



The Impact of Energy Poverty on International Migration: An Econometric Study of Southeastern European Countries

Enerji Yoksulluğunun Uluslararası Göç Üzerindeki Etkisi: Güneydoğu Avrupa Ülkelerine İlişkin Ekonometrik Bir Çalışma

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ARTICLE INFO

Article Type

Research Article

Keywords

Energy Poverty
International Migration
Panel Data
Driscoll-Kraay
Southeastern Europe

Received: Aug, 05, 2025

Accepted: Jan, 09, 2026

ABSTRACT

This research explores the connection between energy poverty and international migration in seven Southeastern European Countries-Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Romania, Serbia, and Türkiye-over the period 2005–2022 using a balanced panel data framework. Indicators of energy poverty are access to electricity and clean cooking fuels, while the net migration rate is used as the dependent variable. To take into account cross-sectional dependence and serial correlation, fixed-effects estimations with Driscoll–Kraay standard errors are used. The findings reveal that facilitating access to clean cooking fuels has a strong impact on migration reduction, which implies that energy poverty alleviation helps to reduce the movement of people driven by deprivation. On the other hand, a higher level of electricity access is associated with an increase in migration, which is interpreted as a migration channel led by development where electrification raises human capital and mobility. The results here emphasize the double function of energy provision in migration changes and call attention to the necessity of combining energy and development policies.

MAKALE BİLGİSİ

Makale Türü

Araştırma Makalesi

Anahtar Kelimeler

Enerji Yoksulluğu
Uluslararası Göç
Panel Veri
Driscoll-Kraay
Güneydoğu Avrupa

Geliş Tarihi : 05 Ağustos 2025

Kabul Tarihi: 09 Ocak 2026

ÖZ

Bu araştırma, dengeli bir panel veri çerçevesi kullanılarak, 2005-2022 döneminde yedi Güneydoğu Avrupa ülkesinde (Arnavutluk, Bosna Hersek, Karadağ, Kuzey Makedonya, Romanya, Sırbistan ve Türkiye) enerji yoksulluğu ile uluslararası göç arasındaki bağlantıyı incelemektedir. Enerji yoksulluğunun göstergeleri elektrik ve temiz pişirme yakıtlarına erişimdir, bağımlı değişken olarak ise net göç oranı kullanılmaktadır. Kesitsel bağımlılık ve seri korelasyonu hesaba katmak için Driscoll–Kraay standart hataları ile sabit etkiler tahminleri kullanılmıştır. Bulgular, temiz pişirme yakıtlarına erişimin kolaylaştırılmasının göçün azalmasında güçlü bir etkiye sahip olduğunu ortaya koymaktadır. Bu da enerji yoksulluğunun azaltılmasının yoksulluktan kaynaklanan insan hareketinin azalmasına yardımcı olduğunu göstermektedir. Öte yandan, daha yüksek düzeyde elektrik erişimi, göçün artmasıyla ilişkilidir. Bu durum, elektrifikasyonun insan sermayesini ve hareketliliği artırdığı, kalkınmanın öncülüğündeki bir göç kanalı olarak yorumlanmaktadır. Sonuçlar, göç değişikliklerinde enerji tedarikinin çift işlevini vurgulamakta ve enerji ve kalkınma politikalarının birleştirilmesinin gerekliliğine dikkat çekmektedir.

1. Introduction

Access to energy is not only a technical necessity for sustaining modern life but should also be considered a basic human right and a fundamental factor of social justice (Bouzarovski & Petrova, 2015: 32). Although progress has been made worldwide, there are still millions of people who lack access to reliable, affordable, and clean energy services. The International Energy Agency (IEA) has estimated that in 2022, about 760 million people worldwide were without access to

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Cite as/Atıf: Şimşek, T. and Yiğit, E. (2026). The Impact of Energy Poverty on International Migration: An Econometric Study of Southeastern European Countries. *International Journal of Economics, Business and Politics*, 10(1), 19-36. <https://doi.org/10.29216/ueip.1759221>



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electricity, and 2.3 billion lacked access to clean cooking fuels (IEA, 2023). This data shows that energy poverty continues to be a problem and that it is a deeply-rooted and multifaceted issue that cannot be separated from the rest of the world. Besides the lack of infrastructure, energy poverty is also associated with income inequality, environmental injustice, social exclusion, and difficulties in achieving Sustainable Development Goals (Sovacool et al., 2019: 5). Having no access to basic energy services deprives people of their potential in areas like health, education, productivity, and social participation.

Similarly, the issue of international migration is also very complicated and is deeply interwoven with economic, political, and environmental factors. Classical migration theories emphasize that factors like income differentials, labor market imbalances, and welfare gaps are the key determinants of migration choices (Todaro, 1969; Lee, 1966). However, recent research shows that even non-income factors, such as access to infrastructure, environmental risks, and overall quality of life, can have a significant impact on migration dynamics (Reuveny, 2007: 660). Therefore, energy poverty being one of the main reasons for people leaving their homes and increasing their tendency to migrate is a very significant concept within this broader framework.

In regions that are characterized mainly by deindustrialization, weak economic structures, and high energy prices, the lack of access to modern energy services not only impedes the trend of internal migration but also that of international one as the standards of living get lower and socio-economic inequalities increase (Bouzarovski & Petrova, 2015; Black et al., 2011; Sovacool et al., 2019). While research that directly links energy poverty to migration is still at an embryonic stage, compelling on-the-ground examples mostly from developing and transition economies are increasingly available and making a strong case for the basic energy deprivation aspect as the one that has considerable weight in the migration decision-making process (Bangake et al., 2025: 2).

In contrast to this scene, the current research is concerned with the correlation between energy poverty and population abroad in seven countries of Southeastern Europe from 2005 to 2022, using a balanced panel data framework. Two of the most significant proxies for energy poverty are access to electricity and access to clean cooking fuels, while the net migration rate is a variable that describes other changes in the system. The main goal of this work is to open up three main ways for the existing literature by documenting the effects of the different dimensions of energy access on migration outcomes. Firstly, the paper treats energy poverty as one of the factors structurally causing people to migrate rather than as a mere developmental problem. Secondly, the paper offers local empirical evidence from the region of Southeastern Europe, which has been almost neglected in the energy-migration studies. Thirdly, it elucidates policy-relevant benefits by emphasizing the necessity of synergizing energy-access-related policies with the broader employment creation and macroeconomic stability strategies for the purpose of lessening the migration pressure. In this manner, the research tries to link energy policy with migration governance, both conceptually and empirically, in a straightforward way.

