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Factor Analysis Of Energy Security: Net Import Dependency

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Abstract

This paper analyzes various aspects of energy dependency and identifies the hidden factors behind national energy security. Based on a review of the scientific literature, the factors that reduce energy security in the consumption of natural gas, oil, and nuclear energy generation were identified. One such factor is import dependency on energy resources. Import dependency on energy is a crucial characteristic of energy security and can exacerbate the effects of external aggression, non-competitive behavior, and pressure. Given the energy crisis of 2022, most countries around the world have revised their energy security policies to reduce import dependency by diversifying supplies and reducing dependence on Russian energy resources.

The factor analysis of energy dependency ratios, 1990-2020, was used to study the energy security of the EU27 countries. The factor analysis was performed for annual indices calculated using the Eurostat database of "Simplified energy balances." The paper hypothesized the existence of latent relationships between energy security variables for the twenty-seven EU countries. The hypothesis was verified using Bartlett's sphericity test and Kaiser-Meyer-Olkin criterion. The results of hypothesis testing showed its statistical significance (the p-value < 0.05) and the possibility of factor analysis. Correspondence indices also indicated the adequacy of possible prediction of a set of variables. The factor analysis was executed in Python using the FactorAnalyzer module (the release 0.4.0). The principal factor extraction and the varimax rotation model were used to obtain the initial solution, preserving the orthogonality of the loading matrix. The factor structure of the model was confirmed for four factors consisting of the twenty-eight elements. The received four factors model allowed us to describe around 80% of the cumulative variance. It was found that each factor separately explained 46.89%, 15.80%, 10.91%, and 6.39% of the variance, respectively.

Keywords: energy dependency, energy policy, energy security, natural gas security, net import dependency.

JEL Classification: O30, Q41, Q42.

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Introduction

Modern cooperation between countries in terms of the energy transition is significantly enhanced against the background of global military conflicts, energy security and environmental protection. Today, European countries have a strong desire to strengthen international cooperation for a sustainable energy transition. The growing crisis in the energy sector of European countries determines the search for alternative ways to solve the above problem, one of which is the development of transformation processes in the context of European integration. Global issues of energy security, digital transformation of the energy sector and environmental protection are attracting the attention of governments, investment companies, the business sector and the scientific community from around the world (George, 2020; Elnikova, yt al., 2020; Sahoo, 2017; Kyrychenko et al., 2021). The main tasks of improving countries' energy security are ensuring the security of electricity and natural gas supply to consumers, integrating energy markets into European markets, increasing the reliability and efficiency of integrated energy systems, diversification of energy sources and routes, developing renewable and low-carbon energy sources, alternatives. types of fuels, increasing energy efficiency along the chain from production to energy consumption, etc. (Ziabina et al., 2021; Bhowmik, 2019; Pimonenko et al., 2021; Us et al., 2020). Reforming in the energy sector is designed to optimize the energy balance and increase economic, energy and environmental security, especially in times of military conflict. The main goal of these transformations is to strengthen the energy security of countries, reliably meet the needs of society and the economy in fuel and energy resources and create a solid foundation for a sustainable energy future for countries. The vast majority of research on assessing the state of energy security is carried out using an integrated approach. The problem with its application is quite the arbitrary selection of groups of parameters that are important for analysis. The application of an integrated approach does not allow to develop a universal method of choosing the parameters of energy security assessment for different countries and specific conditions functioning of their energy markets. Moreover, the application of such an approach does not allow for energy security strategy, as changes during the election set of parameters due to technological transformations and changes in models of energy markets actually necessitate a revision of the methodology for assessing the level of energy security, selection of modern evaluation indicators, search for new data for calculations.

The aim of the paper is to study various aspects of energy dependency and identify the underlying factors behind national energy security.

This work is divided into five sections. In the second section, a review of the literature on specific issues of energy security was conducted. The third part presents the methodology and research methods. And after the results section of this paper, the conclusions are given.

