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How does militarization affect the ecological footprint? The case of the Eastern Partnership countries and Russia

Sinem Eyuboglu ✉[1], **A. Oznur Umit** [2]
[1]Tarsus University, Turkey, [2]Ondokuz Mayıs University, Turkey

Abstract: This study examines the effects of militarization on environmental degradation in the Eastern Partnership countries (Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine) and Russia, which are located in Eastern Europe and Eurasia and are not members of the European Union, over the period 1996-2022. The main research question of the study is whether there are long-run and short-run effects of the increase in military expenditures on the ecological footprint in these countries. Within the scope of panel data analysis, Westerlund (2008) cointegration test shows that there is a long-run relationship between militarization and ecological footprint. Long-run coefficient estimates suggest that increasing militarization increases environmental degradation. The findings are consistent with the Treadmill of Destruction theory, which argues that military activities lead to ecological destruction. On the other hand, Dumitrescu and Hurlin (2012) panel causality test shows that there is no significant causal relationship between militarization and ecological footprint in the short-run. As a policy recommendation, it is suggested to redirect military energy consumption to cleaner sources, such as nuclear and renewable energy and to integrate the environmental dimension into defence planning. Moreover, allocating a certain portion of defence budgets to environmental research and development activities may contribute to reducing the ecological impacts of military activities.

Keywords: militarization, ecological footprint, Westerlund panel cointegration test, Dumitrescu-Hurlin panel causality test

Introduction

Militarization (ME) activities gained momentum after World War II, and the arms race between states intensified on a global scale. During this period, military technologies became more sophisticated, infrastructure development accelerated, and armies shifted toward a capital-intensive production structure. Advanced weapon systems and advanced vehicles increased energy consumption (EC) and, in particular, dependence on fossil fuels, which, in turn, expanded the scale of environmental damage (Kentor et al., 2012; Clark & Jorgenson, 2012). In addition, on the grounds of national security, quite often, environmental protection laws do

✉ Professor, Faculty of Applied Sciences, Department of Customs Management, Tarsus University, Mersin, Turkey; e-mail: sinemeyuboglu@tarsus.edu.tr.

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not apply to military production facilities; consequently, such facilities have turned into some of the planet's most ecologically devastated regions. Furthermore, the military production process necessitates the extraction and processing of extremely hazardous materials. Such conditions can lead to profound impacts on human health and surrounding ecosystems (Gould, 2007, p. 3). In this context, ME activities are among the most significant global issues threatening environmental sustainability, as they significantly increase greenhouse gas emissions.

Since the beginning of the 21st century, the internal and external threats that states face have further accelerated the arms race. The September 11, 2001 terrorist attacks, ongoing conflicts in the Middle East, the 2010 Arab Spring, and intensifying global trade wars between China and the United States (US), China and Japan, and the US and Russia have fuelled the arms race. The Russia-Ukraine war that began in 2022 and the Israel-Palestine conflict that reignited in 2023 have increased geopolitical risks, strengthening countries' ME and security-focused policies (Barış & Barış, 2024).

According to 2024 data from the Stockholm International Peace Research Institute (SIPRI), global ME increased by 37% compared to 2015, reaching 2.718 trillion US dollars. Examining the regional distribution reveals that the US had the highest ME in 2024. However, the highest increase during the 2015–2024 period was in Europe, i.e., 83%.

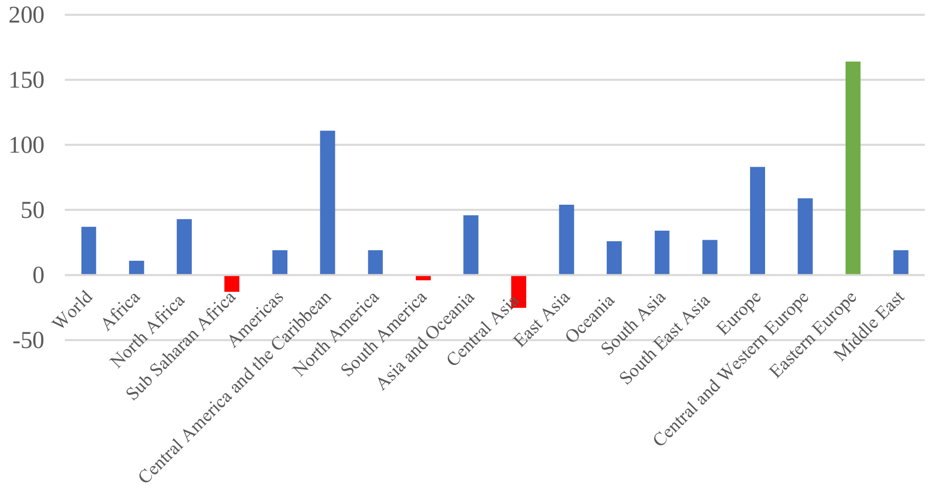
Particularly, according to SIPRI's regional classification, the 164% increase observed in Eastern Europe[1], comprising the six countries covered by the European Union (EU)'s Eastern Partnership[2] initiative (Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine) and the Russian Federation, is noteworthy. This increase is considered to be closely related to the military expenditures and increased security obligations brought about by the Russia–Ukraine war (see Figure 1).

The Russia-Ukraine war has profoundly affected not only military balances but also Europe's energy policies and environmental goals. Restrictions on natural gas supplies resulting from sanctions imposed on Russia have threatened energy security across Europe, leading to a short-run resurgence in coal-based energy production, particularly in some EU member states, such as Poland and Bulgaria.

[1] Unlike the United Nations' classification, which defines Eastern Europe as a broad and heterogeneous geographical area comprising 23 countries, SIPRI adopts a narrower and more homogeneous regional classification based on security considerations and military expenditure; accordingly, six former Soviet states and Russia, which share common historical and geopolitical characteristics, are treated within the same regional category.

[2] The Eastern Partnership is a cooperation initiative launched by the EU in 2009 and carried out with six former Soviet countries (Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine). The Eastern Partnership is a multidimensional regional cooperation framework that aims to promote political rapprochement, economic integration, and sustainable development between the EU and partner countries (European Commission, 2025).