2. Theoretical Framework

Energy poverty is a situation where those living in a house do not have access to sufficient, reliable, and environmentally friendly energy. Besides that, the insufficient energy consumption is only part of the problem; energy poverty covers various dimensions of deprivation, such as lowered living standards, bad air quality in the house, economic vulnerability, and social exclusion. Thus, energy poverty has become a significant structural problem in less developed and transition economies, which has a direct impact on individuals' choices to stay or move out of their place of residence (Maxim et al., 2017: 248). Hence, the link between energy poverty and migration has been a focus of interest in the social sciences research field.

Conventionally, migration studies have elucidated population movements by economic, social, political, and environmental factors. Nevertheless, energy poverty has scarcely featured as a direct

factor in classical migration theories; it has merely been taken into account indirectly via income, employment, or welfare conditions. New studies, especially in the last ten years, indicate that having access to modern energy services is a separate and significant factor that determines where people choose to move (Zhuo & Jia, 2023: 3). Therefore, understanding the effects of energy poverty on migration necessitates the development of a comprehensive theoretical model that includes various migration paradigms.

According to neoclassical migration theory, a change in wages and the availability of jobs are essentially the factors that make people move to other regions (Todaro & Smith, 2007). According to this model, energy poverty may be seen as an element that lowers the quality of life and deepens the economic disadvantage. Energy costs that are too high for a household, an unstable supply of electricity, and the use of inefficient methods of cooking not only reduce the purchasing power of people but also lower their living standards, thus forcing them to move to areas where energy is more economical and reliable. The migration flows from Southeastern Europe to Western Europe serve as an example of this process, as the better welfare systems, energy assistance programs, and more efficient energy infrastructures in the destination countries become very attractive factors (Mihajlović & Savić, 2024: 5).

The New Economics of Labour Migration (NELM) goes beyond seeing migration simply as a way to increase family income and considers it as a means to reduce risks at the level of the household (Stark & Bloom, 1985). According to this model, energy poverty is a cause of the household's economic vulnerability, which forces it to migrate in order to find new sources of income. In this way, migrants can send money back home to pay for energy, buy energy-efficient appliances, or improve their homes. The data from rural China show that households with income from migration have much lower energy poverty levels (Shi et al., 2023: 5), so it is very likely that the same pattern is happening in Southeastern European countries with a high rate of emigration (Yusufi, 2012: 23).

The push-pull model of migration offers a clearer explanation of how energy poverty is linked to movement. According to this model, energy deprivation is considered a push factor, along with bad housing conditions, lack of public services, and an increase in energy prices. At the same time, reliable infrastructure, social protection, and affordable energy systems are considered pull factors in the areas of arrival (Zhuo & Jia, 2023: 4). The research carried out in Europe shows that differences in energy access lead to migration from energy-poor countries to Western European countries where living conditions are more stable and predictable (Kwiliński et al., 2024: 6).

From a structuralist viewpoint, especially World Systems Theory, migration is considered a result of global inequalities that are deeply rooted in the capitalist world economy (Wallerstein, 1974). The lack of access to capital, technology, and infrastructure in the periphery regions of the world only deepens their underdevelopment, and thus, they are increasing the flow of migrants to the core countries (De Haas, 2010: 238). In this scenario, energy poverty can be seen as a clear example of structural disadvantage that reflects the dimension of inequality that has always existed in infrastructure provision and resource allocation. Measures such as energy market liberalization, privatization, and commercialization of public services have, in many cases, led to the increase of both distributive and procedural injustices, especially in Southern and Eastern Europe (Jenkins et al., 2016: 175; Sovacool & Dworkin, 2015: 436). The Greek austerity crisis is a well-known instance of how market-driven reforms can lead to the return of "*lighting poverty*", which, in turn, emigration gets consolidated as a strategy to survive (Petrova, 2018).

Migration systems as well as social network theories continue to emphasize the influence of the already-established migrant networks in mobility facilitation. This is achieved through the lowering of barriers related to information, costs, and risks (Massey et al., 1993; Chi, 2020). Energy poverty is an intersection with these mechanisms only to the extent that remittances resulting from migrant networks are most of the time used to finance the household energy consumption and to

facilitate the access to modern energy services. In this respect, energy access becomes a way of supporting social networks that determine migration processes (Danchev & Porter, 2021: 73).

The energy justice perspective considers the lack of energy as one of the causes of social injustice due to the following factors: limited access to basic resources, being left out of the decision-making processes, and the unfair distribution of environmental burdens (Jenkins et al., 2016). According to this view, energy deprivation is not only a factor that goes against human well-being but also a factor that escalates migration-related issues, especially in those areas that are highly vulnerable (Sovacool & Dworkin, 2015: 436). Moreover, environmental migration literature agrees with this statement by arguing that the lack of energy infrastructure should be considered one of the main environmental stressors caused by climate change and leads to the degradation of the ecosystem, thus having a distant impact on the choice of migration (Reuveny, 2007).

It is very significant that the connection between energy poverty and migration is not only going one way. On the one hand, energy deprivation can be the main reason for migration. Nevertheless, profound poverty could, in a contrasting, situation, make people local as it severely restricts the financial and social resources necessary for migration - this is a condition that is most often called a poverty trap. As a matter of fact, demographic evidence from China reveals that residents of regions suffering from extreme energy poverty are "less" willing to relocate because they do not have enough capabilities and resources (Zhuo & Jia, 2023: 5).

When you take into account all these hypothetical arguments, they together provide a detailed conceptual framework for the influence of energy deprivation on the international migration phenomenon. In fact, energy deprivation can be a push factor, a representation of structural inequality, and a limitation of freedom of movement all at the same time, depending on the conditions prevailing in the area. Thus, from a rights-based viewpoint, it is a must to provide energy access in an equitable way to all, if not only as a means of raising living standards but also as a measure of reducing the involuntary migration pressures.

Given that the energy-migration nexus is highly dependent on the local context, there is still a need for comparative empirical research to be conducted in order to uncover regional heterogeneity and to be able to inform policy-making effectively (Bangake et al., 2025).

3. Literature Review

The linkage between energy poverty and international migration has become a major research theme in the sectors of development economics, energy policy, and environmental justice over the past few years. Traditional migration theories (Todaro, 1969; Lee, 1966) largely depict migration as dependent on economic factors, for example, income disparities, unemployment, and welfare levels. Newest research, however, still highlight differences in infrastructure and energy supply as key factors that influence migration choices on a structural level.