Literature Review

Natural gas security. Global climate problems have led to increased demand for natural gas, which is often used as a more environmentally friendly replacement for coal. In turn, the growth of gas demand rises the dependence of importing countries on the results of international gas trade, especially with insufficient development of domestic gas storage. And in the case of systematic disruptions to natural gas imports, renewables can be an essential source of mitigating the safety and environmental consequences of such violations (Qin et al., 2022; Ziabina et al., 2020; Pavlyk, 2020). According to a study by Rodríguez-Fernández et al. (2022), Russia's blockade of gas supplies to Europe via Ukraine has worsened the security of gas supply. It has increased vulnerability to the risks of gas supply disruptions in EU countries. The example of Ukraine shows how vital its energy security is for the state's territorial integrity. As a result of Russia's military aggression, Ukraine is experiencing partial destruction of energy facilities and their illegal alienation (Mara et al., 2022). In response to Russia's war in Ukraine and its energy blackmail, Lithuania has refused to import Russian gas for domestic use (Government, 2022). This step was made possible by the purposeful implementation of the Lithuanian strategy of national energy independence. After the shutdown of the Ignalina nuclear power plant, Lithuania has become a country dependent on electricity and gas imports. And the situation was significantly aggravated by the fact that the Lithuanian energy system was synchronized not with European energy networks but with Russian-controlled networks. Given the discriminatory nature of energy pricing and relations with Russia, Lithuania has focused on implementing strategic projects to overcome energy dependence (Government, 2018). Although Lithuania is still part of the IPS / UPS energy system for importing electricity from Russia and Belarus, energy connections with Poland and Sweden are helping to restore its energy security (Karpavicius, & Balezentis, 2022). As for gas imports, Lithuania now has diversified sources of gas consumption. Gas needs in Lithuania can be met not only through agreements with Russia's Gazprom but also through the supply of liquefied gas through the Klaipeda terminal, as well as through gas connections with Latvia and Poland (Government, 2022). Similarly, Poland, trying to reduce its gas dependence on Russia, launched the Baltic Pipe project to integrate the Polish gas system into the Scandinavian system (Voytyuk, 2022).

Taking into account the consequences of the gas crisis of 2021/2022, the EU has revised its policy of decarbonization of the economy by strengthening measures to ensure its energy security. In 2022, there was a shock jump in energy prices, for which EU countries were not prepared. The lack of a unified foreign energy policy did not allow the EU to quickly form a common energy position on Russia's invasion of Ukraine (Mišík, 2022; El Amri et al., 2020). Somewhat later, a new European plan, RePowerEU, was proposed, one task of which was to reduce dependence on Russian energy resources. Such a plan is critical given the EU's significant dependence on Russian imports of all primary energy resources. And a possible disruption of gas supplies from Russia requires immediate action to diversify energy imports and reduce dependence on EU fossil fuels. Thus, in 2021, the EU imported more than 40% of its total gas consumption from Russia (COM, 2022). According to Eurostat data, in 2020, Hungary (110.4%), Latvia (100.1%), and Finland (92.4%) had the largest share of Russian gas imports in domestic consumption. The lowest indices of Russian gas dependence were in Ireland, Cyprus, Malta, and Norway. The dependence on Russian gas in the EU varies significantly from country to country. Although there were countries that did not import Russian gas in 2020, there were also countries (Latvia and the Czech Republic) that relied exclusively on a single gas importer, Russia (Eurostat, 2022b), to meet their natural gas needs. And given the significant share of energy supplies, Russia has a considerable instrument of political and economic pressure on other states. This situation forces the EU to look for new ways to supply gas. As only the European Union's needs for natural gas are expected to increase in the future, this could potentially mean an increase in the EU's dependence on Russia. Therefore, it is strategically essential for EU countries to invest in projects of common interest that will diversify the import of energy resources. Among such projects is the East Mediterranean gas pipeline EastMed. However, the EastMed project is already being called expensive and technically problematic because it passes through seismically active parts of the Mediterranean Sea at considerable depths. The alternative Trans-Anatolian gas pipeline TANAP will connect Azerbaijan with European countries and pass through Turkey, strengthening its energy position. The TANAP project is planned to be completed soon as an alternative to South Stream (Tutar et al., 2022).

Outside the EU, gas problems are also significant. Jordan, which is 95% dependent on imported energy supplies from neighboring countries, also has a critical energy security situation. Due to political developments in the Middle East, Jordan has had a disruption in gas supplies from Egypt, which has had a negative impact on the country's economy (Alrwashdeh, 2022). A similar situation with natural gas shortages is observed in Pakistan. Unfortunately, gas consumption growth in Pakistan is not covered by gas from its fields. And projects to build gas pipelines from Iran and Turkmenistan are being postponed due to the need to regulate the safety of channels in transit countries. As a possible solution to increase Pakistan's energy security, Kanwal et al. suggest using syngas to cover the deficit of their own energy needs (Kanwal et al., 2022).

