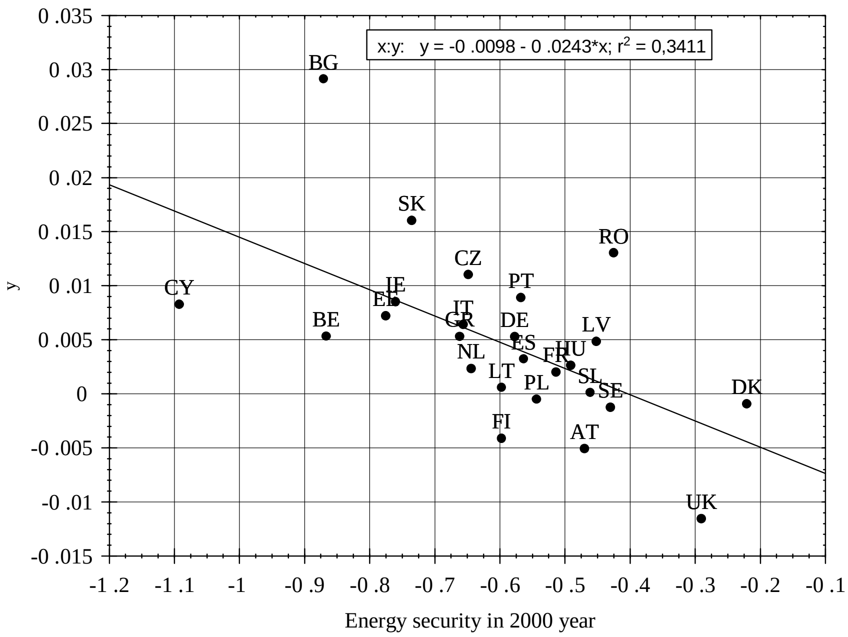

Fig. 1. The dependence of the average pace of the changes in energy security level on the logarithm of the initial energy security level in 2000.

4. Conclusions

The results of the analysis conducted using the indicator of energy security level based on selected variables indicated convergence processes of energy security level in the EU in the period 2000-2010. The results also revealed statistically significant changes in the decrease of dispersion of energy security level in the EU member countries that is the levelling of the disproportions in the level of security. The levelling of the disproportions was further confirmed by the results of the absolute β-convergence, although the speed of convergence with regard to energy security in a group of 25 EU countries was only 2.78 % annually. The results obtained indicate that the EU policy regarding energy security leads to narrowing the differences in energy security level in spite of geographical, political and economic differences between the EU member countries. Similar results, (taking into account the same dataset) were carried out by Śmiech [19].

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