According to Black et al. (2011), the effects of climate change on the essential sectors of the economy, such as energy, water, and agriculture, may make migration an adaptive strategy. In this case, energy poverty as a structural factor influencing migration decision-making would be one of the environmental issues that the migrants come out of. The study shows that supplying the population with energy can be a policy tool that lessens the migration pressure.

Dinkelman (2011) studies the effect of access to energy such as a rural electrification program in South Africa on migration behavior which is an indirect influence. The instrumental variables (IV) and fixed effects models used in the econometric analysis reveal that electrification results in higher female employment and a larger variety of economic opportunities for the local communities. The research finds that electrification changes employment and also has a significant impact on people's mobility. Some households in rural areas can, therefore, remain and go into other production activities thanks to the new energy infrastructure, while others are likely to move to

urban areas because of the higher income and opportunities. This case shows that access to energy has the potential to influence migration decisions both in the direction of "*staying put*" and "*relocating*".

Salehyan and Hendrix (2014) studied the interrelationships between environmental scarcity, energy access, and political violence using a global panel dataset for the period 1970–2006. Their results show that in low-income, agriculturally dependent countries, it is the availability of water rather than scarcity that is associated with the increase of political violence. These results suggest that environmental factors may be considered as the deep structures that can have an indirect influence on the migration decision.

For example, Bouzarovski and Petrova (2015) think of energy poverty as a problem that is not just technical in nature, but a complex social phenomenon and closely related to the people's exclusion and spatial injustice. They maintain that within this conceptual framework, energy shortage not only decreases a person's living standard but also endangers the human development aspects which social belonging, economic productivity, and participation in education and healthcare systems are made of. Additionally, Sovacool et al. (2019) suggest that energy poverty is to be identified as a hierarchical origin of inequalities that restrict the individuals' abilities of integration into the broader social systems. As a result, energy deprivation becomes one of the crucial reasons behind migration decision-making, as people and families move in search of better living conditions to be able to achieve social and economic inclusion.

Maxim et al. (2017) focus on energy poverty in Southeastern Europe and emphasize the particular features of the region. Their research shows that the reasons for energy poverty are, among other things, a very high percentage of home ownership, absence of central heating systems, and insufficient energy efficiency measures in the residential sector. Moreover, the paper states that these shortages significantly raise the likelihood of social exclusion and poverty, thus becoming one of the factors that cause the migration of individuals as a result of increasing indirect pressure.

Zhuo and Jia (2023) did a study on the correlation between energy poverty and internal migration with China as a case study and highlighted the significance of energy access as part of the global goals for sustainable development. In their research, energy poverty was considered from the point of view of access to electricity and the use of clean fuels. Its influence on internal migration was, however, evaluated with a threshold effects model. The results uncover that energy poverty hampers internal migration in a drastic way; thus, in particular, non-coastal regions experience this effect very intensely.

Wijayarathne et al. (2023) carried out an empirical investigation with a particular focus on Sri Lanka to understand how international remittances affect energy poverty at the household level. By using panel data analysis, their results show that a 10% rise in international remittances causes a very significant drop in energy poverty of the households. Besides that, the research discloses that the impact is brought about by income inequality, thus implying that the flow of remittances is a liberating force for the energy-deprived households.

Shi et al. (2023) studied the effect of internal migration on energy poverty in rural China. For the analysis, an instrumental variable method was employed. Their study findings indicate that such households which are the source of labor migrants have a 13.1% lower chance of experiencing energy poverty, and with each additional migrant, the likelihood goes down by 6.4 percentage points. The effect is quite pronounced in the case of low-income households, particularly those that are headed by males, are poorly educated, and reside in the central and western regions. The increased household income as a result of migration is, therefore, the dominant factor.

Choumert-Nkolo & Le Roux (2024) used panel methods to analyze South African data. They found that rural-to-urban migration reduces energy poverty significantly over time. The main reason for this change is the abandonment of traditional solid fuels in favor of modern energy sources as

migrants become part of the urban environment and follow the trend of better infrastructure and access.

Amer & Kareem (2025) performed a panel data analysis that incorporated fourteen West African countries, namely Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo, The Gambia, and Cape Verde, over the period from 2004 to 2020. To handle the issues of cross-sectional dependence and heterogeneity, the authors used the method of moments quantile regression technique. In their study, they demonstrated that the factors technological advancement, green finance, and income level impact energy poverty to the extent of decreasing it by 17–21 units, 0.15–0.82%, and 0.39–1.47 units, respectively. On the other hand, the authors also pointed out that energy poverty was driven by the share of income from natural resource rents and foreign direct investment inflows, which pushed it up by 0.33–0.48 and 0.12 units, respectively.

Korkmaz and Kurkcuoglu (2025) examined the energy poverty spatial distribution of the vulnerability at the provincial level in Türkiye and highlighted significant differences between the regions. The research, which employed principal component analysis (PCA), concluded that the availability of central heating, internet, and natural gas alleviates the vulnerability. Simultaneously, the features of an aging population, unemployment, big household size, and the presence of migrants were factors that elevated it. The regions of Southeastern Anatolia and the coastal provinces by the Mediterranean appeared to be the most vulnerable areas, while Marmara and Central Anatolia were more stable. The data discussed might be interpreted as evidence that disparities in energy access at the regional level may serve as a driver for the migration of individuals.

Bangake et al. (2025) employed panel data from 102 developing countries spanning the years 2000 to 2022 to study the impact of energy poverty on international migration. Energy deprivation in their study was represented by electrification and the use of clean fuels. The authors, through a variety of robust econometric techniques-Driscoll-Kraay standard errors, Lewbel IV, Kinky Least Squares, and System-GMM-demonstrate that energy deprivation is the reason for the rise in migration inflows, and the effect is statistically significant. The results of the paper remain consistent when different modeling and several robustness checks are conducted. The article implies that the expansion of renewable and decentralized energy supply systems might be a practical policy tool to ease the emigration pressure scenario in developing countries.

4. Data and Methodology

To this end, this study utilizes a balanced panel dataset of seven Southeast European countries (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Romania, Serbia, and Türkiye) spanning the period from 2005 to 2022. They were chosen due to their similar structural energy challenges, as both emitters of migration and participants in the Europe-wide economic and political transformation occurring during the transition.

