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Trends of International Energy Security Risk Index in European Countries

Oleksandr Chernyak
Ganna Kharlamova
Andriy Stavytskyy

Department of Economic Cybernetics,
Taras Shevchenko National University of Kyiv
Vasilkivska 90-a
Kyiv 03022, Ukraine
E-mail: chernyak@univ.kiev.ua
E-mail: akharlamova@ukr.net
E-mail: a.stavytskyy@gmail.com

Abstract: *The paper deals with the analysis and forecasting of energy security risk index for eleven European countries (the United Kingdom, Denmark, Norway, France, Germany, Poland, Spain, Italy, Norway, the Netherlands, and Ukraine for the period 1992–2016). Nowadays, energy security plays an important role in guaranteeing the national, political and economic security of the country. A literature review of different approaches to defining energy security gave the possibility to consider the regression model of energy security risk index assessment, which takes into account the levels of economic, technical and technological, ecological, social and resource components. This step was proceeded with clusterization of the analysed countries in three groups according to Energy Security Risk Index. Based on this approach resource-mining countries (Denmark, Germany, Norway and the UK) were grouped in Cluster I, while Ukraine occupied the last Cluster III. The next division in five clusters supported the indicated allocation. Finally, we calculated the forecasts of energy security risk index based on data of 1992–2014. It allowed realizing the perspectives of energy market for the nearest future, particularly for Ukraine, which needs development of a new strategy of energy security.*

Keywords: *cluster analysis, econometric modelling, energy security, forecasting, International Energy Security Risk Index*

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1. Introduction

The relevance of the topic lies in the fact that energy security for each country is a highly important component of its economic situation, since energy is the basis for the necessary and uninterrupted functioning of all branches of industry and services in the modern world. It is obvious that energy security is a significant component of the ecological situation (Stavytskyy *et al*., 2016). It is detected that energy security has social, political and technical components, which is also an important aspect of the successful development of any country and the world overall (Chernyak *et al*., 2017). Therefore, modelling the level of energy security is the key to solving the future energy policy, forecasting the country's energy security level, preventing negative impacts and taking further necessary measures.

The issue of energy security has been investigated by many scientists (Kharlamova, 2015; Shidlovsky *et al*., 2001; Morozov, 2004; Denchev, 2010; Demiryol, 2014, Zemlyanyy, 2009; Svirchevska, 2014; Klopov, 2016; and many others). The problem we address is formulated that Ukraine has a tense energy situation that was demonstrated recently in March 2018, so it requires some energy security approach to have some forecasted vision of its position in correlation to the dynamic external factors. We consider the trends in the energy security of the EU states as a sufficient external factor. Then, the purpose of the study is to consider energy security perspectives for Ukraine in the changing external trends. As one of the steps to reach it, we propose an objective mathematical approach to perceive the future and detect retrospective trends. The energy strategy of Ukraine can be based on adequate facing of objective trends in the EU (as the closest energy market). In our research, the energy security reflects in the International Energy Security Risk Index (IESRI). We analysed 10 European countries (The United Kingdom, Denmark, Norway, France, Germany, Poland, Spain, Italy, Norway and the Netherlands) to determine the position of Ukraine among the EU energy markets (Kerikmäe & Chochia, 2016). Moreover, we suppose that such an approach and analyses have a potential to strengthen national energy security in its core.

To achieve the goal, we distinguish between the following objectives that stimulated the logic of the research:

1. To consider the essence of the concept of 'energy security' of Ukraine in trend with the EU.

2. To carry out a cluster analysis of 11 European countries[1] (The United Kingdom, Denmark, Norway, France, Germany, Poland, Spain, Italy, Norway, the Netherlands and Ukraine); to determine the position of Ukraine from that of the other countries.
3. To make a forecast of the International Energy Security Risk Index of Ukraine for the forthcoming 4 periods based on the data from 1992–2014.
4. To construct econometric models to access the dependence of the International Energy Security Risk Index on the significant factors for each formed cluster.

Accordingly, knowledge of trends and tendencies in the neighbouring market, which Ukraine is aiming to penetrate, will arm the state with more tools for the adequate energy strategy on the agenda.

2. Literature review

2.1 Energy security terminology

Today, there is no country in the world that can be confident in its own security (Kuzemko *et al*., 2016). Countries and their citizens are facing new challenges and threats. Energy, management and security have become "hot" topics for many international meetings, media reports and political debates. The 21st century began with military conflicts on the planet, the main cause for which are energy resources. That is why the issue of energy security is one of the main problems for all the leading powers and unions (Kharlamova, 2013).

Increasing consumption of energy sources, irregular distribution of fuel and other energy resources in the world, the rising prices for the main fuel resources and, consequently, the growth of energy dependence of most countries in the world, and the growing role of the geopolitical component in international energy trade determine the urgency of the problem of improving the level of energy security. Accordingly, a significant amount of research is related to this problem. Yet, active research does not exhaustively cover the problem and does not eliminate the difficulty in understanding the concept of 'energy security' (Prokip, 2011). The reason for different views on the concept of 'energy security', according to Prokip (2011) is the complexity of the research object which covers a significant number of multicomponent constituents linked through numerous bonds. As one

[1] The countries have been chosen on the principle of data consistency, territory comparability and as representatives of old Europe (EU-15). These countries are the flagships of energy security policy in Europe.

of the key spheres of the national economy, energy directly affects the economic performance of the country, is a significant contaminant of the environment, and affects the level of social development of the country, both directly and through the ecological and economic component. Moreover, M. Zemlianyy stressed that it is quite difficult to isolate energy security from economic and national security, since "it includes economic, political, social and environmental aspects, that is a contexture in which it is difficult to understand and build a harmonious system taking into account all interrelationships" (Zemlianyy, 2009).

