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The Dynamics of Energy Import Dependence in the Baltic States

Baltık Ülkelerinde Enerji İthalatına Bağımlılığın Dinamikleri

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Abstract

This study investigates the determinants of energy import dependency in the Baltic states (Estonia, Latvia, and Lithuania) using panel data from 1995 to 2021. Employing panel ARDL and FMOLS methods, the analysis identifies long-term relationships between energy import dependency and key factors such as renewable energy consumption, trade, carbon intensity, industrial competitiveness, and export quality. Findings reveal that while renewable energy use and high export quality reduce dependency, carbon intensity and industrialization increase it. These results highlight the Baltic states' transition towards energy independence, contributing to discussions on regional energy security, sustainability, and European integration within the framework of SDG-7.

Keywords: *Energy Import Dependency, Baltic States, Renewable Energy, Carbon Intensity, Industrialization*

JEL Classification: *Q43, F18, C33*

Öz

Bu çalışma, 1995-2021 yılları arasındaki panel verilerini kullanarak Baltık ülkelerinde (Estonya, Letonya ve Litvanya) enerji ithalat bağımlılığının belirleyicilerini araştırmaktadır. Panel ARDL ve FMOLS yöntemlerini kullanan analiz, enerji ithalat bağımlılığı ile yenilenebilir enerji tüketimi, ticaret, karbon yoğunluğu, endüstriyel rekabet gücü ve ihracat kalitesi gibi temel faktörler arasındaki uzun vadeli ilişkileri tanımlamaktadır. Bulgular, yenilenebilir enerji kullanımı ve yüksek ihracat kalitesinin bağımlılığı azaltırken, karbon yoğunluğu ve sanayileşmenin bağımlılığı artırdığını ortaya koymaktadır. Bu sonuçlar Baltık ülkelerinin enerji bağımsızlığına geçişini vurgulamakta ve SDG-7 çerçevesinde bölgesel enerji güvenliği, sürdürülebilirlik ve Avrupa entegrasyonu tartışmalarına katkıda bulunmaktadır.

Anahtar Kelimeler: *Enerji İthalat Bağımlılığı, Baltık Ülkeleri, Yenilenebilir Enerji, Karbon Yoğunluğu, Sanayileşme*

JEL Sınıflandırması: *Q43, F18, C33*

1. Introduction

Energy import dependency is a multidimensional problem that threatens both economic stability and environmental sustainability as one of the biggest obstacles to sustainable development. "Ensure access to affordable, reliable, sustainable and modern energy for all" (SDG-7), one of the United Nations' Sustainable Development Goals (SDGs), aims to solve the problem of energy dependency and increase

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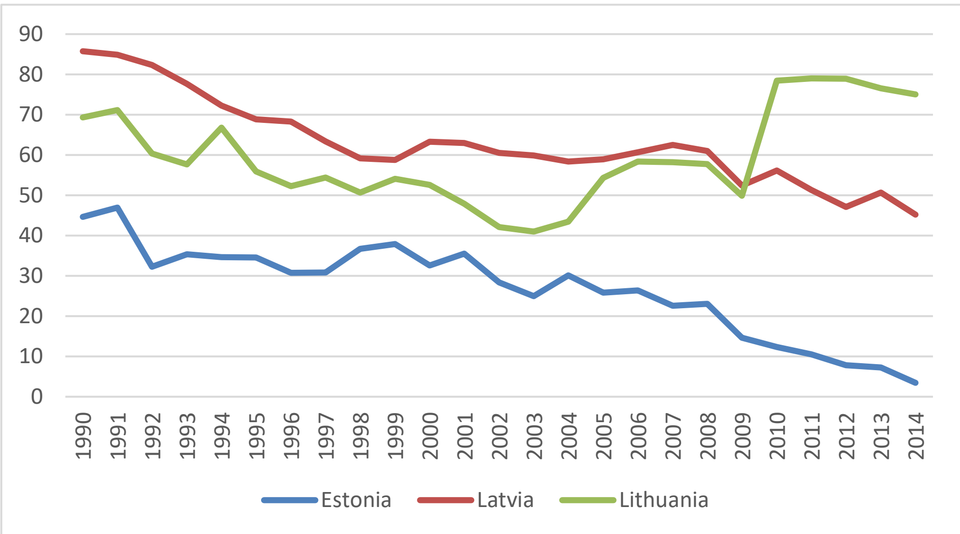
the energy supply security of countries. In line with this goal, strategic measures such as increasing renewable energy sources, energy efficiency improvements and modernizing energy infrastructures come to the fore to reduce energy import dependency. However, energy import dependency is not only an economic and technical problem but is also deeply linked to global political relations and geopolitical risks. In particular, the increase in imports of fossil fuels can make importing countries dependent on energy suppliers, limiting their foreign policy and economic decisions (Boneva, 2018). In this context, energy dependence is a problem area that requires not only diversification of energy sources but also integrated national and international energy policies.

The Baltic states (Estonia, Latvia, Lithuania) have undergone a remarkable transformation process in the field of energy dependence and energy security both at the European Union and international level. After the collapse of the Soviet Union, these countries faced serious political and economic challenges as their energy infrastructure was heavily dependent on Russia (Bluszcz, 2016; Boneva, 2018). In particular, Russia's tendency to use energy supply as a political tool accelerated the Baltic countries' quest for energy independence, which led to radical changes in their energy policies. In this context, the Baltic countries have undertaken comprehensive reforms to diversify their energy supplies, increase the use of renewable energy sources and modernize their energy infrastructure (FPRI, 2024).

Lithuania's liquefied natural gas (LNG) terminal, commissioned in 2014, stands out as a symbolic step in this transformation. This terminal has reduced not only Lithuania's, but also the entire Baltic region's natural gas dependence on Russia and strengthened cooperation with alternative energy suppliers (FPRI, 2024). Similarly, Latvia and Estonia have also taken important steps to ensure security of energy supply by liberalizing their energy markets and modernizing their energy infrastructure (Slišana et al., 2020). Their efforts in the field of energy security have attracted international attention as a model for European energy policy. However, projects for the development of energy infrastructure include critical initiatives such as the Poland-Lithuania Gas Link (GIPL) and the LNG infrastructure at the Lithuanian Port of Klaipėda. These projects have not only diversified energy supplies but also accelerated the integration of the Baltic states into European energy networks (Budginaite-Froehly, 2024).