4.1. Data and Variables Definitions

The dependent variable is the net migration rate (in this context, the net number of migrants per 1,000 people) obtained from the World Bank's World Development Indicators (WDI). To proximate energy poverty, two primary proxy indicators were used in the study, namely;

- Access to electricity (% of population) (AELEC)
- Access to clean fuels and technologies for cooking (% of the population) access to clean fuels and technologies for cooking (ACLEAN)

These two measures represent the infrastructure and health elements of energy deprivation and are well-established in the energy poverty literature.

The Model incorporates a set of control covariates to account for the impact of macroeconomic, infrastructural, demographic, and labor market factors on international migration flows. Inflation, consumer prices (annual %) [INF] represents the annual percentage change in consumer prices and is included to account for macroeconomic instability and changes in the cost of living, both of which affect migration incentives. Fixed telephone subscriptions (per 100 people) [TELSUBS] are the number of fixed-line and mobile telephone subscriptions per one hundred inhabitants, and they serve as a means of measuring infrastructural development and access to basic public services. The Employment-to-population ratio, 15+, total (%) [EMP] is a measure of the labor market's performance and the level of individuals' integration into formal employment, which is a factor that has a direct impact on the decision to move abroad in search of better economic opportunities. Moreover, Population ages 15–64 (% of total population) [POP] has been incorporated as a demographic control because the relative size of the working-age population can have an impact on both the level and the changes of migration flows. Besides, all variables are coming from the World Bank's World Development Indicators (WDI) database, which is a guarantee of consistency, comparability, and uniformity in the measurement process across different countries over time.

4.2. Methodology

In order to understand the connection between energy poverty and international migration caused by Southern Eastern Europe (SEE), we use a dynamic panel data model based on annual data for seven SEE countries-Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Romania, Serbia, and Türkiye-for the years 2005–2022. By taking into account the similarity between these countries in terms of economic transition, energy access divides, and the ongoing trend of emigration, the regional focus increases the internal validity and the relevance of the policy findings.

The empirical approach proceeds in two main steps. To this end, static panel models are estimated by the static Pooled Ordinary Least Squares (POLS), Fixed Effects (FE), and Random Effects (RE) estimators. Then, the Hausman specification test is used to determine the consistency of the RE estimator relative to the FE estimator. The general form of the model specification in the static approach is given by:

$$NETMIG_{it} = \alpha + \beta_1 AELEC_{it} + \beta_2 ACLEAN_{it} + \gamma' X_{it} + \mu_i + \epsilon_{it}$$

where $NETMIG_{it}$ represents the net migration rate for country i in year t , $AELEC$ and $ACLEAN$ denote access to electricity and access to clean fuels and technologies for cooking, respectively, both serving as proxies for energy poverty. X_{it} is a vector of control variables including inflation rate (INF), telephone subscriptions per 100 people (TELSUBS), employment rate (EMP), and population size (POP). μ_i captures time-invariant country-specific effects, and ϵ_{it} is the idiosyncratic error term.

The empirical investigation of the linkage between energy poverty and international migration in the S/SEE region is grounded in the theoretical premise that insufficient access to modern energy services is a significant push factor for migration. Lack of access to electricity or clean cooking fuels can worsen poverty, particularly in rural or less developed areas. This drives individuals to search for improved living conditions in other countries. Furthermore, energy poverty may also interact with broader structural factors, such as inflation, unemployment, and service infrastructure, that indirectly affect migration and migration decisions.

Before presenting the econometric results, we explore descriptive patterns in the data. Summary statistics for the variables analyzed (dependent variable, Net migration, and two Energy poverty indicators: access to Electricity and Clean fuels) and other variables serving as control variables (inflation, Telephone subscriptions, Employment rate, and Population size) are presented in Table 1. These numbers provide the basis for distributing the variables across countries and over time in the sample. Summary statistics for the unadjusted data are reported in Table 1. Variables have been kept in their original units so as to preserve economic interpretability and also make

meaningful comparisons possible across countries and over time. In order to compare coefficient magnitudes in the regression analysis, variables are standardized.

Table 1: Descriptive Statistics and Correlation

Variables	Mean	Std. Dev.	Min	Max	Obs	J-Berra
NETMIG	7864.765	169847.8	-301544	1063140	119	101.41 (0.000)
AELEC	99.53613	0.810705	95.9	100.0	119	63.17 (0.000)
ACLEAN	74.0105	18.41152	40.8	100.0	119	12.03 (0.002)
INF	4.941638	7.5725	-1.5841	72.30884	119	128.46 (0.000)
TELSUBS	22.67992	9.105613	6.27	42.7	119	3.61 (0.164)
POP	67.37702	1.409804	63.56771	69.70595	119	7.46 (0.024)
EMP	43.53132	4.706125	33.871	54.296	119	7.61 (0.022)

	NETMIG	NETMIG	NETMIG	NETMIG	NETMIG	NETMIG	NETMIG
NETMIG	1.0	0.2412	0.1995	0.0096	-0.1329	0.0709	0.102
AELEC	0.2412	1.0	-0.2469	0.0531	-0.063	-0.2971	0.0046
ACLEAN	0.1995	-0.2469	1.0	0.2899	-0.2406	-0.1236	0.6133
INF	0.0096	0.0531	0.2899	1.0	-0.0457	0.0084	0.1477
TELSUBS	-0.1329	-0.063	-0.2406	-0.0457	1.0	-0.2241	-0.3589
POP	0.0709	-0.2971	-0.1236	0.0084	-0.2241	1.0	0.3881
EMP	0.102	0.0046	0.6133	0.1477	-0.3589	0.3881	1.0

Note: The numbers in parentheses indicate the corresponding probability values.

Descriptive statistics for the main variables used in the empirical analysis are presented in Table 1. The average net migration is 7,865 people, but this variable varies widely (standard deviation of 169,847.8) and exhibits extremes ranging from -301,544 to over 1 million. This high degree of variance is symptomatic of the nonhomogeneous structure of migration regimes across the seven SEE country cases from 2005 to 2022. The skewness (4.53) and kurtosis (26.65) statistics further support the existence of substantial positive skewness and fat tails in the distribution, which is suggestive of possible outliers in certain years or countries, potentially reflecting the outbreak of political or economic shocks.

The sample depicts almost universal electrification of the household with an average value of 99.5, the range being from 99.0 to 99.9, and a slight variation (SD = 0.81). This is a consequence of infrastructural development in the region throughout the study period. The access to clean fuels and technologies for cooking is more varied, reaching from 40.8% to 100%, with an average value of 74.0%. This difference indicates that there are still significant disparities in the use of modern energy services, especially between urban and rural populations. The significance of access to such services is not solely based on the provision of electricity.