Oil security. For most countries, the reliability of the oil import network is crucial for energy security. For China, this statement is also true. China imports about 70% of its total oil consumption. However, according to Chen et al., the reliability of China's oil import network is relatively low because it is vulnerable to accidental and attacker attacks and node failures (Chen et al., 2022; Chygryn et al., 2020). It is also essential for China to rationally control oil consumption to ensure the security of the national energy supply (Jiang et al., 2022). Similar problems are present in Ireland. Ireland has no domestic oil sources, so all the country's oil is imported. Given Russia's war in Ukraine, it is possible to expect disruption of oil supply chains, general market volatility, and rising energy prices in Europe and the world (Government, 2022).

Mróz (2022), comparing the security of supply of copper and oil, notes that oil has a much higher risk of intermittent supply than copper. Oil prices are also more volatile and regulated by market mechanisms. The results of Cai et al. on EU energy security shows that the SVAR model makes it possible to prove the existence of a relationship between oil supply shocks and declining production, rising prices, and unemployment in the euro area (Cai et al., 2022).

It is essential to have sufficient oil reserves to prevent countries from using energy as a strategic geopolitical weapon to mitigate the risks of oil disruptions. Unfortunately, any disruptions in oil supply have a direct effect on the level of energy security of countries, as they slow down their economic growth (Yang et al., 2022).

If we consider the issue of energy security from the standpoint of energy-rich countries, then completely different aspects become visible. There are issues of ensuring the security of stable demand, supply of oil and petroleum products, and counteracting geopolitical influences in oil production and trade. There are also impacts on the economies of these countries. For energy-rich countries, there may be barriers to introducing renewable energy sources related to social aspects, infrastructure, tax revenues, and so on. In particular, in Azerbaijan, one of the critical exporters of crude oil in the Caspian region, there is a predominant use of fossil fuels in electricity generation. Renewable energy generation in Azerbaijan is only 8.8%. And despite the announced move to increase renewable energy consumption, such plans seem far from reality, given the instability of Azerbaijani legislation and the lack of targeted tools to support renewable energy (Cholewa et al., 2022).

Nuclear security. Nuclear energy is considered a means of converting low-carbon energy. According to the IEA, hydropower and nuclear power provide the most significant amount of low-carbon electricity for a clean transition worldwide (IEA, 2021). According to Usman et al. (2022), nuclear energy can become a panacea and solve energy security and environmental problems. To this end, it is necessary to increase nuclear energy production by approving the relevant energy and environmental policies of different countries (Usman et al., 2022). In particular, in the new British energy security strategy, nuclear power is among the leading investment priorities of the government. Despite the UK losing its leadership in civilian nuclear energy, the government plans to lead nuclear technology through large-scale construction in the next 30 years. The strategy envisages that the UK will deploy a civilian nuclear energy program to increase the share of nuclear energy consumption from 15 to 25% by 2050 (GOV.UK, 2022).

However, world leaders may also rethink the possibility of using nuclear energy in the event of a nuclear power plant disaster. But this statement is not always confirmed by the facts. Following the example of the Fukushima disaster, Cho concludes that the real reason for the phasing out of nuclear energy in Germany and South Korea was the emergence of new opportunities and policies rather than the nuclear disaster (Cho, 2022). Therefore, leadership in nuclear energy is of great importance. Changing global political and economic conditions change views automatically on nuclear power. Given the geopolitical challenges in the energy sector in 2022, the EU has decided to revise the Taxonomy Regulation on environmentally sustainable economic activities and to consider the generation of energy from nuclear power plants as a means of decarbonization and climate change by EU member states (C/2022/0631, 2022).

However, nuclear risks remain in nuclear energy, as the world leaders in exporting raw materials and nuclear technologies are Russia and China. And it is these countries that can set the standards for nuclear safety and trade in nuclear energy resources in the future. Participation in the programs of construction of nuclear power plants and their further maintenance gives the countries additional points of influence on the policy of foreign countries.