The increasing rates of energy dependence across Europe and the associated geopolitical risks have made the Baltic states' efforts for energy independence even more critical. Energy import dependency in the European Union reached 53.6% as of 2016, and the decline in domestic energy production has increased import dependency (Bluszcz, 2016). This situation has strengthened the Baltic countries' efforts to reshape their energy supply strategies. Moreover, the Baltic states' full integration into the European continental energy network by 2025, leaving the Russian-controlled IPS/UPS electricity grid, will be a major milestone for regional energy security (FPRI, 2024).

Figure 1. Energy imports, net (% of energy use), 1990-2014



Düzce Economics Journal, 6(1), 1-18.
April 2025

Figure 1, which shows energy import dependence, highlights the diverging dependence levels of the Baltic countries since 1990. Lithuania's energy import dependence increased dramatically by 2010, followed by a significant decline to a more balanced level in 2014. This trend can be seen as a reflection of Lithuania's efforts to diversify its energy sources by commissioning a liquefied natural gas (LNG) terminal in 2014 (FPRI, 2024). Similarly, Latvia and Estonia have gradually reduced their energy import dependence. This shows that the Baltic states are utilizing their domestic energy resources more effectively and taking important steps towards integration into European energy networks in order to increase energy supply security (Štreimikienė et al., 2016).

Figure 2. Energy intensity level of primary energy, 2000-2022

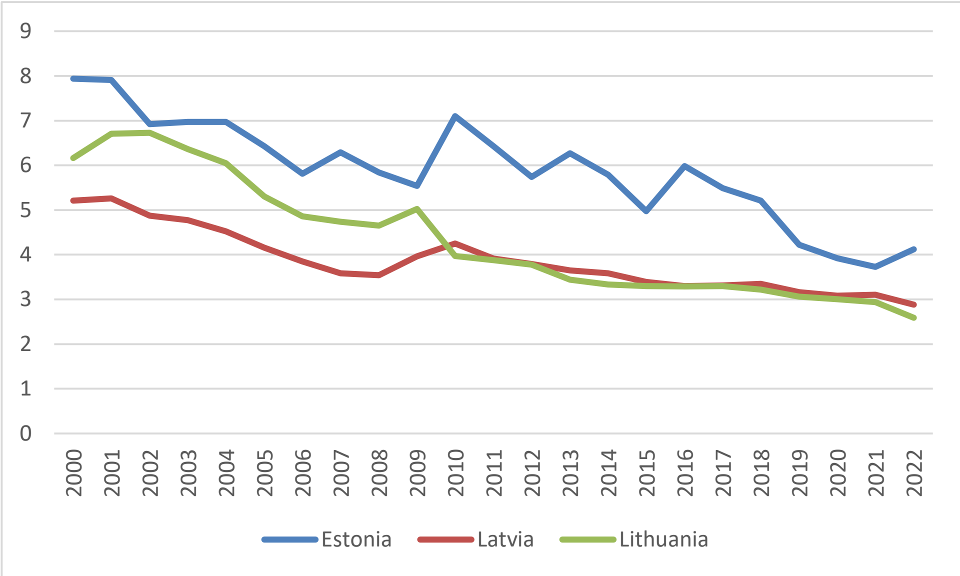
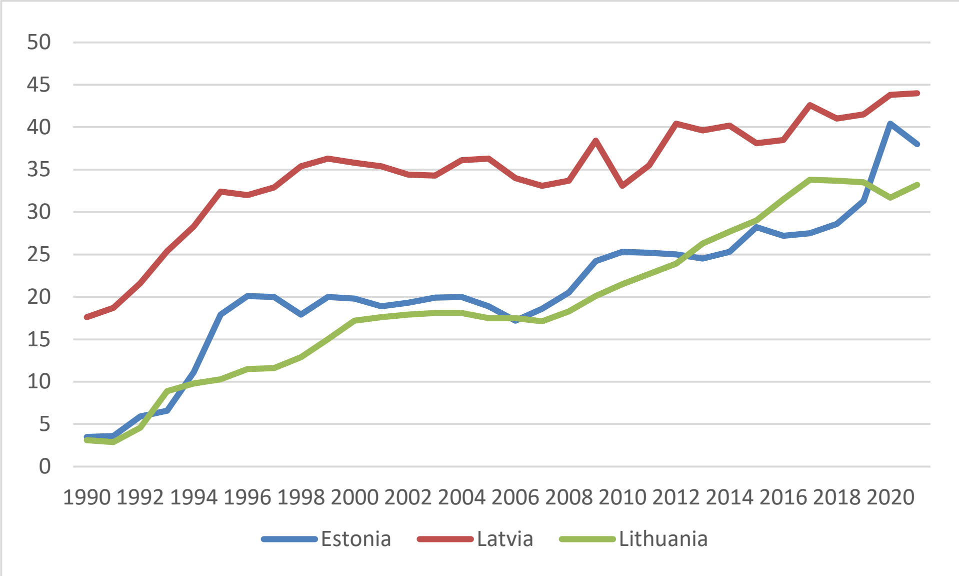


Figure 2, which represents energy intensity, shows that energy intensity in all Baltic countries has been on a downward trend since 2000. This trend shows that economic transformation and energy efficiency policies have been effectively implemented. It can be observed that Estonia had a higher energy intensity in the early 2000s, but over time it has moved closer to the same level as the other countries. This suggests that energy efficiency improvements are integrated with economic growth (Carfora et al., 2022). The decline in Latvia and Lithuania's energy intensity levels also shows that industrialization and the shift towards renewable energy sources have been effective (Vaona, 2016).