The average annual inflation rate is around 4.94% but it is characterized by a large standard deviation of 7.57% and a maximum of 72.3%, which reflects the episodes of macroeconomic instability in different countries or years. The average number of telephone subscriptions per 100 inhabitants is roughly 22.7 with the values varying between 6.3 and 42.7, and can be used as a proxy for infrastructural access and possibly reflect rural-urban disparities. The proportion of the working-age population (15–64) is relatively high, approximately 67.4% of the total population with a small variation. The employment-to-population ratio, which indicates access to the labor market, is quite stable, it is around 43.5% on average.

Table 1 below displays the pairwise Pearson correlation coefficients between variables. Net migration is positively related to household access to electricity (0.241) and access to clean fuels (0.200), which suggests that energy access levels may be linked to having a higher ability/inclination to migrate - a view that is in line with the "*development facilitating migration*" paradigm. Although the associations are modest, they provide early evidence that reducing energy poverty could enable, rather than hinder, mobility.

Inflation is generally uncorrelated with net migration (0.010), exhibits a weak positive relationship with access to clean fuels (0.290), and there is weak evidence that cleaner fuel adoption is more common in economies characterized by inflation or those transitioning to a new economy. Telephone subscribers are negatively associated with net migration (-0.133) and access to clean fuels (-0.241), possibly due to infrastructural or demographic biases between countries. Access to clean fuels strongly and positively correlates with employment (0.613), indicating that labor market participation may be associated with more favorable household energy outcomes.

The descriptive statistics and correlation analysis identify the variety and network of socioeconomic and infrastructure factors throughout the region. There are no multicollinearity problems, so we can proceed with the multivariate estimates.

In what follows, we express all continuous predictors in standardized z-score form prior to estimation. This transformation subtracts the mean over the cross-section and divides by the standard deviation for each variable over the panel, making the variables zero-mean and unit-variance scaled. The two primary reasons for standardizing or simplifying are as follows. First, the units of measure for the explanatory variables in our Model are heterogeneous (including percentages, absolute population terms, and inflation rates, among others), making it more challenging to compare the magnitudes of the coefficients. Standardizing the covariates resolves this problem by assuming that all covariates are on the same measurement scale, which provides a more interpretable order of effect sizes of the covariates within and across the models. Second, standardizing provides some check against potential multicollinearity and numeric instability, mainly when using models like fixed effects with clustered standard errors or dynamic panel estimators. Furthermore, this addresses model convergence and helps identify outliers or influential points, a feature that we will surely take advantage of in relatively small panels like the one used here. Thus, with standardized variables, the econometric results are more easily interpretable and robust, and the direction and statistical significance of the association in the underlying relationships are maintained.

Before estimating the empirical Model, it is important to consider the type of panel effects specification to be used in that process: Do we control for the fixed effect of the individual and the time at which he makes the decision, known as a two-way panel specification, or do we consider the fixed effect of the individual only (a one-way panel effect specification). Under a panel data set, one-way fixed effects models capture the unobserved heterogeneity across cross-sectional units (countries) that is fixed over time, while two-way fixed effects models also control for the time-varying unexplained shocks or time trends that impact all units universally.

To formally test the importance of a set of time-fixed effects, we perform a joint significance test (usually an F-test) on the time dummies in a fixed effects regression. If we reject the null, the two-way Model is selected, which means that all time effects are jointly zero. This choice enables the Model to flexibly represent cross-sectional heterogeneity and common time dynamics, which is crucial in macro-panel databases that cover many countries over a relatively long period.

Policy and macroeconomic changes (e.g., the global financial crisis, regional energy reforms, or migration policy reversals) that may have influenced the countries between 2005 and 2022 thus lend theoretical and empirical support for the inclusion of time-varying fixed effects. Therefore, the specification tests are conducted to inform the model selection procedures. Additionally, the VIF

(Variance Inflation Factor) test is a straightforward diagnostic method used to detect multicollinearity among variables in multivariate regression models. It is also useful in panel models to check/reject estimates when using a large number of independent variables. Table 2 shows the assessment of the panel effects structure and VIF test results.

Table 2: The Assessment of the Panel Effects Structure and VIF Test Results

LR Test			
Effects	Chi-Square Statistics (χ^2)	p Value	Result
Unit and/or Time Effect	17.61	0.000	H_0 hypothesis is rejected, there is a unit and/or time effect.
Unit Effect	17.61	0.000	H_0 hypothesis is rejected, unit effect exists.
Time Effect	0.001	0.999	H_0 hypothesis cannot be rejected, there is no time effect.
Variables	VIF	1/VIF	
AELEC	1.32	0.757	
ACLEAN	1.42	0.706	
INF	1.13	0.884	
TELSUBS	1.22	0.819	
POP	1.31	0.764	
MEAN VIF	1.28		

A Likelihood Ratio (LR) test was conducted to determine the appropriate panel specification to assess the joint significance of unit and time effects. The results indicate that the null hypothesis of no unit and/or time effect is strongly rejected ($\chi^2=17.61$, $p<0.01$), suggesting that unobserved heterogeneity across cross-sectional units and/or periods must be accounted for. When disaggregated, the LR test confirms the presence of unit-specific effects ($p = 0.000$), while the time effects are found to be statistically insignificant ($p = 0.999$). Therefore, a one-way fixed effects model that controls for time-invariant country-specific heterogeneity is considered methodologically appropriate.

In addition, to verify the absence of multicollinearity among the explanatory variables, the Variance Inflation Factor (VIF) diagnostics were applied. The results show that all VIF values lie well below the conventional threshold of 10, with the highest being 1.42 and a mean VIF of 1.28. This indicates that multicollinearity is not a concern in the dataset, and the coefficient estimates are unlikely to be distorted by linear dependence among regressors.

Taken together, the results support the use of a one-way fixed effects panel data model for subsequent estimation and confirm the internal consistency of the explanatory variable set.