As of 2020, Rosatom was the world leader in constructing nuclear power plants (built 36 nuclear power plants) and uranium enrichment (controlling 36% of the world market). Rosatom also ranked second in the world regarding uranium volumes and extraction. Rosatom served 49 power units for nuclear power plants outside Russia. Among Rosatom's most significant projects in 2020 were the following projects: Akkuyu NPP (Turkey), Proryv Project (Russia), and Hanhikivi NPP (Finland) (Performance, 2020). Regarding the latest project, Fennovoima terminated the contract with Rosatom to construct the Hanhikivi NPP in May 2022. For Fennovoima, the main reasons for terminating the contract are significant project delays and Rosatom's inability to complete the project due to Russia's war with Ukraine (Fennovoima, 2022). The Akkuyu NPP project, according to Korkmaz & Önöz (2022), is not the best option for Turkey. According to their research, nuclear energy in the future will increase the cost of electricity production in Turkey, not reduce them. And it is better to invest in renewable energy sources (especially wind and solar) and energy storage technology, which is a more cost-effective option. Restoration technologies combined with the latest energy storage technologies will be able to provide the base load in Turkey. Also, the Akkuyu NPP project does not support the argument of increasing the country's energy security, given the increased dependence on imported energy sources. Turkey has a small supply of nuclear fuel. Therefore, constructing the first nuclear power plant will potentially increase Turkey's energy dependence. And the country's dependence on imported energy sources makes nuclear energy potentially vulnerable to developing geopolitical conflicts.

Methodology and research methods

This paper used Eurostat annual data of the simplified energy balances database for the EU27 from 1990 to 2020. For the study, the authors chose two indicators: net imports energy and gross available energy. These indicators were the basis for studying energy security in the EU27, one of which is the coefficients of energy dependence. According to the Eurostat methodology, the authors calculated the energy dependency ratio as the share between net imports and gross available energy (Eurostat, 2022a).

The energy dependency coefficients were standardized to conduct further machine analysis. After that, factor analysis was performed to identify the relationships between variables and hidden factors. Thus, the authors tested the hypothesis of latent relationships between energy security variables in the EU27. The hypothesis was proved using Bartlett's sphericity test and the Kaiser-Meyer-Olkin criterion. Factor analysis was performed in Python using the FactorAnalyzer module (the release 0.4.0).

Results

Visual diagnosis of the correlation between energy dependency indices using a diagonal correlation matrix mainly shows the absence of such a relationship for data that have not been standardized (Figure 1). Only two countries (Cyprus and Luxembourg) have the opposite situation.

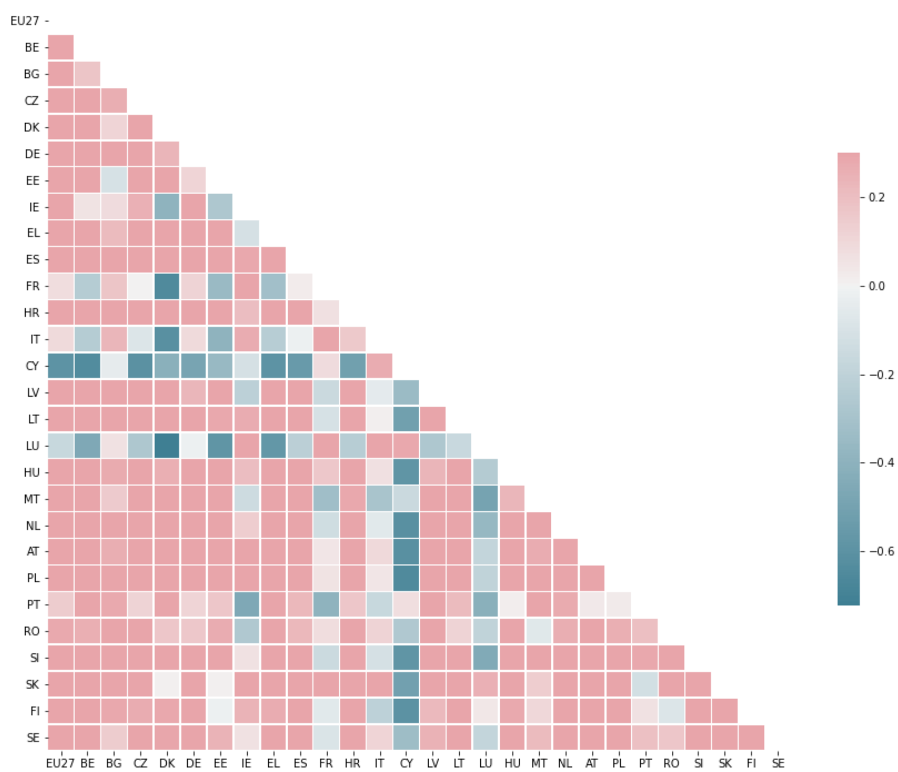

Figure 1. Diagonal correlation matrix for the energy dependency rates, the EU27, 1990-2020

Source: developed by the authors based on (Eurostat, 2022c)

Factor analysis was performed to identify latent relationships between energy security variables. After standardizing the data, such relationships were verified using Bartlett's Sphericity test and the Kaiser-Meyer-

Olkin criterion (Table 1). Since the p-value is much less than 0.05, Bartlett's sphericity test is statistically significant, and factor analysis is possible. The Kaiser-Meyer-Olkin criterion also shows the adequacy of a possible prediction of a set of variables.