Figure 3, which shows the use of renewable energy, reveals the importance that the Baltic countries attach to renewable energy in their energy supply. Latvia outperforms the other two countries with renewable energy use approaching 40%. This can be attributed to Latvia's investments in domestic renewable resources such as hydropower. The increase in Lithuania's renewable energy share is in line with the reduction in energy import dependency. Estonia lags behind the other two countries in the use of renewable energy, reflecting the fact that Estonia is still more dependent on fossil fuels (Bluszcz, 2016).

Figure 3. Renewable energy consumption (% of total final energy consumption), 1990-2021



As a result, the transformation of energy policies in the Baltic countries offers important lessons not only for regional energy security but also for Europe's strategies to tackle energy dependence. This study aims to analyze the determinants of energy import dependence in the Baltic countries (Estonia, Latvia and Lithuania) and assess the effectiveness of their energy policies in the context of energy security and sustainable development goals. The annual data set covering the years 1995-2021 is used in the study, with energy import dependence as the dependent variable and factors such as renewable energy consumption, trade rate, carbon intensity, industrialization intensity and industrial export quality as independent variables. Econometric methods such as fully modified ordinary least square (FMOLS), panel ARDL model and cointegration tests are used to analyze the dynamics of energy import dependence. This study aims to fill existing gaps in the literature by evaluating the energy security strategies of the Baltic countries in a broader context and to provide strategic recommendations for policymakers that consider renewable energy, trade and industrialization factors. Its contribution to the literature stands out both by analyzing the energy policies of these countries in a comparative perspective and by providing a multidimensional approach to energy dependence.

2. Literature Review

Energy import dependence is a critical factor that directly affects a country's energy supply security and economic stability. This issue poses a significant challenge to achieving sustainable economic growth and environmental goals, especially for countries that are heavily dependent on foreign energy resources. The energy security strategies of European Union (EU) countries aim to reduce energy import dependency, increase the use of renewable energy sources and improve energy efficiency. In energy import-dependent regions, such as the Baltic states, the effects of such policies have been carefully studied. However, the vast majority of studies in the literature have focused on different regions, modalities and periods, and have conducted piecemeal analyses rather than providing a holistic approach to the issue. The aim of this study is to contribute to the understanding of the dynamics of energy import dependence in the Baltic countries and fill the literature gaps in this field.

Focusing on the Baltic countries, Štreimikienė et al. (2016) is an important reference in the context of energy import dependence and energy security. The study by Štreimikienė et al. (2016) is the only comprehensive study that addresses the issue of energy import dependence and energy security in the Baltic countries and assesses their progress in sustainable energy policies. The study compares Estonia, Latvia and Lithuania using indicators such as energy import dependence, energy intensity, carbon intensity, diversity in energy mix and renewable energy utilization rate. The findings show that Estonia is the most successful country in terms of energy security thanks to its low energy import dependence (17.1%) and diversity in its energy mix, whereas Lithuania is the most dependent on energy imports with a high rate of 80.3%. Latvia leads in the use of renewable energy with 36.4%, which is due to the country's hydroelectric potential. However, Estonia performs the worst in terms of energy intensity and carbon intensity, while Lithuania achieves the best results in these indicators. The study emphasizes the need to increase renewable energy investments, diversify the energy mix and develop policies that promote energy efficiency in order to increase energy security and reduce dependence.

Carfora et al. (2022) is an important study that analyzes the dynamics of energy import demand and the impact of renewable energy sources on energy dependence in European Union countries. The aim of the study is to understand the factors leading to energy import dependence and to assess the role of renewable energy use in reducing this dependence. Using data from 26 European Union member states between 2007 and 2016, the study examined the differences in energy dependence between countries and the reflections of these differences in energy policies. The relationship between renewable energy utilization rate, energy import demand and energy security is evaluated using panel data analysis and lasso regression method. These methods were chosen to address heterogeneity in energy flows across countries and potential multicollinearity problems among variables. The findings of the study suggest that the use of renewable energy sources is a critical tool to reduce energy import dependence. In particular, it is emphasized that significant improvements in energy security can be achieved if energy imports are substituted by domestic renewable energy production. Moreover, it is noted that increased use of renewable energy supports not only energy dependence but also energy security and sustainable development goals. The study points out that increasing the role of renewable energy sources in the European Union's energy policies can have far-reaching effects that have not only environmental but also economic and social dimensions. In this respect, Carfora et al.'s study provides a more detailed understanding of the positive effects of renewable energy policies on energy dependence and security and provides strong support for strategies to reduce energy imports.

In the literature on the relationship between energy consumption and economic growth, Ozturk (2010) analyzed the causality relationship between energy consumption and economic growth and found that energy consumption has both direct and indirect effects on economic growth. The study also emphasized that the relationship between energy consumption and growth may differ according to country characteristics (Ozturk, 2010). In this context, Sahu and Mahalik (2024) examined the relationship between energy dependence and macroeconomic fluctuations in OECD countries and found that energy import dependence weakens economic stability. These findings suggest that countries with high energy dependence are more vulnerable to external energy shocks (Sahu and Mahalik, 2024). Similarly, Vaona (2016) analyzed the effects of renewable energy generation on import demand and showed that an increase in renewable energy use reduces import dependence. This study emphasizes the importance of local energy sources in energy policy (Vaona, 2016). Kukharets et al. (2023) evaluated energy import dependence in terms of renewable energy and gross domestic product per capita in the context of the European Green Deal. The study revealed that increasing the use of renewable energy has direct positive effects on energy dependence (Kukharets et al., 2023).

Other studies linking energy dependence to environmental impacts are also noteworthy. Murshed et al. (2020) examined the relationship between energy import dependence, energy prices and economic growth in the context of Sri Lanka. The study emphasizes the long-term negative effects of import-dependent energy systems on economic growth (Murshed et al., 2020). Iancu et al. (2023) analyzed the economic impacts of fossil fuel imports in EU countries and showed that innovative energy policies are an important tool to reduce energy dependence (Iancu et al., 2023). Domac et al. (2005) analyzed the socio-economic impacts of biomass energy projects and showed that these projects can increase local employment and economic growth by reducing energy imports (Domac et al., 2005). The importance of renewable energy sources in the EU's energy dependence strategies was also emphasized by Dokas et al. The study analyzed the effects of macro factors such as economic growth, trade openness and innovation on energy consumption and suggested that energy management policies should be differentiated according to country categories (Dokas et al., 2022). Lawson (2020) examined the relationship between greenhouse gas emissions, fossil energy use and economic growth in Africa. The study revealed that economic growth does not directly lead to carbon emissions, and the main source of emissions is fossil energy use. These findings emphasize that energy efficiency and transition to renewable energy sources are critical for environmental sustainability (Lawson, 2020).