Figure 1. Region and subregion change in military spending (%)[3], 2015-2024



Source: SIPRI (2025b), Trends in world military expenditure

These developments have created a scenario that conflicts with the European Green Deal announced by the EU in 2019, which aims for climate neutrality by 2050 and a 55% reduction in emissions by 2030. This energy shock has also increased the strategic importance of the EU's energy relations with countries within the scope of the Eastern Partnership; diversifying energy supply, renewable energy investments, and strengthening cross-border energy infrastructure have become priority policy areas in this context. In this regard, the European Commission launched the REPowerEU Plan on May 18, 2022, aiming to reduce dependence on fossil fuels and accelerate the green energy transition process. While the REPowerEU Plan directly covers EU member states, its objectives to diversify energy supply and strengthen energy security indirectly affect Eastern Partnership countries through strategic energy cooperation developed with these countries (European Commission, 2022).

Within this framework, it is essential to examine the Russia–Ukraine war not only through its humanitarian dimension but also through its ecological consequences, by adopting a holistic perspective that accounts for both direct and indirect effects in the context of the Eastern Partnership countries and Russia. The humanitarian dimension of the war is reflected in forced migration, displacement, loss of life, and disruptions in access to basic services; these dynamics interact with

[3] The figure presented in the study is constructed based on SIPRI's regional classification. Since the military expenditure data used in the analysis are obtained from the SIPRI database, maintaining consistency between the regional definition and the data source enhances measurement reliability and prevents potential classification inconsistencies. Accordingly, the figure is intended not to compare geographical sizes but to clearly illustrate the regional framework adopted in the analysis.

environmental processes by intensifying pressure on natural resources in host regions and by contributing to pollution and environmental degradation resulting from the breakdown of critical infrastructure, particularly water and sanitation systems (Hryhorczuk et al., 2024, p. 2). Direct ecological impacts include substantial damage to regional biodiversity and ecosystem integrity arising from increased fossil fuel consumption associated with military activities, forest fires, infrastructure destruction, and the deterioration of soil and water quality. Notably, the dissemination of heavy metals and explosive residues into soil and water systems during the conflict has further undermined ecosystem functioning (Solokha et al., 2024, p. 1). Indirect effects encompass pressures on environmental sustainability stemming from war-induced energy supply shocks and the policy responses to these shocks. In this context, rising military expenditures through energy-intensive defense industry operations, military infrastructure investments, and increased reliance on fossil fuels have contributed to the further intensification of environmental degradation (Hunder, 2024). Rising security tensions in the Eastern Partnership countries and Russia have contributed to increased militarization, which in turn poses additional threats to environmental sustainability. Despite these multiple impact pathways, the Eastern Partnership countries' long-run efforts toward a transition to sustainable energy continue in alignment with the EU's REPowerEU Plan. Accordingly, analysing the environmental implications of rising ME in the specific context of the Eastern Partnership countries and Russia is of considerable importance for both academic research and policy-making.

The existing literature indicates that studies examining the environmental impacts of ME have increased in recent years (see Section 2 for a detailed review). Although the literature contains relevant studies that analyse the impact of ME on environmental degradation using different methods for different countries/country groups, it was found that there are no studies investigating the environmental degradation caused by the Russia-Ukraine war, specifically in the Eastern Partnership countries and Russia. To address this gap in the existing literature, by using panel data methods, this study seeks to examine the impact of ME on environmental degradation in the Eastern Partnership countries (Armenia, Azerbaijan, Belarus, Georgia, Moldova, Russia, Ukraine) and Russia, *which are located in Eastern Europe and Eurasia and are not members of the EU*.

For this study, the ecological footprint (EF), one of the most important indicators of environmental degradation, was taken as the dependent variable, and the ratio of military expenditure to gross domestic product (military burden), as an indicator of ME, was taken as the independent variable. In this context, the main research question of the study is: how and to what extent does militarization in the Eastern Partnership countries and Russia affect the ecological footprint (EF)? Within the framework of this research question, the evolution of the EF and military expenditure ME in the region under study over the analysis period (1999–2022) is presented in Figure 2 and Figure 3.

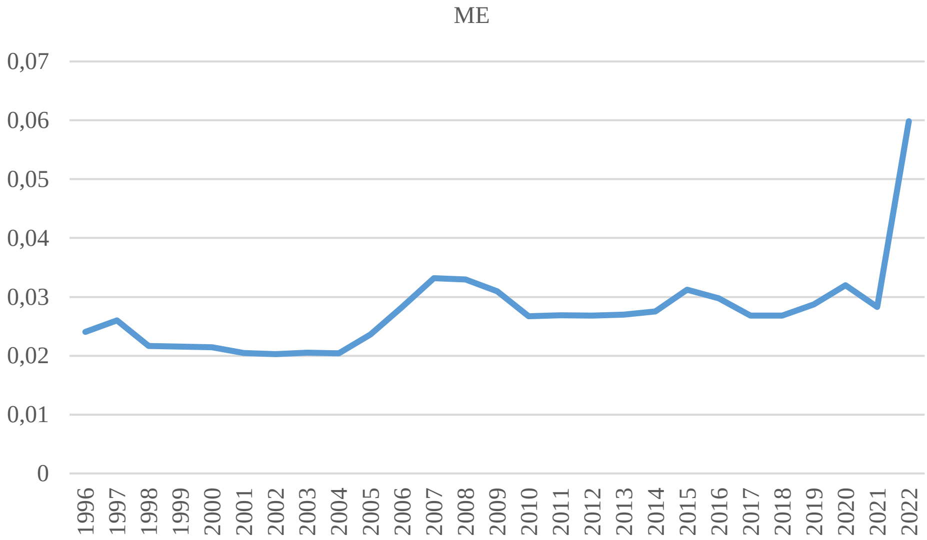
Figures 2 and 3 show that in the early years of the sample period, both ME and EF followed a relatively moderate and stable course in the Eastern European Partnership and Russia[4]. This reflects the post-Cold War environment characterized by reduced security tensions and gradual economic restructuring. However, in the mid-2000s and especially after 2014, the ME started to show more pronounced fluctuations, with increased geopolitical uncertainty in the region. In the same period, EF also showed an upward trend again, suggesting that security-related dynamics, such as the increase in fossil fuel consumption and military expenditures and the strengthening of defense priorities have an increasing impact on environmental outcomes. In 2022, ME increased sharply due to the Russian-Ukrainian war, while EF declined. This may indicate that the environmental effects of increased militarization may not occur simultaneously. On the other hand, the decline in EF can be partially explained by the economic contraction caused by the war, temporary cuts in energy consumption due to the energy crisis, and the indirect effects of the EU's energy transition efforts in line with the REPowerEU Plan on the Eastern European Partnership countries. In this context, although these data do not imply causality between the two variables, they emphasize the importance of econometrically examining militarization and environmental degradation for the Eastern European Partnership and Russia.