It is crucial to consider both slope inhomogeneity and panel data econometrics to make reliable inferences and a structural Model. Cross-sectional dependence typically arises through the presence of (unobservable) global shocks or regional interconnections that simultaneously affect multiple members of the cross-section. Failing to account for this may result in biased standard errors and inconsistent estimates. Both assumptions of slope homogeneity across units are equally important and may not hold in practice when countries or regions follow structurally different responses to the explanatory variables. Although the (2008) Pesaran–Yamagata Δ and Δ_{adj} tests are frequently used to examine slope homogeneity, they are appropriate for panel data with many cross-sectional units ($N \rightarrow \infty$). However, considering the time-series nature of our models, i.e., the number of time periods ($T = 18$) being greater than the number of countries ($N = 7$), the Swamy-type slope homogeneity test is more suitable. This framework also enables the identification of heterogeneity in a small-N, large-T setting, allowing us to compare homogeneous to heterogeneous panel estimates more effectively (e.g., pooled OLS versus Mean Group or Driscoll–Kraay strategies). The pre-estimation problem diagnostics, such as these, enhance the empirical basis of the panel

model and make the Model consistent with the structure of the data. Table 3 presents the results of the cross-sectional dependence and panel homogeneity tests.

Table 3: Cross-sectional Dependence and Panel Homogeneity Test Results

Cross-Sectional Dependency Test		
Tests	Statistics	p Value
LM Test	35.73	0.0235
LM adj Test	2.657	0.0079
CD Test	2.691	0.0071
Panel Heterogeneity Test		
	Chi-Square Statistics (χ^2)	p Value
Swamy S	542.68	0.000

The test statistics for cross-correlation and slope heterogeneity are presented in Table 3. All the LM (Breusch-Pagan) statistic, the bias-adjusted LM test (Pesaran et al., 2004), and the CD test of Pesaran (2004) reject the null hypothesis of cross-sectional independence at the 1 percent and 5 percent significance levels (p-values are 0.0071, 0.0079, 0.0235). These results imply substantial cross-sectional dependence among the panel units, meaning that countries in the sample are vulnerable to standard shocks or linked regional dynamics.

Regarding slope homogeneity, we obtain a chi-square statistic of 542.68 and a p-value of 0.000 for Swamy's S test, which refutes the null hypothesis of the same slope coefficients across cross-sectional units. This finding reflects considerable heterogeneity in the structural relationship of the variables of concern among the countries considered.

In light of the substantial cross-sectional dependence prevailing in the panel units, which the LM captures, as well as the adjusted LM and CD results, applying the standard first-generation unit root tests with cross-section independence would be inappropriate and misleading. To overcome this problem, we employ the PANIC (Panel Analysis of Nonstationarity in Idiosyncratic and Common Components) approach suggested by Bai and Ng (2004). The panel unit root test proposed in this paper is a second-generation test that incorporates unobserved common factors, which can be potential sources of correlation among countries. However, no clear options are discussed in the case of a second-generation test. Hence, this test provides a more robust framework for assessing the stationarity properties of the panel and individual series. By separating the portion of the variation common to and specific to the variables, the PANIC test allows a more nuanced investigation of the behavior of unit roots in cases where cross-dependent behavior is likely to impact the processes that the variables in question follow. PANIC is, therefore, methodologically required and indispensable to guarantee the validity of inferences made from the panel data.

The second-generation panel unit root test results, based on the PANIC (Panel Analysis of Nonstationarity in Idiosyncratic and Common Components) approach, which exploits cross-sectional dependencies among panel units, are shown in Table 4. The tests are implemented under two specifications: with and without a constant, and with and without a time trend.

The level form results indicate that all the series appear highly nonstationary, evidenced by very high p-values (almost 1.000) for the constant-only and constant-and-trend models. Precisely, the series net migration, access to electricity (AELEC), access to clean fuels and technologies for cooking (ACLEAN), inflation (INF), telephone subscriptions (TELSUBS), the employment rate (EMP), and population (POP) all do not reject the null hypothesis of a unit root. These results indicate that I(1) level data aggregates across the sample.

Table 4: PANIC Unit Root Test Results

Variables	Constant		Constant and Trend	
	Test Statistics	p Value	Test Statistics	p Value
NETMIG	-12.361	0.999	-14.143	0.999
AELEC	-17.298	0.998	-12.950	0.997
ACLEAN	-5.474	0.999	-11.364	0.999
INF	-4.108	0.999	-14.133	0.999
TELSUBS	-1.095	0.999	-2.309	0.999
EMP	2.904	0.999	-0.303	0.999
POP	-4.165	0.999	-3.978	0.999
Δ NETMIG	-2.207	0.027	-2.645	0.008
Δ AELEC	9.056	0.000	2.078	0.037
Δ ACLEAN	-4.887	0.000	-5.335	0.000
Δ INF	-3.780	0.000	-2.645	0.008
Δ TELSUBS	-2.643	0.008	-2.985	0.000
Δ EMP	-2.617	0.008	-3.806	0.000
Δ POP	-1.989	0.044	-6.076	0.000

However, when the first differences (Δ) are taken, the results differ significantly. All differenced series of the variables reject the null hypothesis of a unit root at the 5% level or stronger. For example, the differenced ACLEAN, INF, and TELSUBS series exhibit strong stationarity, with a p-value close to 0.01. These findings validate that all variables are stationary at the first difference, and thus I(1).

In brief, the results of the PANIC Test align with theoretical considerations, demonstrating that the included variables in the empirical Model are nonstationary in levels but stationary in first differences, despite the existing cross-sectional dependence. This aligns with the use of estimation methods for I(1) variables, for example, using models based on differenced terms or cointegration-based approaches if long-run relationships are assumed to be present.

We subsequently tested all variables for first-order integration and chose the appropriate estimation method for the panel data model. In particular, the most important methodological issue is the choice between fixed effects (FE) and random effects (RE) models. The Hausman test is used to control this by checking whether the individual effects are jointly correlated with the independent variables. If the null hypothesis is rejected, it means that the FE model is preferred by the data as it produces consistent estimates of endogeneity between the unit effects and the explanatory variables. The results of the Hausman specification test are shown in Table 5.

Table 5: Hausman Specification Test Results

Tests	Statistics	p Value	Result
Hausman	36.06	0.000	H_0 rejection indicates that fixed effects are practical.

The Hausman examination has been done to test the proper estimation of the FE and RE models. The obtained test statistic is 36.06, and the corresponding p-value of 0.000 indicates that the null hypothesis that the coefficients differ randomly should be rejected. This finding reveals a significant correlation between the unobserved unit effects and the explanatory variables, and therefore, the fixed effects model is a suitable estimator. Accordingly, the FE estimator is considered the most appropriate for this panel data context, as it delivers consistent and unbiased point estimates. These results thus justify using a within-estimation strategy in further analyses, for which the complete projections are presented in Table 5.