Thus, energy security is one of the most important aspects of national security. It influences policies in the field of international relations, military security, trade, infrastructure investment and technology (BP, 2016). Scientists have been exploring the definition of 'energy security' for centuries, investigating the ways to measure energy security, concepts and interpretations of this definition (Table 1). The analyses reveal that the concept of energy security in Ukraine varies from the European to global.

Table 1. The main approaches to the concept of 'energy security'

Source	**Interpretation**
Energy Strategy of Ukraine by 2030 (2006)	Energy security is an integral part of economic and national security, a necessary condition for the existence and development of the state. In the modern sense, guaranteeing energy security is the country's achievement of a technologically reliable, stable, cost-effective and environmentally acceptable supply of energy resources of the economy and the social sphere of the country, as well as creation of conditions for the formation and implementation of a policy of safeguarding national interests in the field of energy.
International Energy Agency (2017)	Energy security is a state of protection of vital "energy interests" of the individual, society and state from internal and external threats, ensuring uninterrupted satisfaction of consumers with economically accessible fuel and energy resources of acceptable quality under normal conditions and in emergency situations.
Methodology for calculating the level of economic security of Ukraine (2007)	Energy security is a state of economy that ensures the protection of national interests in the energy sector from existing and potential threats of internal and external character. It offers an opportunity to meet the real needs for fuel and energy resources to ensure the life of the population and the reliable functioning of the national economy in the normal, extraordinary and martial law.

Source	Interpretation
World Energy Council (2017)	Energy security is the certainty that energy will be available in the quantity and quality that is required under these economic conditions. It is noted that the energy security of a country is a state of protection of its citizens, society, and economy from the deficiencies caused by internal and external factors in ensuring their justified energy needs, in economically accessible fuel and energy resources of acceptable quality, under normal conditions and in extraordinary situations, as well as from the breakdown of stability, continuity of fuel and energy supply.
Bondarenko (2009)	Energy security as one of the components of national security appears, firstly, as a state of providing energy commodities for the implementation of reproductive processes in the national economy that guarantee its full functioning, and secondly, as the state of security of the country's energy complex.
Denchev (2010)	Takes into account the difference in the priorities of different groups of countries in the field of energy security. For the importing countries, this is primarily ensuring the reliability of their energy supply, diversification of sources of energy supply, security of energy infrastructure, implementation of new technologies to reduce the dependence on energy imports. For exporting countries, this is a fix in strategic markets at economically advantageous prices, providing capital and financing investment in infrastructure and resource development.
Kharlamova (2013)	Energy security is a connection between national security and the availability of natural resources for energy consumption. Formation of energy security includes approximation to the regulatory framework; development of electricity, gas and oil nets, energy efficiency improvement and the use of renewable energy sources.
Kisel *et al*. (2016)	Presents a novel Energy Security Matrix that structures relevant energy security indicators from the aspects of Technical Resilience and Vulnerability, Economic Dependence and Political Affectability for electricity, heat and transport fuel sectors.
Kovalko *et al*. (2009)	Energy security is a component of economic security, the targeted influence of the managing subject on threats and dangers; the creation of necessary and sufficient conditions for the state and non-state institutions to make the deficit in the provision of consumers with affordable fuel and energy resources of acceptable quality in normal and extraordinary conditions; consistent and active carrying out the policy of energy saving and diversification of energy supply sources.

Source	Interpretation
Kruyt *et al*. (2009)	Distinguishes between four dimensions of energy security that relate to the availability, accessibility, affordability and acceptability of energy and classified indicators for energy security according to this taxonomy. There is no one ideal indicator, as the notion of energy security is highly context-dependent. Rather, applying multiple indicators leads to a broader understanding.
Lucas *et al*. (2016)	Considers import dependence as a proxy for energy security, which is an approach that ignores the potential effect of other energy security strategies, such as the diversification of energy source. Renewable energy sources (RES) deployment is a consequence of a combination of energy security strategies including environmental concerns rather than being solely caused by a shift towards more sustainable energy policies
Mykytenko (2005)	Energy security is a system of combination of potentials—economic, political, technological, resource and, in fact, energetic, as well as factors of scientific, geographic, organizational, managerial, etc. character, without which analysis of any security is impossible.
Sovacool *et al*. (2010)	Energy security is composed of availability, affordability, efficiency, and environmental stewardship.
Yergin (2006)	Energy security is the state of electric power industry which guarantees technically and economically safe satisfaction of current and future needs of consumers in energy and environmental protection.

As the literature review shows, the definition of energy security is contextual and dynamic in nature. The scope of energy security has also expanded with a growing emphasis on dimensions such as environmental sustainability and energy efficiency. Significant differences among studies are observed in the sense how energy security indexes are framed and constructed (Ang *et al*., 2015).

Consequently, the concept of 'energy security' can be interpreted as a level of technical security of energy systems. Also, energy security, by its definition, ultimately aims to guarantee the protection of the individual, society and the state from the shortage of fuel and energy resources. It has a broader context than the notion of reliability and acts as an economic, political and philosophical category. Energy consumption is an indispensable condition for the existence of humanity (Prokip, 2011).

Similarly, Yu. Svirchevska (2014) has highlighted the internal and external factors that influence on energy security of a country. Internal factors include the following:

- The level of prosperity of the country's own energy resources;

- Monopolistic dependence on one supplier fuel and energy balance of the country;
- The technical state of the energy industry and the level of energy efficiency of the economy;
- The ecological state;
- Social dangers (fuel prices for the population, high accident risk of manufacture, strikes and other possible protests related to the activities of the energy industry and local authorities);
- Political, legislative and management activities.