In addition, factors that may affect EF, such as economic growth (GDP), trade openness (TO), urbanization rate (UP), and energy consumption (EC), are added to the model as control variables. To this end, Westerlund's (2008) cointegration test is utilized to investigate the trade-off between these variables. Subsequently, the long-run coefficients are obtained with the Augmented Mean Group (AMG) estimator. The short-run dynamics among the variables are analysed by using the Dumitrescu-Hurlin (2012) causality test. The findings provide several recommendations for policymakers in the Eastern Partnership countries and the Russian region who want to mitigate the negative effects of ME on the environment. Thus, the study not only fills the gap in the literature but also contributes to policies to reduce the impacts of ME in terms of environmental sustainability in the Eastern Partnership countries and Russia. These aspects of the study reveal its originality and contribute to the related literature.

The structure of the study is as follows. Section 2 summarizes the studies in the literature. The next section provides the data set and methodology. Section 4 denotes the empirical findings, and the final section provides the conclusions and policy recommendations.

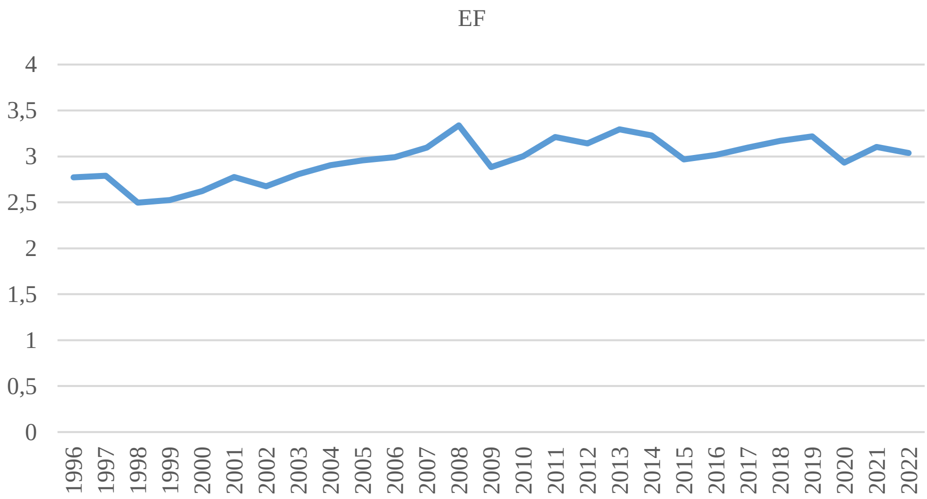
[4] Figures illustrating environmental degradation and militarization expenditures at the country level for the selected countries are presented in Annex 1.

Figure 2. Military expenditure as a share of GDP in Eastern Partnership countries and Russia (1996–2022, %)



Source: authors' representation based SIPRI military expenditure database (2025a)

Figure 3. Trends in the ecological footprint in Eastern Partnership countries and Russia (1996–2022)



Source: Global Footprint Network & York University (2025)

1. Theoretical and empirical studies in the literature

The effects of ME on the environment were first addressed by environmental sociologists; in this context, the theoretical basis for these effects was established by Hooks and Smith's (2005) "Treadmill of Destruction" theory. The theory is based on four fundamental assumptions regarding the relationship between militarization and environmental outcomes. First, increases in ME and armed conflicts disrupt ecological balance and threaten the sustainable use of natural resources. Second, armed forces are among the largest consumers of fossil fuels worldwide, which does not only lead to higher carbon emissions but also to generation of toxic waste. Third, environmental degradation is not confined to periods of active conflict; even in times of peace, activities related to the maintenance and expansion of military infrastructure exert negative pressures on the environment. Finally, military decisions such as the use of nuclear weapons or drone strikes cannot be evaluated solely in terms of economic profitability, as the environmental degradation they cause is more apparent when assessed in the context of national security considerations and geopolitical power balances.

The Treadmill of Destruction theory has been further developed and expanded both theoretically and empirically by various environmental sociologists in the following years (Jorgenson, 2005; Jorgenson & Clark, 2009; Jorgenson et al., 2010; Clark & Jorgenson, 2012; Bradford & Stoner, 2014; Givens, 2014; Smith et al., 2014; Bradford & Stoner, 2017). Among the empirical studies in this field, Jorgenson and Clark (2009) applied a random effects (RE) model using panel data from 53 developed and developing countries for the years 1975-2000. The study showed a significant positive nexus between per capita EF and military spending per soldier. In a subsequent study, Jorgenson et al. (2010) analysed panel data from 72 countries from 1970 to 2000 utilizing a fixed effects (FE) model. The results indicated that both the ME per soldier and the share of military personnel in the total population had significant impacts on total and per capita carbon dioxide (CO2) emissions as well as the EF. Bradford and Stoner (2014) tested the influence of ME on biological capacity utilizing data from 142 countries from 1961 to 2007, employing an FE model and the Prais-Winsten regression method. The study's findings revealed that modern warfare has a negative impact on the biocapacity of low- and middle-income countries compared to high-income countries. Givens (2014) analysed data from 194 countries between 1997 and 2012 using survival analysis techniques and the Cox proportional hazards model. Jorgenson and Clark (2016) tested data from 81 countries from 1990 to 2010 using the panel corrected standard errors (PCSE) method. The analysis results showed that the influence of ME on emissions is more pronounced in developed OECD countries than in developing non-OECD countries. Bradford and Stoner (2017) used panel and cross-sectional regression methods with data from 62 countries during the period 1975-2014. The results of the median-

median (MM) regression analysis conducted on cross-sectional data showed a clear relationship between ME and carbon emissions.

In recent years, there has been an increase in studies investigating the linkages between ME and environmental degradation in economic literature. In most of these studies, which use econometric analyses based on data from different countries and periods, the results indicate that ME is harmful to the environment. Among these studies, Bildirici (2017a) utilised panel Johansen cointegration tests, panel causality tests, and panel autoregressive distributed lag (ARDL) methods with data from G7 countries during the period 1985-2015. The outcomes revealed a bidirectional causality between ME and GDP, EC and GDP, and EC and ME. Additionally, the analysis results showed a unidirectional causal relationship from militarization to CO2, from GDP to CO2, and from EC to CO2. Using data from the US for the period 1960-2013, Bildirici (2017b) employed the ARDL, FMOLS, DOLS, Toda-Yamamoto MWALD, and Rao's F test methods. The Toda-Yamamoto causality test results showed a one-way causality relationship from CO2 to ME, while the Rao's F test results revealed a two-way causality between the two variables. Bildirici (2017c) used ARDL, DOLS, FMOLS, and Rao's F test methods with US data from 1984 to 2015. The analysis results revealed a two-way causality between biofuel consumption and GDP, between GDP and ME, between ME and biofuel consumption, and between biofuel consumption and CO2. Afia and Harbi (2018) used multivariate cointegration methods with data from 120 countries covering the years 1980-2015, and denoted that ME has an impact on CO2.