One needs to check if the basic assumptions of the model hold, particularly if the residuals are normally distributed. While normality is not necessary for consistent parameter estimation, it is a relevant issue for asymptotic validity, particularly for small sample inference. As such, a

residual normality test was performed on the fixed effects model to assess the distributional characteristics of the error term. The findings of these normality tests are shown in Table 6.

Table 6: Normal Distribution Test in Fixed Effects Model

Tests	Statistics	p Value	Result
Combined Test Vit	3.94	0.104	H ₀ accepted, normal distribution exists.
Combined Test μi	2.58	0.274	H ₀ accepted, normal distribution exists.

A joint normality test was used to evaluate normality in the residuals of the fixed effects model, separately testing the idiosyncratic error term (Vit) and the individual-specific effects (μi). The test for Vit, which captures the within-unit error term (i.e., time-varying disturbances), yielded a test statistic of 3.94 with a p-value of 0.104. Likewise, the test for μi, which accounts for the unobserved time-invariant heterogeneity over units, yielded a test statistic of 2.58, p = 0.274. In both cases, the null hypothesis of normally distributed residuals is not rejected at the usual significance levels. These findings indicate that the within-dimensional and between-dimensional disturbances in the panel model are approximately normally distributed, thus providing some evidence for the statistical appropriateness of the fixed effects specification.

Another diagnostic used in panel data analysis is to check for heteroskedasticity or non-constant variance of the error term across observations. Standard errors and test statistics rely upon assumptions of homoskedastic residuals, and failure to meet these assumptions can result in inefficient estimates and incorrect inference. A heteroskedasticity test was conducted to assess the robustness of the fixed effects model. This pattern of diagnostic findings is demonstrated in Table 7.

Table 7: Levene, Brown, and Forsythe's Test Results

Heteroskedasticity Test			
	Test Statistics	P Value	Result
W ₀	10.867	0.000	H ₀ is rejected. Heteroskedasticity exists.
W ₅₀	5.974	0.000	H ₀ is rejected. Heteroskedasticity exists.
W ₁₀	9.076	0.000	H ₀ is rejected. Heteroskedasticity exists.

The purpose of a set of tests, applying various weighting schemes (W0, W50, and W10), was to examine heteroskedasticity in the fixed-effects panel data regression model. By all specifications, the null hypothesis of homoskedasticity could be rejected systematically at a 1% level. In particular, the test statistics for W0 (10.867), W50 (5.974), and W10 (9.076) were all p = 0.000, indicating strong evidence of non-constant variance in the error terms. These findings suggest that the data may be subject to heteroskedasticity and that conventional standard errors are potentially inefficient and inconsistent.

Aside from the heteroskedasticity, one of the classic regression assumptions that would likely be violated in the panel data model is serial correlation (autocorrelation) in the error terms. Serial correlation indicates that the residuals are correlated over time within each cross-sectional unit, which can result in downwardly biased standard errors and an overstating of the level of statistical significance. An autocorrelation test was conducted within the fixed effects framework to verify the reliability of inference and the consistency of variance estimates. The results of this autocorrelation test are presented in Table 8.

Table 8: Durbin-Watson and Baltagi-Wu's LBI Test Results

Tests	Statistics	Result
Durbin Watson	0.824	There is autocorrelation
Baltagi Wu LBI	0.936	There is autocorrelation

Serial correlation in the residuals of the fixed effects model was tested using the Durbin-Watson (DW) statistic and the Baltagi-Wu Locally Best Invariant (LBI) test. The DW statistic yielded a value of 0.824, which is well below the critical value of 2, indicating positive first-order autocorrelation in the residuals. The Baltagi-Wu LBI statistic, for its part, was computed to be. This also points to the possibility of autocorrelation embedded in the panel structure. That is, the estimated errors of the coefficients can be downward-biased, leading to overly confident statistical inferences. Hence, strong b-s deduction methods, such as Driscoll-Kraay standard errors and other serial correlation-consistent methods, should be used to reconcile the inconsistency.

Since the standard errors in estimation are symptomatic of heteroskedasticity and serial correlation in the residuals of the fixed effects model, standard estimators that depend on traditional standard errors may yield inefficient information and biased inference. In particular, the rejection of the null hypothesis in the heteroskedasticity tests and the surprisingly low values of the Durbin-Watson and Baltagi-Wu LBI statistics clearly emphasize the failure to fulfill the main classical hypotheses. We use the Driscoll-Kraay standard error estimator to mitigate these problems and facilitate strong inference. This approach addresses heteroskedasticity, autocorrelation, and cross-sectional dependence, producing heteroskedasticity- and autocorrelation-consistent (HAC) standard errors to account for spatial and temporal correlation. The outcome using the Driscoll-Kraay procedure is given in Table 9.

Table 9: Driscoll-Kraay Estimator Results

Variables	Net Migration	
	Model (1)	Model (2)
AELEC	0.152 *** (0.000)	
ACLEAN		-0.515*** (0.003)
INF	-0.383 *** (0.000)	-0.405*** (0.000)
TELSUBS	-0.782 * (0.068)	-0.891** (0.036)
EMP	0.237 ** (0.033)	0.376*** (0.001)
POP	0.262 * (0.055)	0.223 (0.113)
C	0.373 *** (0.000)	0.306*** (0.000)
R²	0.2687	0.2737

Note: The variables were included in the analysis by taking the first degree difference. Values in parentheses indicate the p probability value. ***p <0.01, **p <0.05, *p <0.1.

Table 9 presents the results of the fixed effects estimations, which are robust to heteroskedasticity, serial correlation, and cross-sectional dependence, using Driscoll-Kraay standard errors. The dependent variable is net migration, and the samples comprise seven Southeast European countries between 2005 and 2022. We present two model specifications to capture the separate effects of two features of energy poverty (AELEC and ACLEAN) on migration dynamics.

In Model (1) with AELEC as the sole key independent variable, the coefficient of AELEC is positive and highly statistically significant at the 1% level ($\beta = 0.152$, $p = 0.000$), implying that higher access to electricity is positively linked to higher net migration inflows. This will likely indicate better living conditions and infrastructure that make a country more appealing to migrants or may reflect a proxy for general developmental levels. Control variables are also highly significant: inflation (Inf) has a strong negative impact on net migration ($\beta = -0.383$, $p = 0.000$), indicating that macroeconomic instability reduces migration inflows or paradoxically stimulates outflows. Sales

and use of telephones (TELSUBS) are also negatively associated with net migration ($\beta = -0.782$, $p = 0.068$), albeit at the 10% level, which may indicate that investment in digital infrastructure development does not necessarily translate to labor opportunities or perhaps a proxy for structural changes in access to public services. Moreover, employment (Emp) ($\beta = 0.237$, $p = 0.033$) and working-age population share (Pop) ($\beta = 0.262$, $p = 0.055$) exhibit a positive effect on net migration, indicating that high labor market and demographic structure foster migration attractiveness.