External factors include:

- Unequal distribution of stores and the concentration of major stocks in politically unstable regions, zones of military conflicts;
- The threat of terrorist acts on energy facilities, including those in countries that transit energy resources;
- The threat of nuclear terrorism, the problem of the non-extension of nuclear materials;
- Geopolitical interests of countries; economic threats (unfavourable market conditions);
- Ecological (large-scale accidents in the energy industry, greenhouse gas emissions which threaten the whole planet);
- Energy poverty (lack of access to sufficient energy in undeveloped countries);
- Speculation in the media that is a negative manifestation of the modern globalized world (artificial creation of panic, which leads to the destabilization of energy markets) (Svirchevska, 2014).

In the same manner, Natalie Garthwaite in her *Contested Planet: Geography Revision Guide* highlights the following key risks that affect the level of energy security:

1) Physical (exhaustion of stocks or violation of supply lines);
2) Ecological (ecological changes due to the exploitation of energy resources);
3) Economic (sudden increase in energy consumption, which leads to importation);
4) Geopolitical (political instability in the regions of energy production) (Garthwaite, 2010).

For each country, the significance of factors depends on certain conditions. Analysing these factors allows us to distinguish between two main directions of energy security support at the proper level, namely:

- Supply of physical volumes of energy resources in accordance to the needs of the economy, while reducing the influence of external factors on the stability of energy supply, and
- Reduction of growth rates of energy needs in the energy sector while ensuring a stable GDP growth by improving the efficiency of the use of energy resources by the national economy.
- Moreover, these directions also contribute to the improvement of the economic security of the state (Bobrov, 2013).

Critical view on the academic resources (Table 1), which are highly cited in terms of energy security concept, pushed us towards the specific definition of this concept for Ukraine: *Energy security is the connection between national security, the availability of natural resources for energy consumption and the potential for the use of renewable resources* (Kharlamova *et al*., 2016). Such definition is in synergy with the EU approach. The most crucial is our insistence to consider energy security as the indicator that consists of different relative compounds and should be monitored annually with the support of mathematical modelling.

2.2 Systems of energy security in the EU countries

Considering of Ukraine energy security is currently impossible without an understanding of EU energy security trends. Minimizing the negative impact of energy processes on the environment, along with ensuring energy security, the development of a competitive energy market has become the basis of energy policy of the European countries. The mitigating environmental impact of energy activities is a challenge, but it creates new opportunities. *The World Energy Outlook 2012* newsletter (IEA, 2012) answered some of the issues, such as “How will global energy markets evolve in 2035?”:

1) Despite innovative developments in the field of the economic security, and the intentions of politicians, the world is still unable to put the global energy system on a more sustainable path.
2) Emerging economies are a good place for countries that dominate global energy markets.
3) Energy subsidies are quite important for the growth of renewable energy sources since renewables are still more expensive than conventional sources.

EU countries have a high level of energy dependence (~50%), so they are fully experiencing new energy realities. Consider the Green Paper *A European*

Strategy for Sustainable, Competitive and Secure Energy. Its content recognizes issues for discussion and suggests possible actions at the pan-European level, in particular. It is noted that despite the priority of national interests, the need for joint actions remains. In the world of global interdependence, the energy policy of individual countries must be carried out within the framework of a common European space. This general energy policy of Europe has three main objectives:

- Constancy;
- Competitiveness; and
- Security of energy supply.

That is, the EU has a single strategic objective, a general EU energy review scheme, and it ensures the creation of the minimum required level of overall EU infrastructure with reliable energy-saving sources of energy and energy sources with minimal carbon emissions.

For Europe, there are still threats to energy security, in particular:

- Urgent need for investments;
- Increase in dependence on imports;
- Rising oil and gas prices;
- Significant warming;
- Insufficient development of competitiveness of European energy markets.

Nevertheless, the EU countries define and respond adequately to the challenges of time. These are formed in six key areas:

1. Competitiveness and the internal energy market. The EU plans to complete the creation of domestic European electricity and gas markets as a priority step for ensuring sustainable, secure and competitive energy. The following mechanisms of realization of this direction are offered:

- Creation of a single European grid;
- Investing in the upgrading of generating capacities;
- Development of open internal energy markets (in form and content);
- Increasing the competitiveness of European industry (reliability of supply and affordability for various, including energy-intensive, industries).

2. Guarantee of energy supply security:

- Improving the security of supply (including physical) on internal markets through their transparency and predictability;
- Rethinking EU approaches to strategic oil and gas stocks aimed at the joint response and use of these stocks.

3. Creation of an efficient and diverse energy production structure.

4. An integrated approach to addressing climate change issues.

5. Incentives for innovation. This direction includes a series of measures aimed at developing and implementing the European Strategic Energy Technology Plan (The SET Plan, 2017).

6. A coherent external energy policy to implement:

- A clear energy diversification policy;
- Partnerships with producers, transit countries and other international performers;
- An effective response to external crises;
- Integration of energy with other branches of industrial production;
- Promoting the development of energy in the world.

In this way, the Green Paper, identifying six key areas for finding answers to current challenges, aims to create and effectively implement a common energy policy for the EU.

Today, Europe is meeting its own needs for the main energy resources at the expense of their own production by half, and by 2030 it is assumed that this figure will decrease to 35%. The positions of European countries regarding ways to solve the problem of energy dependence are divergent. Some countries, primarily Germany, wish to continue to have long-term contracts for energy supplies from Russia. Other countries consider the issue of diversification of sources of energy resources more relevant. The EU countries are still in a growing dependence on gas supplies. Therefore, the long-term forecast (up to 2025) implies an increase in gas consumption from 430 billion cubic meters to 720 billion cubic meters.