Noubissi Domguia and Poumie (2019) used data from 54 African countries for the period 1980-2016 and applied the generalized method of moments (GMM) in the system and structural vector autoregression (SVAR) methods. The findings indicate that ME has a significant and positive influence on CO2, nitrous oxide, and methane. Zandi et al. (2019) used FMOLS and DOLS methods with data from 1995 to 2017 for six ASEAN countries and found that ME has a statistically significant and positive effect on CO2. Ahmed et al. (2020) employed cointegration tests and bootstrap causality test methods with data from Pakistan covering the period 1971-2016 and found that ME increases the EF. Gokmenoglu et al. (2021) used FMOLS estimation and the Toda Yamamoto causality test method with data from Turkey between 1960 and 2014. The FMOLS method outcomes denoted that ME increases the EF and CO2. The causality test results also revealed a one-way causality from ME to EF and CO2. Applying the common correlated effects mean group estimator (CCEMG), dynamic CCEMG, and cross-sectional ARDL (CS-ARDL) method with the data of 10 countries with the highest military expenditures for the period 1993-2010, Isiksal (2021) obtained results that ME increases CO2. Qayyum et al. (2021) applied the Westerlund panel cointegration test, the ARDL method, and the Granger causality test to data from South Asian countries covering the period 1984-2019 and concluded that ME has a positive influence on the EF. Using data from 47 countries with high military expenditures for the period 2000-2015 and the two-stage GMM method, Tarczyński et al. (2023) found that per capita military expenditures increase per capita CO2.

In their study, Çolak et al. (2023) used panel ARDL and panel nonlinear ARDL methods for 15 NATO countries based on data from 1965 to 2018. While the panel ARDL test results showed no significant effect of defense expenditures on CO2, the panel NARDL results indicated a significant positive effect. Eregha et al. (2022) applied the bootstrap causality and the cointegration tests to data from Nigeria for the period 1961-2018 and obtained results indicating that ME increases the EF. Additionally, the study concluded that there is a one-way causal relationship from ME to the EF. Asongu and Ndour (2023) applied the GMM method to data from 40 Sub-Saharan African countries between 2010 and 2020 and found that per capita military spending increases per capita CO2 in non-interactive regression results. In the interactive regression results, they found that improved governance contributes to reducing CO2. Chang et al. (2023) used the CS-ARDL method with data from 15 countries participating in the Regional Comprehensive Economic Partnership (RCEP) agreement for the period 1990-2018. The analysis results showed that GDP and ME had a positive effect on the EF. Saba (2023) used the novel dynamic ARDL simulations method with data from South African countries for the period 1960-2019 and reached the conclusion that ME increases CO2. Zhu et al. (2023) used the CS-ARDL method with data from N-11 countries for the period 1990-2022 and found that GDP and ME increase the EF.

Azam et al. (2025) used data from 142 countries in the Belt and Road Initiative for the period 2000-2015, applying the STRIPAT model and a two-stage GMM method. The analysis results showed that, when other variables in the model were controlled for, both per capita military spending and the ratio of military spending to GDP increased CO2. Muhammad et al. (2024) used ARDL and Gregory-Hansen cointegration test methods with data from Pakistan between 1971 and 2014 and found that military spending and GDP increase CO2. Uddin et al. (2024) applied the Westerlund co-integration test, panel ARDL, and GMM estimation methods using data from G-20 countries for the period 1980-2019. The results showed that ME, EC, and communication technology increase CO2.

A few studies in the literature have found that ME can have positive effects on the environment. In one such study, Ullah et al. (2021) used a NARDL model with data from Pakistan and India for the period 1985-2018. The findings revealed that ME reduced CO2 in both countries during the study period. Ben Youssef (2023) used ARDL and error correction model (ECM) methods with data from the US between 1980 and 2016 and found that defence spending reduced CO2. The author noted that this situation stems from at least two channels. First, military spending increases renewable energy consumption, leading to a reduction in pollution. Second, the military sector in the US uses fossil energy more efficiently than most other economic sectors. In addition to this finding, the study determined that renewable energy consumption reduces CO2 and that GDP increases. Using data from the US for the period 1970-2018, Cutcu et al. (2024) employed the Maki cointegration test and time-varying causality test methods to obtain results indicating that military spending, exports, and agricultural land reduce the EF. Konuk et al. (2024) applied the Westerlund ECM cointegration test, FMOLS, and DOLS methods to data covering the years 1971-2019 for G7 countries. The findings revealed that ME reduces CO2.

On the other hand, some studies have reached unclear conclusions regarding the effects of ME on environmental degradation. In this context, Solarin et al. (2018) used time series techniques (cointegration test, ARDL, FMOLS, DOLS, etc.) that allow for two structural breaks with US data from 1960 to 2015 and took CO2 and EF as indicators of air pollution. The results of the study showed that military spending had both positive and negative effects on CO2 while reducing the EF. According to the authors, this positive relationship stems from the military's intensive use of fossil fuels and the negative effect of the use of innovative technologies that reduce fossil fuel consumption as a result of research and development (R&D) activities in this sector. Wang et al. (2021) used the Fourier ARDL method with data from 11 net oil-importing countries among the G-20 countries from 1990 to 2019. The findings of the study showed that cointegration between the variables existed only in China, India, and Italy. Idroes et al. (2024) applied the ARDL and Granger causality test methods to data from North African countries for the period 1995-2021. The analysis results did not reveal a statistically significant relationship between ME and CO2. The causality test results, however, revealed a one-way causality relationship from ME to CO2.