The difference from Model (2) is that A clean is replaced by A elec as the key independent variable, and a significant negative relationship is found between clean fuel and net migration ($\beta = -0.515$, $p = 0.003$). Such a negative association might indicate that reduced migration results from improvements in clean cooking technologies, which lead to better household well-being while alleviating push factors linked to domestic health and environmental externalities. The other variables remain unchanged in terms of the sign of the effect and the significance of the coefficient, indicating that Inf and TELSUBS continue to have a negative and significant impact, and Emp has a negative and significant effect ($\beta = 0.376$, $p < 0.001$). However, Pop is no longer statistically significant ($p = 0.113$), suggesting a weakening of its explanatory power in the presence of ACLEAN.

The overall fit of the models is only moderate (R^2 values of 0.2687 and 0.2737, respectively), indicating that while the models account for some important structural determinants of emigration, other country-specific factors may not be considered here.

These outcomes highlight how differently the individual aspects of local energy supply influence migration outflows in Southeast Europe. For instance, electrification is linked to net migration inflows whereas access to clean cooking technologies is not, thereby implying that it helps to reduce migration pressures. The contrast between the two underlines the importance of breaking down energy poverty into several facets when analyzing its effects on the development sector.

5. Conclusion

This paper investigates the connection between energy poverty and global migration through panel data of seven countries in the Southeast and Eastern Europe: Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Romania, Serbia, and Türkiye. The dataset covers the period from 2005 to 2022. By employing a fixed-effects model (which accounts for characteristics that do not change over time) and making a correction for Driscoll-Kraay standard errors, the study offers a detailed insight into the interplay between various aspects of energy access and migration processes in a region that is a post-socialist transformation, infrastructural heterogeneity, and labor mobility.

The outcome indicates that access to electricity (AELEC) has a positive relationship with net migration, whereas access to clean fuels and technologies for cooking (ACLEAN) has a negative relationship. This implies that there is a structural difference in the energy poverty aspects which operate in different ways: while electrification in general can be a replacement for development, can attract migrants, and can relieve push effects, better access to clean cooking solutions seems to increase local welfare and decrease migration pressures. It is very important to take these findings also into account when discussing developmental pathways and the socioeconomic status of the countries under consideration.

Recent progress concerning access to electricity in Albania – where rural energy poverty endured deep into the 2010s – may have increased local mobility and reversed the direction of return migration from Western Europe. However, biomass fuel use for cooking remains prevalent in mountainous and rural areas, and gains in access to clean cooking may have reduced health and time burdens, possibly mitigating the need for external migration.

Bosnia and Herzegovina is a more mixed picture. Even with substantial top-down financing of energy infrastructure, there are still huge variations between bodies and municipalities. In the

present study, increased access to clean fuel (often through off-grid LPG supply solutions) has also had an area-specific effect on reducing emigration, particularly within semi-rural communities with the most severe war-induced displacement history.

In Montenegro, the pattern is somewhat related to more general macroeconomic indicators, such as employment and inflation, although electrification rates have been high since the early 2000s. However, access to cooking energy appears to have improved, particularly in underserved Roma and minority localities, which might have helped reduce outward pressures from these excluded groups.

Historically marked by its reliance on energy imports and regular network interruptions, North Macedonia has gradually improved access to electricity and clean cooking, particularly in rural areas. These results imply that, even if emigration motives are reinforced by development, it can also act as a stabilizing force against migration.

The special case of Romania. As the only EU country in the sample, Romania stands out. Even with EU investment in rural energy retrofits, regional differences persist – particularly in northeastern counties. In this case, increased accessibility to cleaner sources of fuel – for example, natural gas and modern wood-pellet stoves – has improved well-being, which is in line with the negative impact of migration effects seen in the Model. However, the positive interaction between electricity access and net migration suggests that Romania, as a transit country and a destination country within the larger regional migration system, is likely a key factor behind the positive relationship.

With shrinking demographics and a continuing labor outflow, Serbia has made significant investments in modernizing its grid and promoting energy conservation. Such initiatives are in fact a major factor behind migration inflows, which is a consequence of electrification, and this pattern is especially visible in Belgrade and the corridor cities. Nevertheless, the minimal use of clean cooking methods in the rural areas of Serbia is still a source of emigration from these parts.

Moreover, the last subheading features Türkiye, the most important and quite a different case. Türkiye represents the intersection of the two patterns revealed by the study, being a country with almost universal electricity access and notable advancement in clean energy utilization, especially in urban and peri-urban households. Based on the mixed migration dynamics in Türkiye, a situation where it is simultaneously a source, a transit, and a destination country, it is further indicated that energy development plays two roles in migration: as a jolt to attract migrants and as one to hinder the lessening of internal migration in the more developed areas like Central Anatolia and the Marmara belt.

Their analysis makes it clear that the issue of energy poverty needs to be broken down into different dimensions, with the separate impacts of the problem for different countries and regions at the sub-national level taken into account. A policy instrument aimed at relieving migration pressure in the region should, apart from the need to raise the energy infrastructure to a higher level, also include the provision of unprejudiced access to the clean household energy solutions, particularly for the groups at risk. Second, macroeconomic stability, job creation, and demographic sustainability are complementary.

In sum, while energy access cannot account for all differences in migration regimes, it is a structurally embedded factor that mediates the influence of institutional, economic, and demographic characteristics. Adding other drivers into such work, such as spatial heterogeneity, gender-specific migration motivations, or climate-change-related energy shocks, especially in this geopolitically fragile and developmentally disparate region, would further enrich our understanding.

Support and Acknowledgement Statement: No external support was used in the preparation of this research.

Researcher's Contribution Rate Statement: The authors' contribution share in the study is equal.

Conflict of Interest Statement: As the authors of this study, we declare no conflict of interest.

Research and Publication Ethics Statement: All rules specified in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed at every stage of this research. None of the actions specified under the heading "Actions Contrary to Scientific Research and Publication Ethics" of the directive were carried out. During the writing process of this study, citations were made in accordance with ethical rules, and a bibliography was created. The study was subject to plagiarism control.

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