2.3 Predictions for the world and Ukraine in terms of energy security

The International Energy Agency provides forecasts in the main aspects of energy in the world by 2035 (IEA, 2017). The total consumption of fuel and energy resources by 2030 will increase by an average of 2% per annum, and electricity consumption—5% annually. The forecast data of Ukraine's energy development, identified in the Energy Strategy by 2030 (Energy Strategy, 2006) are consistent with the global trends (Baseline Scenario). Still, the main energy resource will be coal, the share of which will increase to 32.7% (Energy Strategy, 2006), and the share of nuclear, hydropower and alternative energy sources will increase from the current 23.6% to 37.8%. On the contrary, the share of natural gas will decrease from the current 41% to 18.4% (Energy Strategy, 2006).

A significant reduction of the energy dependence from the actual 55.1% (dependence on imports of energy resources) will be expected to reach 11.5% by 2030.

Ensuring the increasing demand for fuel and energy resources by 2030 is planned to be carried out under the following conditions:

- Reduction of energy intensity of GDP and increase of energy supply of the country;
- Increase of own extraction of coal, oil, gas and uranium;
- Production of electric energy at nuclear power plants on own nuclear fuel;
- Increase in export of petroleum products due to increased oil refining;
- Implementation of energy conservation programs in the branches of economy and social sphere;
- Increase of the use of non-traditional and renewable energy sources;
- Reduction of the country's energy dependence on external fuel supplies and an increase of consumption of own energy products (World Energy Council, 2017).

The latter highlights the necessity of Ukraine to develop the energy strategy in synergy with the EU trends and considering its forecasted energy risks.

3. Data: International Risk Indicator for Energy Security (International Energy Security Risk Index) mirror

Taking into account that there is no exact energy security index[2], we have chosen for the analyses the International Risk Indicator for Energy Security (International Energy Security Risk Index or IESRI). The index aims to compare the risks of energy security in different countries and groups of countries. It can be calculated in two ways: in absolute terms and relative to the average for the countries of the Organization for Economic Co-operation and Development. This index is also complex, similarly to "Trilemma" (World Energy Trilemma Index, 2016). Its measuring components include a set of indicators that characterize the processes in the energy sector associated with traditional fuels, imports, energy costs, prices and volatility of the market, the efficiency of energy use, the electricity sector, transport, and the environment.

[2] WEC Energy Trilemma Index Tool and International Energy Security Risk Index are widely used in assessing the level of energy security.

4. Results

4.1 Clustering of the ten countries of Europe according to International Energy Security Risk Index

In 2016, Denmark, Switzerland, Sweden, the Netherlands, Germany, France, Norway, Finland, New Zealand, Austria became the top ten countries. Unfortunately, Ukraine was in the 63rd position (out of 125), with the code ABD (IESRI, 2016). That pushes the idea of a great break between Ukraine and the EU countries and stimulates the hypothesis of the ability of convergence of Ukraine in the time perspective to the EU. To test this hypothesis we use the best appropriate method to deal with "mountain: data stock" cluster analyses.

By means of SPSS software, we will cluster the countries of Europe (Austria, Belgium, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom) with Ukraine using the *k*-means method, setting respectively 3 and 5 clusters. The clusters are arranged in line with the growth of the IESRI. We use cluster analysis to identify homogenous groups of countries on the energy security that have similar needs and attitudes. *K*-means cluster is a method to quickly cluster large data sets. The number of clusters was determined in advance, which is useful in testing different models with a different assumed number of clusters. In general, the *k*-means method will produce exactly *k* different clusters of the greatest possible distinction. It should be mentioned that the best number of clusters *k* leading to the greatest separation (distance) is not known a priori and must be computed from the data. The results are presented in Tables 2 and 3.

Table 2. Results of the clustering of 11 European countries according to International Energy Security Risk Index (3 clusters) for 1993–2014

Cluster		
I (595–1043)[3]	**II (841–1252)**	**III (1944–2606)**
Denmark Germany Norway UK	France Italy Netherlands Poland Spain	Ukraine

Source: Authors' calculations based on Large Energy, 2016.

[3] Fluctuations in the International Energy Security Risk Index within the corresponding cluster are shown in parentheses.

Table 3. Results of the clustering of 11 European countries according to the International Energy Security Risk Index (5 clusters) for 1993–2014

Cluster				
I (595–923)	**II (663–951)**	**III (780–1173)**	**IV (933–1252)**	**V (1944–2606)**
UK	Denmark Norway	France Germany Poland Spain	Italy Netherlands	Ukraine

Source: Authors' calculations based on Large Energy, 2016.

We consider the entry of the UK, Denmark and Norway into clusters (I, II) as the best state of energy security and Ukraine's accession to the cluster as having the highest risk in energy security. The UK has entered the Cluster I as the country with the lowest risk for energy security owing to sufficient coal availability, low oil exports, energy intensity, and relatively low energy costs. The country produces the largest amount of coal among all other Western European countries. It is worth noting that the United Kingdom will gradually curtail electricity production at coal-fired power plants, and by 2025 plans to close all plants of this type to reduce CO_2 emissions (Brown, 2017). In March 2017, the country set a record for solar energy production (15% of total production), indicating the country's orientation towards energy ecologization (Hanna, 2017).