Some recent studies in economic literature have investigated the environmental consequences of ME in different regions and periods, utilizing a range of empirical techniques. However, while most of these studies have obtained results that support the Treadmill of Destruction theory, a few studies have reached inconclusive results that do not support this theory. This situation can be linked to developments such as the military's investment in renewable energy for energy security reasons and the resulting increase in the use of solar energy systems, portable energy storage devices, hybrid generators, and biodiesel in military vehicles. Therefore, the study of the impact of militarization on environmental degradation remains relevant and important. Furthermore, the lack of consensus on this issue in the literature and the fact that the subject has not been examined specifically in the Eastern Partnership countries and Russia, as mentioned in the previous section, point to a significant gap in the empirical literature. Thus, this study analyses the influence of militarization on environmental degradation by using panel data for the Eastern Partnership countries and Russia. Thus, this study aims to fill the gap in the empirical literature.

2. Data and methodology

2.1. Data and empirical model

This study aims to examine the impact of ME on EF in the Eastern Partnership countries and Russia (Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine) defined by SIPRI for the period 1996-2022 by using the panel data method. The model used in the study is based on Bildirici, (2017a, 2017b), Solarin et al. (2018), Gokmenoglu et al. (2021), Tarczyński et al. (2023), Chang et al. (2023), Zhu et al. (2023), and shown in equation (1).

$$LEF_{it} = \beta_0 + \beta_1 LME_{it} + \beta_2 LGDP_{it} + \beta_3 LTO_{it} + \beta_4 LEC_{it} + \beta_5 LUP_{it} + u_{it} \quad (1)$$

In equation (1), ME represents the military expenditure variable, TO denotes the trade openness variable, EC stands for the energy consumption variable, and UP refers to the urbanization rate. Descriptions of these variables are presented in Table 1.

Table 1. Variables and data sources

Variables	Definition	Source
EF	Ecological Footprint consumption per capita	Global Footprint Network York University
ME	Military expenditure %of GDP	SIPRI
GDP	GDP per capita (constant 2015 US dollar)	WDI
TO	Exports and imports of goods and services to GDP	
EC	Energy use (kg of oil equivalent per capita)	
UP	Urban population (% of total GDP)	

Source: authors' representation

The data was compiled from Global Footprint Network, World Development Indicators (WDI), and SIPRI (see Table 1). In Equation (1), β_0 is the constant term and β_1, β_2 β_3, β_4 and β_5 are the coefficients of the independent variables. Countries are denoted by i (i=1,…,N) and time period by t (t=1,…,N). u_{it} is the error term. In addition, the variables in the model are logarithmically transformed before being included in the analysis.

EF, which represents environmental impact, is taken as the dependent variable. This indicator was selected because the EF serves as a comprehensive and holistic measure of environmental sustainability, providing a quantitative assessment of a country's or society's total natural resource consumption and its resulting environmental impact (Global Footprint Network & York University, 2025; Wackernagel et al., 2019). Accordingly, this study employs EF to capture the environmental impacts associated with military operations. This is because the effects of militarism on nature are not only limited to the direct use of weapons, but also cause environmental degradation through many different channels, such as military exercises, construction of bases, intensive use of fossil fuels, nuclear testing, defense industry activities, and excessive consumption of natural resources. In order to assess these multidimensional impacts, EF provides a comprehensive and appropriate measure to analyse the environmental consequences of militarization (Jorgenson et al., 2010; Qayyum et al., 2021). As an independent variable in the model, the ME, which refers to the ratio of military expenditure in a country's GDP, is used. This variable represents the economic aspect of ME and is considered a key determinant in analysing the environmental impacts of defense spending.

2.2. Environmental impacts of control variables

In line with the related literature, GDP, TO, EC, and UP variables, which are considered to affect the dependent variable, are included in the model as control variables. The impact of GDP on environmental degradation, which is included in the model as one of the control variables, can be evaluated both positively and negatively in the theoretical and empirical literature. In this context, interest in the environment-economy relationship has increased, especially since the early 1990s, and many empirical studies have been conducted in this field. Among these studies, pioneering studies by Grossman and Krueger (1991), Panayotou (1993), and Selden and Song (1994) stand out. These studies evaluated the relationship between GDP and environmental degradation, inspired by Simon Kuznets' (1955) "Kuznets Curve" approach to income distribution and introduced the "Environmental Kuznets Curve" (EKC) hypothesis to the literature. The EKC hypothesis posits that environmental degradation first increases and then decreases with rising per capita income, forming an inverted-U-shaped nexus. Accordingly, while the trend of environmental degradation increases in the early stages of economic development, this trend reverses after a certain income threshold is exceeded and GDP starts to improve environmental quality. In this context, it is argued that the environmental impacts of GDP depend not only on the level of income but also on the production structure, EC pattern, and environmental quality.

On the other hand, TO can have either an increasing or decreasing effect on environmental damage depending on structural characteristics and country conditions. Copeland and Taylor (2013) explain the negative impact of TO on the environment through two main channels: the scale effect and the composition effect. The scale effect refers to the environmental consequences of increased economic activity due to openness. Increased trade volume leads to expansion in production and consumption activities as well as transportation services, which in turn causes increased use of natural resources and higher greenhouse gas emissions. Thus, the GDP triggered by TO paves the way for more intensive use of resources and increased environmental degradation. The composition effect refers to the power of trade to shape the production structure between countries. In particular, low-income countries with more flexible environmental regulations specialize in the production of environmentally harmful (polluting) products, while high-income countries with strict environmental policies tend toward cleaner and more environmentally friendly production activities. As a consequence, polluting industries are shifted from high-income to low-income countries, reshaping the distribution of environmental burdens across the globe (Le et al., 2016, p. 46). However, there are also conceptual foundations for the idea that trade can have positive effects on the environment. Antweiler et al. (2001) argue that opening up to the outside world can improve environmental quality through technical impact mechanisms. Increased real income through trade liberalization can enable countries to implement environmental regulations more effectively, thereby improving environmental quality. Additionally, increased economic activity encourages the development of cleaner production techniques, contributing to a reduction in pollutants. Therefore, the income growth provided by trade can benefit the environment by enabling some countries to specialize in more environmentally friendly sectors (Le et al., 2016).

In the model, the EC variable is measured in metric tons of oil equivalent (Mtoe) and includes both fossil and renewable energy use. In fossil fuel-based economies, EC causes increased environmental degradation, whereas consumption from renewable energy sources can contribute to environmental quality. The influence of rising energy demand on the environment and ecosystems is a critical issue for energy economists, environmental scientists, and policymakers developing sustainable energy and environmental policies. While the nexus between EC and GDP is important in the context of sustainable development, CO2 resulting from the use of fossil fuels in industrial production increases environmental degradation. Concerns about climate change caused by fossil fuel consumption have encouraged many countries to turn to renewable energy sources to improve environmental quality (Kuriqi et al., 2019). However, a study by Ali et al. (2019) highlights the negative impacts of hydroelectric energy production on ecosystems. Depending on the type of energy used, the environmental impact of EC in Mtoe terms can be positive or negative. Therefore, detailed assessments of energy sources are necessary to understand their environmental impact.