Table 1. The variance explained by the factors

Index	Returns	Thresholds
p-value for Bartlett's sphericity test	2.2408280399565725e-95	< 0.05
Kaiser-Meyer-Olkin criterion	0.6767029066572187	> 0.6

Source: developed by the authors based on (Eurostat, 2022c).

Given the factor correlation matrix, eigenvalues were calculated. Then there was a search for statistically significant factors. A scree plot (Figure 2) was constructed, and the Kaiser criterion was used to determine the number of factors retained during the analysis. For this case, as seen from the graph, the number of such factors is four.

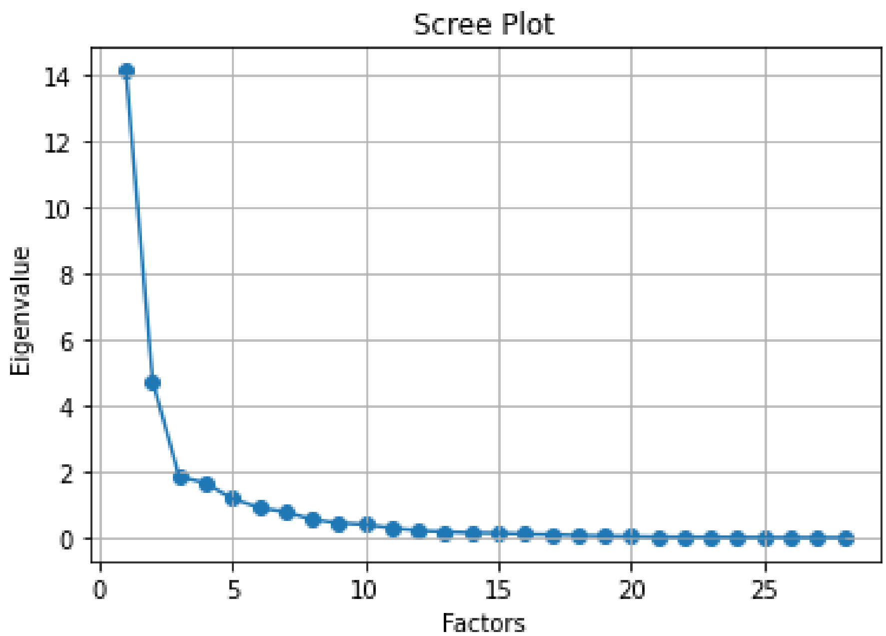

Figure 2. Scree plot for the energy dependency rates, the EU27, 1990-2020

Source: developed by the authors based on (Eurostat, 2022c).

A model with principal factor extraction and varimax rotation was used to obtain the initial solution. The accepted model for four factors allowed us to describe around 80% of the cumulative variance (Table 2).

Table 2. The variance explained by the factors

Index	Factor 1	Factor 2	Factor 3	Factor 4
variance	13.128425	4.424757	3.055241	1.788647
proportional variance	0.468872	0.158027	0.109116	0.063880
cumulative variance	0.468872	0.626899	0.736015	0.799895

Source: developed by the authors based on (Eurostat, 2022c).

Conclusions

As a result of the factor analysis and the varimax rotation, a study of energy security in the EU27 was performed. The factor analysis was executed for annual indices calculated using the Eurostat database "Simplified energy balances." The paper hypothesized the existence of latent relationships between energy security variables for 27

EU countries. The hypothesis was tested using Bartlett's sphericity test and the Kaiser-Meyer-Olkin criterion. Hypothesis testing showed its statistical significance ($p < 0.05$) and the possibility of factor analysis. Correspondence indices also showed the adequacy of possible prediction of a set of variables. Factor analysis was performed in Python using the FactorAnalyzer module (the release 0.4.0). The obtained model for four factors allowed to describe around 80% of the cumulative variance. It was found that each factor separately explained 46.89%, 15.80%, 10.91%, and 6.39% of the variance, respectively.

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