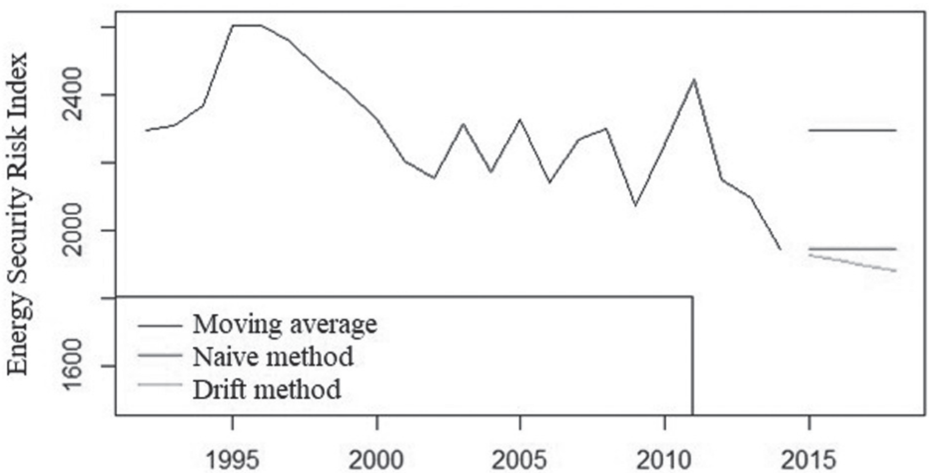
Denmark and Norway have fallen into Cluster II as countries with a rather low level of risk for energy security. This can be explained by the following. Denmark has significant coal reserves, is a leader in clean energy production, is constantly increasing its investments in renewable energy, is sufficiently supplied with petroleum products (it is the second largest product in terms of its exports), and has a low level of energy consumption. In 2016, the country produced more than 56% of its electricity from renewable resources (Lipp, 2007).

Norway is one of the largest oil producers in Europe. It ranks among the first among the world countries in the volume of electricity generation from hydroenergy. More than 40% of the country's electricity is produced from renewable energy sources. Ukraine's entry to Cluster V as a cluster with the worst level of energy security is due to insufficient oil reserves in our country, a significant volume of natural gas imports, the high value of energy import costs, high-energy intensity, extremely high-energy intensity, and high CO_2 emissions per capita.

4.2 Forecasting International Energy Security Risk Index for Ukraine

After realizing the situation, it is quite crucial to support it with the mathematically proven conclusion that this tendency is predicted to remain the same in short term or there is a surge in changes. We forecast the International Energy Security Risk Index for Ukraine for four years (2015–2018) by means of RStudio (*Large Energy*, 2016). We use simple methods of forecasting: a fluid medium, a naive method, a method with drift (Fig. 1).

Figure 1. Forecast of the International Energy Security Risk Index for Ukraine for 4 years (2015–2018) using the moving average, naive method, drifting



Source: Created using RStudio tools based on Large Energy, 2016.

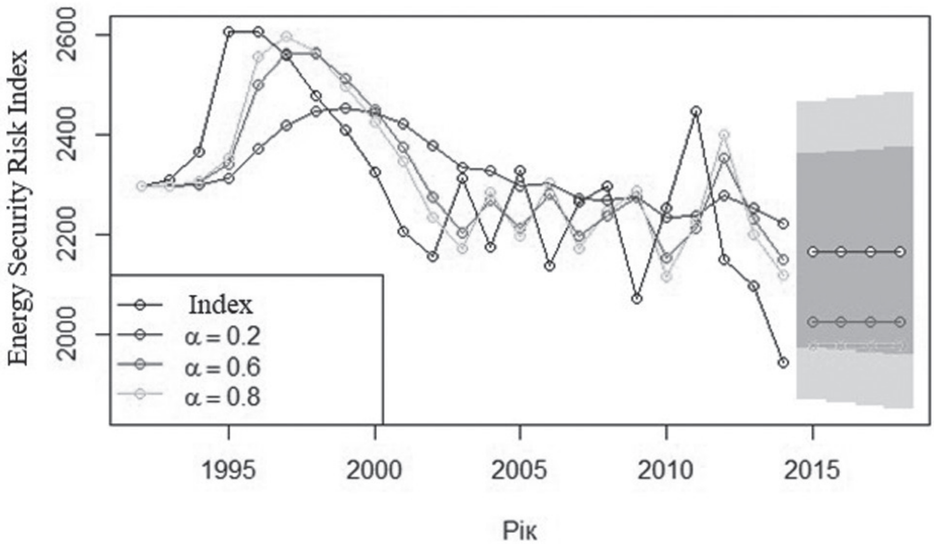
Table 4. Results of the forecast of the International Energy Security Risk Index for Ukraine for 4 years using simple methods of forecasting

Year	Method		
	Moving average	Naive	Drifting
2015	2295.44	1944.00	1927.96
2016	2295.44	1944.00	1911.91
2017	2295.44	1944.00	1895.86
2018	2295.44	1944.00	1879.82

Source: Created using RStudio tools based on Large Energy, 2016.

Figure 2 shows the forecast using the method of simple exponential smoothing.

Figure 2. Forecast of the International Energy Security Risk Index for Ukraine for 4 years (2015–2018) with the help of simple exponential smoothing



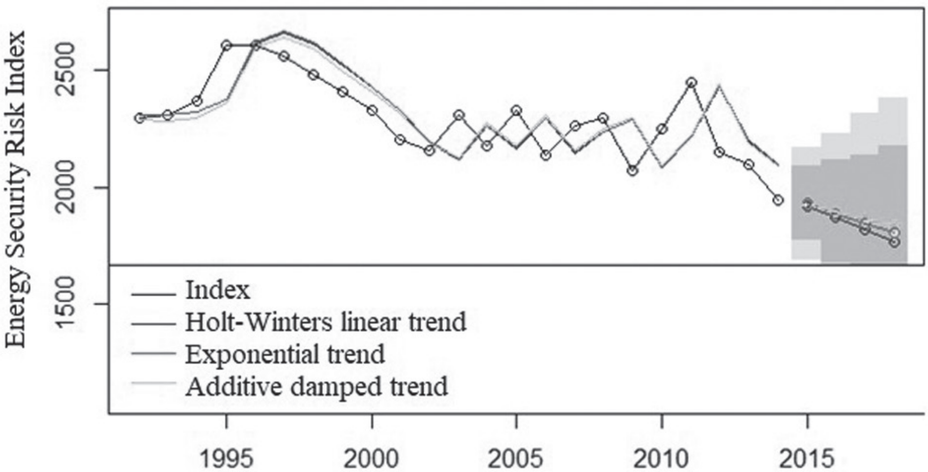
Source: Created using RStudio tools based on Large Energy, 2016.