Shahbaz et al. (2016) analyzed the impact of globalization on energy demand in India and found that social, economic and overall globalization reduces energy demand in the long run. The study examined the effects of variables such as globalization, financial development and urbanization on energy demand using Bayer-Hanck cointegration test and ARDL method. The results showed that globalization can reduce energy demand while promoting sustainable economic growth (Shahbaz et al., 2016). Similarly, Acheampong et al. (2021) examined the impact of economic, social and political globalization in analyzing the relationship between economic growth and energy consumption in 23 emerging economies. In this study, the dependence between energy consumption and economic growth was found, and it was determined that social globalization increases economic growth, while economic and political globalization slows down economic growth. In addition, it was concluded that economic and social globalization have an increasing effect on energy consumption, while political globalization balances these effects (Acheampong et al., 2021). In parallel with these studies, Ratha et al. (2019) examined the effects of fossil fuel and renewable energy consumption on total factor productivity (TFP) and found that renewable energy consumption increases TFP while fossil fuel consumption decreases TFP. Using panel data cointegration and Granger causality analyses, this study emphasized the importance of shifting energy consumption towards renewable energy for sustainable growth. The results have important implications for policy decision-makers, especially in terms of long-term environmental sustainability and economic productivity (Ratha et al., 2019). Ali et al. (2021) conducted a comparative analysis of the relationship between natural resource depletion, renewable energy consumption and environmental degradation in the context of developed and developing countries. It is concluded that renewable energy consumption has a mitigating effect on environmental degradation, while fossil fuel consumption increases environmental damage. The study points to the need to strike a balance between economic growth and environmental sustainability and makes recommendations for policymakers (Ali et al., 2021).

Energy import dependence and the effects of renewable energy sources in reducing this dependence have been studied with increasing interest in recent years. Yadav and Mahalik (2024) investigated the effects of renewable energy consumption on energy import dependence in a study covering 16 emerging economies. By applying CS-ARDL and panel causality analyses, the study concludes that renewable energy use can partially substitute energy imports. However, it is emphasized that economic growth increases energy import demand. These findings show the importance of energy security policies for developing economies (Yadav and Mahalik, 2024). Aslantürk and Kıprızlı (2020) examined the role of renewable energy on energy security and its potential to reduce energy imports. The study reveals that countries dependent on energy imports can both increase energy security and reduce foreign trade deficits by turning to renewable energy sources. It is emphasized that the use of renewable energy will make economic growth sustainable while reducing external dependence (Aslantürk and Kıprızlı, 2020). Ürkmez and Okyar (2022) analyzed the effects of renewable energy generation on energy import dependency in Turkey. Using the ARDL bounds test approach, the study concluded that renewable energy generation decreases energy import dependency, while GDP per capita increases this dependency. The study emphasizes the need for Turkey to ensure energy security by increasing renewable energy investments (Ürkmez and Okyar, 2022). Najm and Matsumoto (2020) analyzed the effects of renewable energy policies on liquefied natural gas (LNG) trade. The study concluded that renewable energy policies reduce LNG trade and natural gas can be partially substituted by renewable energy. These findings emphasize the importance of renewable energy investments in the energy transition process (Najm and Matsumoto, 2020)

Consequently, this study assesses the impact of strategies to reduce energy import dependence in the case of the Baltic states and aims to fill the gaps in literature. In this context, the effects of renewable energy sources and domestic energy policies on energy dependence will be discussed in depth. Policy recommendations will be presented to reduce the negative effects of energy import dependence on economic stability and to promote sustainable development.

3. Data and Methodology

3.1. Data

In this study, energy import dependence is taken as the dependent variable, while the independent variables are renewable energy consumption, trade ratio, carbon intensity, CIP score, industrialization intensity and industrial export quality index. Energy import dependence is taken from Eurostat data and defined as follows: This ratio, which shows how much of a country's energy needs are met by imports, is calculated as net energy imports divided by gross available energy and expressed as a percentage. A negative dependency ratio indicates that the country is a net exporter of energy, while a ratio exceeding 100 indicates that energy products are stockpiled. Nuclear power generation and renewable energy production are considered as domestic production regardless of the origin of their resources, such as raw materials or biomass. This dependency ratio is an important indicator for energy security and sustainable development goals. Previous studies have found that energy dependence increases economic stability and vulnerability to external shocks (Bluszcz, 2016; Štreimikienė et al., 2016).

Renewable energy consumption refers to the share of renewable energy sources in total final energy consumption and is provided by the World Bank. Renewable energy has a key role in reducing energy dependence and increasing energy security. Previous studies have shown that the use of renewable energy reduces energy import dependence and offers an opportunity for sustainable energy policies (Carfora et al., 2022; Vaona, 2016). As a result of the analysis, this variable is expected to have a reducing effect on energy import dependency in both the short and long run.

The trade ratio (% of GDP) is the ratio of a country's total exports and imports to its gross domestic product and is an indicator of economic openness. The effects of more open economies on energy import dependence are known to vary. This indicator plays a critical role in energy policies, especially due to the increasing risks associated with the trade deficit in energy imports (Murshed et al., 2020). In the short run, the trade ratio may have a complex effect on energy import dependency, but in the long run, this effect is expected to stabilize with renewable energy investments.

Carbon intensity is an indicator that measures the contribution of economic activity to carbon emissions. This variable is important for evaluating energy policies in the context of environmental sustainability and energy efficiency. Previous studies have shown that carbon intensity affects energy import dependence indirectly, mainly through dependence on fossil fuels (Acheampong et al., 2021; Ali et al., 2021). Therefore, carbon intensity is projected to increase energy import dependence in the long run.