Finally, the UP can also affect the environment. In particular, rapid and unplanned UP can lead to environmental degradation by increasing air, water, and soil pollution through increased EC, transportation demand, and waste production. The consumption of fossil fuels and increased use of motor vehicles caused by dense populations can also lead to an increase in CO2 and other pollutant gas emissions. On the other hand, when the UP process is supported by appropriate environmental policies and technological infrastructure, it can also offer opportunities for more efficient use of resources and the implementation of environmentally friendly solutions. Especially in developed cities, environmental impacts can be reduced through the widespread use of public transportation, the use of renewable energy sources, and effective waste management systems. Therefore, the impact of UP on the environment depends not only on population density but also on the quality of urban management and the environmental strategies implemented (Uttara et al., 2012; Zhang & Lin, 2012; Liang et al., 2019, p.1-2). Therefore, including the UP variable in the model will enable a more comprehensive analysis of environmental dynamics.

2.3. Econometric methodology

In selecting unit root and cointegration tests to be used in econometric analyses, determining cross-sectional dependence (CSD) among variables and homogeneity of parameters is an important prerequisite. Therefore, before proceeding with the analyses in this study, the homogeneity of slope coefficients was examined, and CSD was investigated. In this context, the homogeneity of the slope coefficients was investigated by using the Delta test proposed by Pesaran and Yamagata (2008). To test for the presence of CSD, the CD test proposed by Pesaran (2004) was utilized. Subsequently, the Cross-sectional Augmented Dickey-Fuller (CADF) panel unit root test was applied to determine the stationarity levels of the series. After determining the levels at which the series were integrated, the existence of a long-run nexus among the relevant variables was investigated by using the Westerlund (2008) cointegration test. The AMG estimator was employed to estimate the long-run effects. To investigate the short-run causality among the variables, the Dumitrescu and Hurlin (2012) panel causality test was employed.

The detection of CSD is critical in panel data econometric analyses; neglecting CSD in error terms can lead to misleading results, particularly in unit root tests, by causing significant size biases (O'Connell, 1998). Chudik and Pesaran (2013) note that spatial dependence, omitted common influences, and socioeconomic network interactions are common sources of cross-sectional correlation in error terms. Additionally, if CSD is correlated with the regressors, traditional estimation methods may yield inconsistent results. Therefore, in this study, a CSD test was conducted utilizing the CD test developed by Pesaran (2004). The CD test maintains its validity even when the error terms do not follow a normal distribution and structural breaks are present. Subsequently, since the data used was found to contain CSD, the slope homogeneity test developed by Pesaran and Yamagata (2008), which remains valid under CSD conditions, was applied to analyse whether the effect of the explanatory variable differed between units.

In panel data analysis, when series contain CSD, traditional unit root tests may be insufficient, and second-generation unit root tests must be used (Baltagi, 2008, p. 284). The CADF unit root test, developed by Pesaran (2007) and taking into account

CSD between units, proposes a new test structure by incorporating the lagged values and first differences of the means of the units in the panel into the classical Augmented Dickey-Fuller (ADF) test. This approach is referred to as the CADF and provides more reliable results in the stationarity analysis of series containing CSD in panel data structures (Yerdelen Tatoğlu, 2020).

Panel cointegration techniques are widely used methods for identifying long-run relationships between integrated series. However, first-generation cointegration tests are insufficient in some cases because they neglect the assumption of CSD. In this context, it is widely accepted in the literature that second-generation cointegration tests, which take CSD into account, provide more appropriate and reliable results in panel data analysis. In line with this, the second-generation panel cointegration test developed by Westerlund (2008) was used in this study. This test consists of two components: the Durbin–Hausman panel (DHp) test and the Durbin–Hausman group (DHg) test. Both components, as shown in Equation (2), make significant contributions to determining cointegration relationships in panel data analysis.

$$DH_p = \hat{S}_N(\overline{\emptyset} - \widehat{\emptyset})^2 \sum_{i=1}^{N} \sum_{i=2}^{T} \hat{e}_{it-1}^2$$
$$DH_g = \sum_{i=1}^{N} \hat{S}_i(\overline{\emptyset} - \widehat{\emptyset})^2 \sum_{i=2}^{T} \hat{e}_{it-1}^2 \tag{2}$$

Here, $\hat{S}_i = \widehat{\omega}_i^2/\hat{\sigma}_i^4$ and $\hat{S}_N = \widehat{\omega}_N^2/\hat{\sigma}_N^4$ and $\widehat{\omega}_i^2\hat{\sigma}_i^2$ are short- and long-run variance estimators of the error terms obtained from the Ordinary Least Squares (OLS) estimate (Bulut et al., 2020). DH_p test operates under the assumption that the autoregressive parameter remains constant across all cross-sectional units, both under the H_0 and alternative hypotheses. A rejection of the H_0 hypothesis implies that cointegration exists in the panel. In contrast, the DH_g test allows for heterogeneity in the autoregressive parameter under the alternative hypothesis, meaning it can vary from one cross-section to another. Nevertheless, rejection of the H_0 hypothesis in the DH_g test denotes the presence of cointegration among across all cross-sections.

As a result of the slope homogeneity, CSD, and unit root tests applied to the variables, it was determined that the slope coefficients of the series are heterogeneous, contain CSD, and are not stationary at their levels, but there is a cointegration between them in the long-run (see section 4). Given the presence of long-run cointegration under slope heterogeneity and CSD, an estimator capable of addressing these features is required. Accordingly, the AMG estimator was employed, as it explicitly accounts for both slope heterogeneity and CSD in long-run coefficient estimation.

The AMG estimator, developed by Eberhardt and Bond (2009) and Eberhardt and Teal (2010), adopts a two-stage procedure to control for unobservable common dynamic processes. In the first stage, time dummy variables are introduced to capture common shocks affecting all cross-sectional units. In the second stage, the common dynamic component extracted from the first-stage regression is removed from the dependent variable, and group-specific long-run coefficients are estimated. The overall panel estimates are then obtained by averaging the individual coefficients across cross-sections, while constant terms are included to control for time-invariant fixed effects.