Table 5. Results of the forecast of the International Energy Security Risk Index for Ukraine for 4 years using the method of simple exponential smoothing

Year	α = 0,2	α = 0,6	α = 0,8
2015	2166.776	2026.693	1978.759
2016	2166.776	2026.693	1978.759
2017	2166.776	2026.693	1978.759
2018	2166.776	2026.693	1978.759

Source: Created using RStudio tools based on Large Energy, 2016.

Figure 3. Forecast of the importance of the International Energy Security Risk Index for Ukraine for 4 years (2015–2018) using the Holt method



Source: Created using RStudio tools based on Large Energy, 2016.

Consequently, we have also used the Holt-Winters method to reflect all possible fluctuations (Fig. 3). The predicted values obtained are shown in Table 6.

Table 6. Results of the forecast of the International Energy Security Risk Index for Ukraine for 4 years using the Holt-Winters method

Year	Linear trend	Exponential Trend	Additive damped trend
2015	1921.952	1930.365	1927.686
2016	1870.954	1887.508	1891.491
2017	1819.957	1845.604	1862.534
2018	1768.959	1804.629	1839.369

Source: Created using RStudio tools based on Large Energy, 2016.

The most optimistic predictions were received only by the drifting method and the Holt method.

In order to prevent implementation of a non-optimal scenario, Ukraine needs to reduce its dependence on natural gas imports, energy intensity, reduce energy intensity, and CO_2 emissions per capita in the future. An important tool for solving such problems is the active use of renewable energy sources. It should be noted that in April 2017, Ukraine and Denmark signed a Memorandum of Understanding on Energy Efficiency and Renewable Energy. Its implementation will contribute to the improvement of Ukrainian legislation and business climate in the implementation of energy efficiency and renewable energy projects. Today, Denmark is one of the world leaders in terms of wind power generation (State Agency on Energy Efficiency, 2017).

4.3 Assessment of the International Energy Security Risk Index for Cluster I countries (Denmark, Germany, Norway, UK)

The purpose of this section is to determine the key factors affecting the state of energy security in the group of countries from each cluster. This helps to identify key indicators that could be improved by Ukraine to reach the EU level, on the one hand, and that could make the EU states vulnerable, on the other hand. Hence, having precise information on these factors, Ukraine can predict a possible scenario for the EU market and determine more efficiently its niche.

The following possible impact factors on the IESRI were proposed:

- Reserves and annual volume of traditional fuel (oil, natural gas, coal) extraction;
- The volume of imports of each type of traditional fuel, the volume of imports to GDP;
- Energy intensity;
- Energy expenditure per capita;
- Retail prices for electricity;
- Fuel prices (oil, natural gas, coal);
- Volatility of oil prices;
- Volatility of energy consumption;
- GDP per capita;
- The intensity of energy consumption per capita;
- Fuel diversification for electricity production;
- Use of energy resources by transport per capita;
- Intensity of energy consumption by transport;
- Amount of CO_2 emissions;
- Amount of CO_2 emissions per capita;
- Intensity of CO_2 emissions to GDP.

From each group of impact factors, we selected those that have the highest level of correlation with the IESRI. The results of the selection are shown in Table 7, leading to the following conclusions.

The correlation coefficient between the volume of coal mining and IESRI shows an average direct relation which means that increase in coal production provokes worsening in energy security for this cluster. This process can be explained by a significant environmental pollution under the conditions of widespread use of coal for the production of electricity, which shows the growth of IESRI.

Table 7. The pairwise correlation coefficients between the corresponding factors and value of International Energy Security Risk Index for Cluster I (Denmark, Germany, Norway, the United Kingdom)

Factor	Coefficient of correlation	
	Connection	
	Direct	Inverse
Volume of coal extraction	0.4900	
Total imports volume of energy resources per GDP	0.5738	
Intensity of energy consumption	0.6405	
Energy cost volatility	0.5864	
The volume of CO2 emissions		-0.4042

Source: Created by the authors based on Large Energy, 2016.

With an increase in the total volume of energy resources import (to GDP), there will be deterioration in the country's energy security, which is a natural phenomenon. An increase in the intensity of energy consumption worsens the state of energy security. With the increasing volatility of energy costs, there will be an increased risk in the energy security, which is explained by the fact that the more volatile energy consumption is, the more difficult it will be to react quickly in order to satisfy the energy demand. The coefficient of the correlation between the volume of CO_2 emissions and IESRI shows the outcome that is contrary to reality, so this factor is excluded from consideration. To construct a more accurate econometric model, we limited the number of factors to 2–3. With the help of RStudio tools, we implemented the automatic selection of factors among those listed in Table 10 (using step function). The best model (with the smallest Akaike coefficient) for the countries in the first cluster was the one which has as independent variables the total volume of import of energy resources to GDP, the intensity of energy consumption and volatility of energy consumption. When testing the model based on the criterion of the correctness of the functional form (RESET test), the model was linear. Thus, the resulting model has the following form:

$$Index1kl = 572.06 + 0.11\ Fossil\_Fuel\_Import\_Expenditure\_per\_GDP + 0.29\ Energy\_Expenditure\_Intensity + 0.12\ Energy\_Expenditure\_Volatility.$$

The model is adequate ($p\text{-value}<0.0001$), adj-$R^2 = 0.66$ shows that the model is constructed quite well. All variables are significant with a 95% reliability level. All criteria showed the absence of heteroscedasticity. Durbin-Watson and Breusch-Godfrey Criteria showed the presence of autocorrelation. Therefore, in order to improve the state of energy security (thus reducing the IESRI value), countries in the first cluster need to reduce energy imports to GDP, the intensity of energy consumption and volatility of energy consumption.