The CIP score (Competitiveness Industrial Performance) measures a country's competitiveness in the industrial sector. This variable is closely related to energy consumption patterns and energy intensity. Increased competitiveness in the industrial sector can have both positive and negative effects on energy dependence. Increasing investments in energy efficiency and renewable energy sources can turn the impact of the CIP score on energy import dependence into a transformative factor (Dokas et al., 2022). This variable is expected to have a neutral effect in the short run but reduce energy dependence in the long run.

Industrialization intensity and the industrial export quality index are other important indicators that shape energy consumption dynamics and have a direct impact on energy security. More industrialized economies face the risk of external dependence when they cannot meet their energy needs with domestic resources. However, high-quality industrial exports can improve energy efficiency and optimize energy consumption. The impact of these variables can vary depending on industrial policies and the level of renewable energy integration (Shahbaz et al., 2016; Ratha et al., 2019).

Table 1. Descriptive Statistics

	lnEID	CI	CIP	EXQ	lnTRADE	lnRNW	IND
Mean	3.6379	0.6324	0.0547	0.6637	4.7935	3.2561	0.3152
Maximum	4.3700	1.8531	0.0800	0.7700	5.1308	3.7842	0.470
Minimum	0.2062	0.2391	0.0300	0.5400	4.3119	2.3321	0.210
Std. Dev.	0.8254	0.3799	0.0156	0.0532	0.2122	0.3541	0.062
Observations	81	81	81	81	81	81	81

Table 1 presents descriptive statistics of energy import dependence (EID), carbon intensity (CI), industrial competitiveness index (CIP), industrial export quality index (EXQ), trade ratio (TRADE) and renewable energy consumption (RNW). These variables represent the key elements used in the analysis of the study and the table presents the mean, maximum, minimum, standard deviation and number of observations for each variable. In this study, a logarithmic transformation is applied to energy import dependence (EID), trade ratio (TRADE) and renewable energy consumption (RNW) variables. This transformation improves the comparability of the coefficients by reducing the magnitude differences between the variables and alleviates heteroskedasticity problems in the model by limiting the effect of possible outliers.

The distributions of the variables suggest that variables such as energy import dependence (EID) can vary significantly across different countries, which can be explained by the diversity of energy sources and differences in energy policies. Similarly, environmental factors such as carbon intensity (CI) and renewable energy consumption (RNW) also vary depending on countries' economic structures and energy consumption patterns. This highlights the complexity of the relationship between energy import dependence and environmental sustainability.

The industrial competitiveness index (CIP), industrialization intensity index (IND) and the industrial export quality index (EXQ) reflect the structure and international competitiveness of the industrial sector. The low standard deviations of these variables suggest that there may be relatively similar industrial structures across countries. The trade ratio (TRADE) is a critical variable for assessing the impact of economic openness and international trade on energy import dependence. The table reveals that the variables analyzed vary widely and this diversity provides an important basis for understanding the dynamics of energy policies.

3.2. Methodology

The methods used in this study consist of panel data techniques to analyze the factors affecting energy import dependence. In the research process, panel unit root tests were applied to determine the stationarity levels of the variables, cointegration tests were applied to determine the existence of long-run relationships, and Panel ARDL and FMOLS models were applied to examine the short and long run relationships between variables. Each method is explained in detail below.

In order to determine the stationarity levels of the variables, IPS and Breitung tests from panel unit root tests were used. The IPS test (Im, Pesaran and Shin, 2003) is suitable for panel data with a heterogeneous structure when analyzing whether individual time series are stationary. The test tests the individual unit root hypothesis and assumes that some series may be stationary under the alternative hypothesis. The advantage of the IPS test is that it allows for heterogeneity in the panel and different dynamics can be considered for multiple cross-sectional units. The Breitung test (Breitung, 2000) analyzes the joint stationarity properties of the series and assumes that all panel units have the same stationarity property. This test can provide robust results especially for panels with fewer observations. The degrees of stationarity obtained from both tests reveal that the variables should be analyzed by taking their first differences.

However, since the results of the cross-section dependence tests indicated significant interdependencies among panel units, the assumptions of these first-generation unit root tests (IPS and Breitung) may be violated. Specifically, these tests assume cross-sectional independence, which does not hold in the presence of common shocks or unobserved factors that affect all countries simultaneously. To address this issue, we employed the Cross-sectionally Augmented IPS (CIPS) test proposed by Pesaran (2007), which accounts for cross-sectional dependence by incorporating cross-sectional averages of the dependent and independent variables into the testing equation. The CIPS test is particularly well-suited for panels with a small number of cross-sectional units (N) and a relatively long time dimension (T), as is the case in this study. By using the CIPS test, the risk of biased inferences due to neglected cross-sectional dependence is mitigated, providing more reliable evidence on the integration properties of the variables.

Pedroni (1999) and Fisher (Maddala and Wu, 1999) cointegration tests are applied to test the existence of long-run relationships in the panel data set. The Pedroni test is designed for heterogeneous panel data models and analyzes cointegration relationships at the individual and group level. The test uses the following equation:

$$y_{it} = \alpha_i + \delta_i t + \beta_i x_{it} + \varepsilon_{it} \tag{1}$$

where y_{it} is the dependent variable and x_{it} is the independent variable. The Pedroni test reveals the cointegration relationship by evaluating whether the error term is stationary or not. The Fisher test determines the degree of cointegration using Trace and Maximum Eigenvalue statistics. These tests strongly confirmed the existence of a long-run relationship between the variables.

Panel ARDL model (Autoregressive Distributed Lag) was applied to examine the short and long run relationships between the variables. The ARDL approach developed by Pesaran et al. (1999) can analyze both short-run and long-run effects in a manner compatible with cointegration tests. The ARDL model can be expressed as follows:

$$\Delta y_{it} = \alpha_i + \sum_{j=1}^{p} \varphi_{ij}\, \Delta y_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} \Delta x_{i,t-j} + \lambda_i y_{i,t-1} + \delta_i x_{i,t-1} + \epsilon_{it} \tag{2}$$

where Δ is the first difference of the series, y_{it} is the dependent variable and x_{it} is the independent variables. The panel ARDL model analyzes short-run and long-run relationships together with the help of the error correction term (ECM). The ARDL results obtained in this study clearly reveal both short-run and long-run effects of the factors affecting energy import dependence.