Finally, to examine the short-run nexus among the variables, this study employs the Dumitrescu and Hurlin (2012) panel causality test. By extending the traditional Granger causality framework to panel data, this approach allows for cross-sectional heterogeneity in both the regression structure and the causal relationships among variables, while maintaining the assumption of time-invariant coefficients. Moreover, by explicitly accounting for CSD, the test yields more reliable and realistic inference in heterogeneous panel settings. Within this framework, the null hypothesis posits the absence of Granger causality across all cross-sectional units, whereas the alternative hypothesis permits the existence of causality in at least one unit (Dumitrescu & Hurlin, 2012).

3. Empirical results and discussion

As seen in Table 2, for the period 1996–2022, the average EF in the Eastern Partnership countries and Russia is 2.964. Over the same period, the average values of the variables are 0.027 for ME, 3,799.196 for GDP, 90.200 for TO, 2,086.275 for EC, and 61.816 for UP. On the other hand, the standard deviation and other descriptive statistical measures of the variables are reported in detail in the corresponding table.

Table 2. Descriptive statistics

	EF	ME	GDP	TO	EC	UP
Mean	2.964	0.027	3799.196	90.200	2086.275	61.816
Median	2.237	0.027	3085.333	88.470	1497.903	63.573
Maximum	6.374	0.258	10206.95	157.9743	5681.392	80.326
Minimum	1.036	0.002	995.728	43.258	543.249	42.490
Std. Dev.	1.504	0.022	2325.529	26.689	1305.427	10.863
Observations	189	189	189	189	189	189

Source: authors’ representation

The results of the slope homogeneity test (Delta test) developed by Pesaran and Yamagata (2008), presented in Table 3, show that the null hypothesis, which suggests that the slope coefficients in the model are homogeneous at a 1% significance level, has been rejected. This indicates that the slope coefficients in the model are heterogeneous.

Table 3. Homogeneity test results

	Test Statistics	P-Value
Δ	4.647	0.000
Δ_{adj}	5.400	0.000

Source: authors' representation

The Pesaran CD test results presented in Table 4 are significant at the 1% level, denoting the presence of CSD in the panel. This situation shows that a shock occurring in one country can also affect other countries. Therefore, for series where CSD was detected, the CADF test, which takes CSD into account as a unit root test, was preferred.

Table 4. CSD results

Tests	**LEF**	**LUP**	**LME**	**LGDP**	**LTO**	**LEC**
Pesaran CD	7.34***	4.08***	1.74*	22.35***	2.06**	6.47***

Note: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10, respectively.
Source: authors' representation

The outcomes of the CADF unit root test indicated in Table 5 denote that EF, ME, GDP, TO, EC, and UP are stationary in their first differences.

Table 5. CADF unit root test results

Variables	**Level**	**First Difference**
LEF	-2.034	-3.041***
LME	-1.296	-3.482***
LGDP	-1.276	-2.969***
LTO	-1.817	-3.452***
LEC	-2.038	-2.316*
LUP	-0.493	-2.617**

Note: ***,**, and * indicate significance at the 0.01, 0.05, and 0.10, respectively.
Source: authors' representation

Table 6 presents the findings of Westerlund (2008) regarding the panel cointegration test. As the computed test statistics exceed the critical values from the table, the null hypothesis is rejected, indicating the presence of cointegration among the variables. Across the panel and in Eastern Partnership countries and Russia (Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine), the LEF, LUP, LGDP, LTO, and LEC variables move together in the long-run.

Table 6. Westerlund cointegration test results

Test Statistics	
DHg	DHp
340.742* **	7.668***

Note: *** indicates significance at the 0.01.
Source: authors' representation

The long-run coefficients obtained by using the AMG method are presented in Table 7. A statistically significant and positive relationship was found between ME and EF; when ME changes by 1%, EF changes by 0.1% in the same direction. This finding indicates that ME has a reinforcing effect on environmental degradation in the economies of the Eastern Partnership countries and Russia. The high energy and resource intensity of the defense sector, along with the development of advanced technology-based infrastructure and CO2 resulting from production and operational activities, explain the main mechanisms underlying the relationship between ME and EF. The fact that this relationship is particularly significant in the long-run stems from the cumulative and structural effects of ME, rather than its immediately observable short-term impacts. For instance, military investments typically involve high-cost and capital-intensive technological systems; the production, deployment, continuous maintenance, and modernization of these systems take considerable time and consistently increase fossil fuel consumption, thereby exacerbating environmental pressures. In addition, the extensive network of military bases and logistical systems generates limited short-term effects but, over time, reinforces carbon-intensive production and consumption patterns, producing indirect effects. Within this framework, consistent with the Treadmill of Destruction theory, it can be argued that the impact of ME on environmental degradation emerges cumulatively over time and becomes more pronounced in the long-run through indirect mechanisms (Hooks & Smith, 2004, 2005; Clark & Jorgenson, 2012; Jorgenson et al., 2010; Crawford, 2022).

The long-run coefficient for GDP is positive and significant. This shows that GDP has a positive impact on a country's EF. In other words, the positive relationship between EF and GDP shows the environmental cost of economic growth. Especially after the 1990s, with the transition to a market economy and the process of integration with the EU, the Eastern Partnership countries and Russia entered a period of rapid GDP. This growth was largely driven by factors that increased natural resource consumption and environmental pressure, such as increased industrial production, development based on energy-intensive sectors, and infrastructure investments (transportation, construction, etc.). This finding is consistent with most studies in the literature (Ahmad et al., 2020; Ahmed et al., 2020; Ahmed et al., 2020; Chang et al., 2023).

A positive relationship has been found between EC and EF. This finding reveals that energy use in the region is a significant pressure factor in terms of environmental sustainability. This relationship is likely driven by the fact that fossil fuels constitute the main input in energy production and usage. In the Eastern Partnership countries and Russia, limited investments in renewable energy and relatively old and inefficient energy infrastructure may result in higher CO2 and resource consumption per unit of EC. This finding is consistent with the studies by Ahmed et al. (2019), Destek and Okumus (2019), Ahmed et al. (2020).

Table 7. AMG long-run coefficients

Dependent Variable LEF	Coefficient	Standard Error	P-Value
LME	0.103	0.029	0.000
LGDP	0.490	0.243	0.044
LTO	-0.049	0.108	0.646
LEC	0.338	0.135	0.012
LUP	4.524	4.784	0.344
Constant	-24.187	19.877	0.224

Source: authors' representation

As seen in Table 7, there is no statistically significant relationship between the TO and EF variables. The effect of TO on EF can be positive or negative. The direction of this effect is generally shaped by the country's level of economic development and degree of industrialization. In the case of Eastern Partnership countries and Russia, the absence of a significant relationship between TO and EF is thought to stem from the heterogeneity of these countries' economic structures and levels of development, which makes it difficult to identify a general effect. Similarly, Hossain (2011) and Omri (2013) also found that TO had a negative but insignificant effect on EF.