4.4 Assessment of the International Energy Security Risk Index for Cluster II countries (France, Italy, the Netherlands, Spain and Poland)

From each group of impact factors, were selected those that have the highest level of correlation with IESRI (Table 8). The interpretation of the direct connection between IESRI and factors such as the volume of coal production, the total volume of energy imports per GDP and intensity of energy consumption is analysed in chapter 4.3.

Table 8. The pairwise correlation coefficients between the corresponding factors and value of International Energy Security Risk Index for II Cluster (France, Italy, Netherlands, Spain and Poland)

Factor	Coefficient of correlation
Volume of coal extraction	0.6816
Total imports volume of energy resources per GDP	0.7119
Intensity of energy consumption	0.7885
Energy cost volatility	0.6790
The volume of CO_2 emissions	0.4970

Source: Created by the authors based on Large Energy, 2016.

With the growth of oil prices' volatility, the state of energy security is deteriorating, since, as a rule, prices are rising. With the increase of the amount of CO_2 emission, the state of energy security of the country is deteriorating, which is quite natural.

To construct a more accurate econometric model, we limited the number of factors to 2–3. Using RStudio tools, we implemented the automatic selection of factors among those listed in Table 2 (using step function). The best model (with the smallest Akaike coefficient) for the countries from the first cluster were those that have the independent variables of intensity of energy consumption, oil price volatility and CO_2 emissions. When testing the model according to the criterion of the correctness of the functional form (RESET test), it was found that the model is linear. The resulting model has the following form:

$$Index1k2 = 619.80 + 0.21\ Energy\_Expenditure\_Intensity + 0.11\ Crude\_Oil\_Price\_Volatility + 0.16\ CO2\_Emissions\_Trend$$

The model is adequate (p-value<0.0001); adj -R^2 = 0.8984 indicates that the model is well built. All variables are significant with a 95% reliability level. Checking the model for the presence of heteroscedasticity with the general criterion (Goldfeld-Quandt) and regression criteria (Glazer, White) showed the absence of heteroscedasticity. While checking the model for auto-correlation, the Durbin-Watson and Breusch-Godfrey criteria show autocorrelation. Therefore, in order to improve the state of energy security (correspondingly, to reduce the IESRI value), countries in the second cluster need to reduce energy costs and carbon dioxide emissions.

4.5 Assessment of the International Energy Security Risk Index for Ukraine (Cluster III)

From each group of impact factors, were selected those that have the highest level of correlation with the International Index of Energy Security Risk in direct or inverse connection (Table 9). The correlation coefficient -0.7346 shows that with an increase in natural gas production by one unit, IESRI will decrease by -0.7346 for Ukraine. Consequently, the result is reliable enough, as the smaller the IESRI is, the smaller is the country's energy security risk. The greater the import value of energy resources, the greater the value of IESRI will be, so the country will be in the worst situation. The more intensively the country uses its energy resources, the faster their resources will run out and the more energy import will be needed. And the more intense are the CO_2 emissions.

Table 9. The pairwise correlation coefficients between the corresponding factors and value of International Energy Security Risk Index for Ukraine

Factor	Coefficient of correlation	
	Connection	
	Direct	Inverse
The volume of natural gas extraction		-0.7346
The total volume of import of energy resources	0.6734	
GDP per capita	0.6504	
Intensive use of energy resources	0.7188	
The intensity of CO2 emissions per GDP	0.7157	

Source: Created by the authors based on Large Energy, 2016.

To construct a more accurate econometric model, we limited the number of factors to 2–3. With the help of RStudio tools, we implemented the automatic selection of factors among those listed in Table 8 (using step function). The best model (with the smallest Akaike criteria) was the one that has the total volume of imports of energy and GDP per capita as independent variables. Testing the model on the criterion of the correctness of the functional form (RESET test) revealed that the model is linear. The best of the tested models with different functional forms was the logarithmic-linear model of the form:

$$\log(\text{index\_ukraine}) = 7.29 + 0.0017\ \text{Total\_Energy\_Import\_Exposure} + 0.007\ \text{GDP\_per\_Capita}$$

The model is adequate (p-value< 0.0002), adj-R^2 = 0.6111 shows that the model is built quite correctly. Both variables are significant with a 95% reliability level. While checking the model for the presence of heteroscedasticity with the general criterion (Goldfeld-Quandt) and regression criteria (Glazer, White), all the criteria showed the absence of heteroscedasticity. Simultaneously, while checking the model for auto-correlation, the Durbin-Watson and Breusch-Godfrey criteria showed a lack of auto-correlation. So, in order to improve the state of energy security (and accordingly reduce the importance of IESRI), it is necessary, first of all, to reduce its dependence on the import of key energy resources, rational use of its own energy resources, and actively switch to alternative energy sources. In addition, IESRI is directly related to GDP per capita for Ukraine.

5. Discussion and conclusions

Covering the approaches to understanding the concept of 'energy security' we emphasise the importance of its assessment and regulation in the direction to apply the modelling approaches.