Finally, the FMOLS method (Phillips and Hansen, 1990) is applied to test the robustness of the long-run coefficients and to improve the accuracy of cointegration relationships. The FMOLS method aims to estimate the long-run coefficients in the presence of cointegration relationship in a bias-free manner (Pedroni, 2000). The FMOLS method is expressed as follows:

$$\hat{\beta}_{FMOLS} = \left(\sum_{i=1}^{N} X'_{it} X_{it}\right)^{-1} \sum_{i=1}^{N} X'_{it}\,(y_{it} - \hat{\gamma}_{it}) \tag{3}$$

This method provides more reliable estimates by correcting for autocorrelation and heteroskedasticity problems among the series. The FMOLS analysis supported the long-run results obtained from the Panel ARDL model and confirmed the long-run effects of the factors affecting energy import dependence.

As a result, these methodological approaches allow for a detailed analysis of the factors affecting energy import dependence and increase the credibility of the study. The methods used are widely accepted in literature, both theoretically and practically, and have important implications for energy security and sustainable development policies.

4. Empirical Results

The cross-sectional dependence test results in Table 3 indicate that the variables may be correlated with each other and therefore the error terms in the model are not independent. The Breusch-Pagan LM, Pesaran scaled LM, bias-corrected scaled LM and Pesaran CD tests largely confirm the existence of cross-sectional dependence for all variables. This suggests that the variables analyzed in the panel dataset may be influenced by common factors across countries.

The results reveal that variables such as energy import dependence and renewable energy consumption are significantly affected by common influences such as regional or global energy policies, price shocks and economic contexts. Moreover, economic variables such as the trade rate and industrial competitiveness may also exhibit interdependencies arising from international trade and regional economic dynamics.

Table 2. Cross Section Dependency Test

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
lnEID	41.632 (0.000)	15.771 (0.000)	15.714 (0.000)	-1.501 (0.134)
CI	71.713 (0.000)	29.277 (0.000)	29.219 (0.000)	8.642 (0.000)
CIP	61.718 (0.000)	23.971 (0.000)	23.914 (0.000)	7.847 (0.000)
lnTRADE	44.761 (0.000)	17.049 (0.000)	16.991 (0.000)	6.526 (0.000)
IND	31.706 (0.000)	11.719 (0.000)	11.661 (0.001)	5.563 (0.000)
lnRNW	57.952 (0.000)	22.434 (0.000)	22.376 (0.000)	7.612 (0.000)
EXQ	19.955 (0.003)	6.922 (0.000)	6.864 (0.000)	4.376 (0.000)

Given the presence of significant cross-sectional dependence among the variables, as confirmed by Breusch-Pagan LM and related tests, the use of first-generation panel unit root tests such as IPS or Breitung would be inappropriate due to their assumption of cross-sectional independence. To address this limitation, this study employs the Cross-sectionally Augmented IPS (CIPS) test developed by Pesaran (2007), which accounts for common factors and cross-sectional dependence across countries. This approach is particularly suitable for small-N, large-T panels, as in the case of the Baltic states.

As shown in Table 4, the CIPS test results indicate that most variables are non-stationary at level (I(0)) but become stationary after first differencing (I(1)), as the null hypothesis of a unit root is rejected at the 1% significance level for their first differences. Only three variables—CIP, lnRNW, and IND—are found to be stationary at level, suggesting an integration order of I(0). In contrast, variables such as lnEID, CI, lnTRADE, and EXQ are integrated of order one, I(1), and were differenced accordingly in the cointegration analysis. These results validate the use of panel ARDL and FMOLS models, which can accommodate variables of mixed integration orders (I(0) and I(1)) but not I(2).

Table 3. Unit root test results

Variables	**CIPS**			
	I(0)	**p-value**	**I(1)**	**p-value**
lnEID	-1.226	>=0.10	-2.832	<0.01
CI	-1.333	>=0.10	-4.165	<0.01
CIP	-2.764	<0.01		
EXQ	-2.311	<0.10	-3.934	<0.01
lnTRADE	-1.671	>=0.10	-2.947	<0.01
lnRNW	-2.987	<0.01		
IND	-2.409	<0.05	-3.726	<0.01

The results of the panel cointegration tests in Table 4 indicate that there is a long-run relationship between the variables. Pedroini Test results show that all test statistics are significant at both panel and group level. In particular, Panel PP and Group PP test results strongly support the cointegration relationship between the series. The Fisher test evaluated the degree of cointegration based on trace statistics. The results reveal that the cointegration relationship is significant at the first few levels. In particular, significant results at the first two levels indicate that there are significant and consistent long-run relationships between the analyzed variables. The weakening of cointegration relationships at higher levels may indicate that a limited subset of variables contributes to this relationship.

Table 4. Panel Cointegration Test[1]

	Pedroni Test	
	statistic	Prob.
Panel PP	-2.2271	0.0130
Panel ADF	-2.4745	0.0069
Group PP	-3.0188	0.0013
Group ADF	-2.4852	0.0076
	Fisher Test	
	statistic (from trace)	Prob.
None	151.9	0.0000

[1] Slope homogeneity was tested using the $\tilde{\Delta}$ and $\tilde{\Delta}$adj statistics proposed by Pesaran and Yamagata (2008). The results rejected the null hypothesis of slope homogeneity, indicating the presence of heterogeneity across cross-sectional units. Accordingly, Pedroni and Fisher-type cointegration tests, which allow for heterogeneous slope coefficients, were employed to ensure methodological consistency with the panel structure.

At most 1	111.0	0.0000
At most 2	70.16	0.0000
At most 3	34.22	0.0000
At most 4	13.68	0.0334
At most 5	8.626	0.1957
At most 6	9.481	0.1483

These findings suggest the existence of a long-run equilibrium relationship between energy import dependence and independent variables. The results suggest that the analyzed variables move together in the long run and the impact of policies towards energy dependence may emerge over time. Accordingly, considering cointegration relationships in panel data models will increase the accuracy of the analyses and ensure that policy recommendations are based on sound foundations.

Table 5. Panel ARDL Results – Selected Model: ARDL(3, 2, 2, 2, 2, 2, 2)[2]

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run				
CI	2.281475	0.160006	14.25871	0.0007
CIP	26.78807	2.585078	10.36258	0.0012
lnTRADE	-0.770972	0.109553	-7.037450	0.0148
IND	1.673150	0.263778	6.343032	0.0055
lnRNW	0.504375	0.041509	12.15113	0.0264
EXQ	-3.164585	0.259576	-12.19137	0.0106
Short-Run				
ECM	-0.603378	0.317248	-1.901911	0.0679
D(lnEID(-1))	0.056011	0.187277	0.299082	0.7672
D(lnEID(-2))	-0.378239	0.408129	-0.926763	0.3623
D(CI)	-2.934422	0.586117	-5.006546	0.0000
D(CI(-1))	-0.187531	0.599687	-0.312715	0.7569
D(CIP)	4.804960	23.28057	0.206394	0.8380
D(CIP(-1))	-0.277060	11.43715	-0.024225	0.9809
D(lnTRADE)	-0.194051	0.640638	-0.302902	0.7643
D(lnTRADE(-1))	-1.024278	1.372455	-0.746311	0.4619
D(IND)	3.954134	2.837733	1.393413	0.1749
D(IND (-1))	2.043065	1.859734	1.098579	0.2817
D(lnRNW)	-1.375294	0.756028	-1.819106	0.0800
D(lnRNW(-1))	-0.453570	0.184815	-2.454190	0.0209
D(EXQ)	-0.965515	5.122127	-0.188499	0.8519
D(EXQ (-1))	-0.603353	2.585158	-0.233391	0.8172
C	2.943620	1.738571	1.693126	0.1019

The results of the panel ARDL model presented in Table 5 reveal both long-run and short-run dynamics of the variables influencing energy import dependence in the Baltic countries. In this updated

[2] The optimal lag structure for the panel ARDL model was determined using the Akaike Information Criterion (AIC), with the maximum lag length initially set to 3 for all variables. This approach ensures an adequate balance between model complexity and goodness of fit, particularly in panels with a limited time dimension.

specification, log-transformations were applied to selected variables to address scale heterogeneity and to facilitate elasticity-based interpretation.

In the long-run, carbon intensity exhibits a statistically significant and positive effect on energy import dependence. This finding suggests that as the carbon emissions per unit of output increase, so does the reliance on imported energy, reaffirming the critical link between fossil fuel intensity and external energy vulnerability. Similarly, industrial competitiveness, measured by a composite competitiveness index, has a strong and significant positive influence, indicating that as industrial capability expands, so does energy consumption, which in turn increases import dependency—particularly in energy-importing economies with limited domestic resources.

Interestingly, the trade openness ratio, defined as the sum of exports and imports relative to GDP, now shows a statistically significant and negative long-run effect on energy import dependence. This may suggest that greater integration into international markets encourages diversification in energy sourcing or leads to improved efficiency through competitive pressures. Industrialization intensity also maintains a significant positive effect, highlighting that expanding industrial structures in the Baltic states continue to drive higher energy demand, often met through imports.

As expected, renewable energy consumption significantly reduces energy import dependence over the long run. This result supports the hypothesis that investment in local, renewable energy sources contributes meaningfully to energy autonomy and long-term supply security. Lastly, the industrial export quality index also has a statistically significant and negative effect, indicating that as the quality and technological sophistication of exports increase, overall energy efficiency in production improves, thereby reducing the need for imported energy.

In the short-run, the error correction term (ECM) is negative as expected and relatively significant at the 10% level, suggesting a moderate speed of adjustment toward long-run equilibrium. This indicates that approximately 60% of the deviations from the equilibrium level of energy import dependence are corrected within one period, reflecting a meaningful, though not rapid, adjustment mechanism. The presence of a relatively significant ECM confirms the validity of the long-run relationship identified by the model and supports the notion that the system gradually converges toward equilibrium following short-term shocks.

Other variables—including trade openness, industrialization intensity, industrial competitiveness, and export quality—do not show significant short-term impacts, suggesting that their influence manifests more structurally and over longer time horizons.

In conclusion, the updated results strengthen the evidence that energy import dependence in the Baltic states is primarily driven by long-term structural factors such as carbon emissions intensity, industrial development, and energy sourcing strategies. Policies that emphasize renewable energy investment, promote high-quality industrial exports, and improve energy efficiency in industrial sectors are essential for reducing import dependence and achieving long-term energy security.

Table 6. FMOLS Analysis

Variables	Coefficient	Std. Error	t-stat	p-value
CI	2.488147	0.446211	5.576168	0.0001
CIP	53.39790	10.71958	4.981343	0.0001
lnTRADE	-0.671208	0.181923	-3.689516	0.0091
IND	-6.130334	2.085325	-2.939750	0.0045
lnRNW	1.021386	0.471315	2.167099	0.0337
EXQ	-1.941263	0.571381	-1.906631	0.0607
R^2=0.736				
Adj. R^2=0.714				

In order to support the finding that the long-run results obtained in the panel ARDL analysis are more robust and determinant than the short-run dynamics, and to test the consistency of these long-term relationships, the Fully Modified Ordinary Least Squares (FMOLS) method was applied. The FMOLS approach, originally developed by Phillips and Hansen (1990), is specifically designed to provide consistent and unbiased estimates in the presence of cointegration relationships. It also corrects for serial correlation and endogeneity in the regressors, making it particularly suitable for small panels with long time dimensions. Thus, the method was employed to validate and reinforce the long-run findings derived from the panel ARDL model.