Conducting a cluster analysis of 11 European countries (the United Kingdom, Denmark, Norway, France, Germany, Poland, Spain, Italy, Norway, the Netherlands and Ukraine) using the *k*-means method helped to group these countries according to the similarity in their level of energy security. It was proposed to group countries according to the level of energy security (the level of the international energy security risk index) into 3 or 5 clusters. The resulting grouping to 3 clusters has the following structure:

I. Denmark, Germany, Norway, the United Kingdom
II. France, Italy, the Netherlands, Poland, Spain
III. Ukraine

A clusterization into 5 clusters has the following structure:

I. The United Kingdom
II. Denmark, Norway
III. France, Germany, Poland, Spain
IV. Italy, the Netherlands
V. Ukraine

From the resulting grouping, it can be concluded that Ukraine is in the weakest state in terms of energy security in comparison to the other countries under consideration. The lowest risk of energy security is detected for such countries as the United Kingdom, Denmark, Germany, and Norway. Therefore, for Ukrainian future transition to the cluster with a higher level of energy security, it is essential to be guided by some best practices of the countries. For example, as the UK has a leading position among countries in Energy Security Risk Index it may be speculated that the UK could become an example for Ukraine (Smith, 2014). It should be mentioned that the UK has one of the most reliable electricity systems in the world, and high standards of security of supply have been maintained even though margins for generation supply over demand have fallen as older (mainly coal-fired power stations) have been closed. The Office of Gas and Electricity Markets (UK) took steps to ensure that National Grid (the high-voltage grid system operator) could manage the risks by allowing them to use New Balancing Services (where they procured extra reserve power from power stations, and demand-side response services from the industry.) Those measures were in place until last winter (2016–2017). In winter 2017–2018 the Government's Capacity Market took over as the long-term incentive for power stations to provide security of supply.

With practice in ensuring the energy security of France and Germany, who are leaders in the energy policy of Europe, the British experience can be productive for Ukraine to embed it to the coordination policy of the EU countries and the EU integrated energy market: diversification of energy sources and de-carbonization policy. At the same time, such blind copying of European experience would not be successful in Ukraine due to different reasons. Primarily, Ukraine needs to improve the efficiency of energy use. It is not a secret that the losses of energy in Ukraine are three times higher than in the EU countries. Furthermore, the poor population of the country is not ready to pay accordingly for the high quality supply of energy resources. Consequently, the increase of energy security in Ukraine will be an evolutionary and slow process.

One of the main purposes of this work was to conduct an econometric modelling of the International Energy Security Risk Index dynamics under the impact of crucial external factors for each cluster (only 3). As a result, it was found that for Cluster I (Denmark, Germany, Norway, and the United Kingdom) the most significant factors influencing their energy security status were:

- the total volume of energy imports per GDP,
- the intensity of energy consumption,
- the volatility of energy consumption.

For Cluster II countries (France, Italy, the Netherlands, Poland and Spain), the most significant factors influencing their state of energy security are:

- energy intensity,
- the volatility of oil prices,
- CO_2 emissions.

Contrarily, for the country of Cluster III (Ukraine), the most significant factor influencing its state of energy security was:

- the total volume of imports of energy resources, GDP per capita.

The predicted values of the international energy security risk index for Ukraine as an index of diversity for 2015–2018 based on the data of 1992–2014 showed increasing negative tendencies that prove the necessity to change the system of energy security on the whole.

Summing up, despite significant reforms, financial and advisory assistance of European partners, Ukraine remains at an extremely low level of energy security.

The analysis showed that the main factors of influence on energy security in Ukraine differ significantly from those of the European countries. That explains the necessity of significant reforming of the national economy and the rules of the energy market in Ukraine. The calculated forecasts of the energy security risk index prove that the changes are urgent, as lagging behind the European countries will only increase. This situation looks particularly threatening against the backdrop of the occupation of part of the country's territory, which weakens the economy and the situation of the citizens in the country. However, it should not be forgotten that the research carried out has shown that different factors are at work in different countries and different clusters, and therefore, the development of Ukrainian policy should be unique.

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Oleksandr Chernyak, PhD is Professor (since 2005) and Head of the Economic Cybernetics Department at the Taras Shevchenko National University of Kyiv (since 1996). His research interests focus on Survey Sampling and he has pioneered in this field by developing several new methods and their applications, as presented in more than 250 scientific publications and presentations at international meetings. For more than 39 years he has investigated various aspects of primary in the field of statistics, econometrics, risk analysis, sampling technique, actuarial mathematics. Prof. Chernyak has a well-established national and international scientific network and an excellent track record for attracting and coordinating large-scale funding and multidisciplinary research projects together the National Bank of Ukraine, the Ministry of Economics of Ukraine, etc. He is a member of IASS (International Association of Survey Statisticians) and local coordinator in Ukraine of ENBIS (European Network for Business and Industrial Statistics).

Ganna Kharlamova, PhD is Associate Professor of Economic Cybernetics Department, Faculty of Economics at the Taras Shevchenko National University of Kyiv. She has participated in a number of research and development projects, is a certified coach in soft skills development of students, university staff and managers (UK, 2014); Erasmus professor with an experience of lecturing and training work at the universities of Romania, Turkey; co-director and member of Organizing Committee of a few NATO ARWs, ASIs, also coach and successful grant programme applicant for NATO grant for the provision of educational services in English language training within the framework of the

NATO-Ukraine professional development of civilian personnel security and defence sector (2015–2018), NATO ARWs, and the executive editor of *Bulletin of Taras Shevchenko National University of Kyiv. Economics*.

Andriy Stavytskyy, PhD is Associate Professor in Economic Cybernetics Department, a trainer, facilitator of the British Council Higher Education Leadership Development Programme (2016/2018), National Expert on Higher Education Reform in Ukraine within the Bologna Process, Erasmus professor with an experience of lecturing and training work at the universities of Lithuania, Turkey. He has coordinated ECTS of Taras Shevchenko National University of Kyiv (since 2011), and tutored the course 'Economics' (in English), at Edinburgh Business School.

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