According to the FMOLS results reported in Table 6, carbon intensity has a statistically significant and positive effect on energy import dependence. This suggests that an increase in carbon emissions per unit of economic output corresponds to a greater reliance on imported energy, reflecting continued dependence on carbon-intensive energy sources such as fossil fuels. Industrial competitiveness, measured through a composite performance index, also exerts a strong and statistically significant positive effect, implying that as a country's industrial productivity and output expand, the associated energy demand tends to outpace domestic supply, increasing import dependence.

The logarithm of trade openness is found to have a statistically significant and negative effect on energy import dependence. This implies that greater economic openness may facilitate diversification of energy supply sources, access to energy-efficient technologies, and overall reductions in energy vulnerability. This result aligns with the ARDL findings and underscores the potential of trade liberalization to support energy security objectives.

Interestingly, industrialization intensity exhibits a negative and statistically significant effect on energy import dependence. Contrary to earlier expectations, this suggests that deeper industrial development may, in some cases, foster more efficient energy use or increase domestic energy production capacity, thereby reducing reliance on imports. However, this result might also reflect structural adjustments or policy reforms during the observed period in the Baltic countries.

Logarithm of renewable energy consumption also has a statistically significant and positive effect on energy import dependence. While initially counterintuitive, this outcome could reflect transitional dynamics where increases in renewable energy investment do not immediately translate into reduced import levels, particularly if renewable sources are not yet sufficient to meet baseline demand. Moreover, the positive relationship may indicate substitution delays or reliance on imported renewable technologies and fuels (e.g., biomass, solar equipment) in early stages.

Finally, the industrial export quality index has a negative coefficient that is marginally significant at the 10% level. This may suggest that improvements in the quality and technological sophistication of industrial exports can lead to more efficient production processes, thereby indirectly lowering the need for imported energy inputs.

In conclusion, the FMOLS findings largely confirm and complement the long-run results obtained from the panel ARDL analysis, while providing additional nuance. They highlight the complex interplay between industrial dynamics, trade openness, carbon intensity, and renewable energy in shaping the energy import dependency of the Baltic countries. These results underscore the necessity of long-term strategic planning, targeted industrial policy, and careful energy transition management to achieve sustainable reductions in energy import reliance.

Discussion

This study examines the structural and macroeconomic determinants of energy import dependence in Estonia, Latvia, and Lithuania from 1995 to 2021, employing panel ARDL and FMOLS estimation techniques with log-transformed variables for improved consistency. The empirical results confirm a long-run equilibrium relationship between energy import dependence and key explanatory variables, including carbon intensity, trade openness, industrial competitiveness, renewable energy consumption, industrialization intensity, and industrial export quality.

Carbon intensity exhibits a robust and significant positive effect on energy import dependence, underscoring the direct link between fossil fuel-based energy systems and external vulnerability. This relationship is particularly pronounced in Lithuania, where the high carbon intensity is coupled with limited domestic energy production capacity, as also emphasized by Štreimikienė et al. (2016). In contrast, Estonia, while having the lowest energy import dependence among the three, displays relatively higher carbon intensity, highlighting a dual challenge of achieving both energy independence and decarbonization through renewable investment—especially in wind and solar sectors.

Trade openness reveals divergent dynamics: while the panel ARDL model suggests a positive association, FMOLS results indicate a statistically significant negative relationship. These contradictory findings align with the arguments by Vaona (2016) and Murshed et al. (2020), who note that trade can both increase energy import dependence through rising activity, and reduce it by facilitating access to efficient technologies and diversified energy sources. This nuanced role of trade is particularly relevant for Latvia, where openness has facilitated integration with European energy markets, yet seasonal fluctuations in hydropower output and limited storage continue to create import vulnerabilities.

Industrial competitiveness positively influences energy import dependence in both models. This result suggests that industrial expansion, particularly when energy-intensive, places additional stress on domestic energy systems, leading to increased reliance on imports. Lithuania exemplifies this situation, where a strong industrial base correlates with high import dependence. However, as noted by Dokas et al. (2022), industrial competitiveness may also stimulate innovation and efficiency, suggesting a potential long-term mitigating effect.

Renewable energy consumption has divergent effects across models. While panel ARDL results support its expected role in reducing import dependence, FMOLS reveals a positive coefficient. This may indicate a lag in the energy transition process, especially when renewable expansion relies on imported technologies or fails to fully replace conventional sources in the short run. Latvia, a leader in renewable energy utilization—especially hydropower—demonstrates the capacity of domestic renewables to reduce dependency, although its system still suffers from intermittency and underinvestment in storage capacity.

The industrial export quality index shows a marginally significant and negative impact on import dependence. This finding suggests that high-tech, energy-efficient export sectors contribute to lowering external energy needs. However, the effect likely varies across countries depending on innovation intensity and export structure.

Regionally, the Baltic countries have made strategic progress in aligning their energy systems with European Union standards and goals. Initiatives such as the Poland–Lithuania Gas Interconnector (GIPL), and full market integration with continental Europe by 2025, are milestones that not only enhance regional energy security but also reduce geopolitical risk, especially regarding historical dependence on Russian energy. The geopolitical significance of these developments cannot be overstated, as reducing external vulnerability strengthens both national sovereignty and regional stability.

Conclusion

This study offers a comprehensive analysis of the macroeconomic and structural drivers of energy import dependence in the Baltic states over the 1995–2021 period. By employing panel ARDL and FMOLS estimation strategies, the results reveal that carbon intensity, industrial competitiveness, and industrialization intensity are significant positive contributors to energy import dependence, while renewable energy consumption and industrial export quality demonstrate a mitigating effect—though with variations across models.

The relatively significant error correction term supports the presence of a stable long-run relationship, suggesting that deviations in energy import dynamics gradually return to equilibrium over time. The observed negative long-run effect of trade openness in the FMOLS model points to the potential of international integration to reduce import vulnerability.

The findings indicate that reducing energy import dependence in the Baltic states requires an integrated strategy that includes lowering carbon intensity, expanding renewable capacity, improving the technological sophistication of industrial production, and aligning trade policy with energy efficiency goals. Such measures are not only critical for national energy resilience but also for strengthening regional energy integration and long-term sustainability across the Baltic region.

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