No significant relationship was found between UP and EF. Findings regarding the relationship between UP and EF vary greatly depending on regional, economic, and technological factors. Danish et al. (2020) stated that the results regarding the nexus among these two variables are complex. While no significant relationship was found between these two variables in some regions, significant positive or negative effects were observed in other regions. Chen et al. (2022) found that the relevant variables were not statistically significant in their study of 110 countries. They stated that this situation may be related to the sample size. Al-Mulali and Öztürk (2015) found a positive relationship between UP and EF, while Hassan et al. (2019), Nathaniel et al. (2019), and Danish et al. (2020) found a negative nexus among these variables.

Table 8 denotes the results of the panel causality test by Dumitrescu and Hurlin (2012). As seen in the table, EF has been identified as the cause of EC. The increasing EF in these countries is leading to a reshaping of energy policies; in this context, pressures toward environmental sustainability are emerging as a factor influencing the level and structure of EC. In this region, where environmental degradation is accelerating due to fossil fuel-based energy production, increasing environmental awareness and efforts to comply with international environmental standards are paving the way for EC to shift toward more efficient and environmentally friendly sources. In this regard, the causal effect of the EF on EC demonstrates that environmental indicators are not merely outcomes but also serve as an active input in the formulation of energy policies. Consistent outcomes were also observed in Khan and Hou (2021). Therefore, the findings reveal that environmental degradation plays a guiding role in energy policies and that the relationship between sustainable development goals and energy strategies should be taken into account in this context.

EF has been found as the cause of TO. This is because the obligation to comply with international environmental policies (such as the European Green Deal or carbon border adjustments) necessitates that the structure of foreign trade becomes sensitive to environmental indicators. In this case, the size of the EF becomes a guiding factor in the level of openness to the outside world. This causal relationship indicates that environmental policies must be addressed in an integrated manner with foreign trade strategies. In their studies on G7 countries, Yılancı et al. (2022) obtained a unidirectional causality from EF to for Canada and Germany.

Table 8. Dumitrescu-Hurlin test results

Direction of causality	W-Statistic	Z-Statistic	Probability	Result
LEC→LEF	2.904	0.703	0.481	not the cause
LEF→LEC	3.879	1.728	0.083	**The cause**
LGDP→ LEF	3.477	1.306	0.191	not the cause
LEF→ LGDP	2.265	0.031	0.974	not the cause
LME→ LEF	1.989	-0.258	0.795	not the cause
LEF→ LME	1.893	-0.359	0.719	not the cause
LTO→ LEF	1.012	-1.285	0.198	not the cause
LEF→ LTO	4.674	2.564	0.010	**The cause**
LUP→ LEF	1.741	-0.519	0.603	not the cause
LEF→ LUP	2.534	0.314	0.753	not the cause

Note: The lag length is taken as one.
Source: authors' representation

Given the complexity of military and environmental policy dynamics in the region, findings on Eastern Partnership countries and Russia show that the relationship between ME and EF is not statistically significant in the short-run. Similarly, Riaz et al. (2024) state that military expenditures have a significant and clear effect on CO2 in the long-run for NATO countries, but no relationship between these two variables could be detected in the short-run. The fact that both military and environmental policies in Eastern Partnership countries and Russia are largely shaped by external pressures, geopolitical uncertainties and economic fragilities make it difficult to establish direct and short-run systematic relationships between these two areas. In particular, while some countries in the region (e.g., Ukraine, Azerbaijan, Armenia) are facing armed conflicts, others are in strategic tension with actors such as Russia, which have large military budgets. This situation leads to military expenditures being used largely for defense or deterrence, with the environmental impacts of these expenditures taking a back seat. At the same time, environmental policies are largely shaped by the need to comply with EU norms or access international funds, and are therefore determined by external drivers rather than internal sustainability goals. Consequently, environmental policies may focus solely on short-run compliance rather than integrating long-run sustainability goals, hindering the development of holistic strategies that address the environmental effects of military operations. In this context, the inability to establish a short-run and direct relationship between military expenditures and EF may stem from the multi-layered and uncoordinated nature of policy-making processes in the region and from strategic considerations.

4. Conclusion and policy recommendations

This study aims to investigate the impact of ME on environmental degradation in the Eastern Partnership countries and Russia (Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine) for the period 1996-2022 by using panel data methods.

In the study, Westerlund (2008) results showed that there is a long-run nexus among the variables. The long-run coefficients obtained using the AMG method are summarized as follows: (i) A statistically significant and positive nexus was found between ME and EF. This finding shows that ME increases EF in the Eastern Partnership countries and Russia and supports the Treadmill Destruction theory. (ii) A positive and significant nexus was found between GDP and EF. This finding shows the environmental cost of GDP in the Eastern Partnership countries and Russia. (iii) A positive relationship was found between EC and EF. This positive relationship can be attributed to the heavy reliance on fossil fuels for energy production and consumption in the Eastern Partnership countries and Russia. (iv) The analysis revealed no statistically significant trade-off between TO and EF. This result may be explained by the trade composition in certain Eastern Partnership countries such as Armenia, Belarus, Georgia, and Moldova, where a substantial share of exports and imports is concentrated in sectors like agriculture, services, and light industry, which are generally characterized by lower environmental externalities compared to heavy industry or extractive sectors. On the other hand, the heavy reliance on fossil fuel exports in some countries (such as Azerbaijan and Russia) may lead to greater environmental degradation. Additionally, TO can both reduce the EF by increasing the transfer of environmentally friendly technologies and increase the EF by supporting the growth of polluting industries. These opposing effects may cancel each other out in data analysis, resulting in no significant relationship. (v) No relationship was found between UP and EF. This may be because industry and UP are concentrated in different areas in Central European countries.

The results of the Dumitrescu-Hurlin panel causality test, used to determine the causal relationship between variables in the study, are summarized as follows. (i) No causal relationship was found between ME and EF. An examination of the Eastern Partnership countries and Russia reveals that the environmental consequences of militarization vary between the short and long-run. In the long-run, the capital intensity of military expenditures (spending per soldier) and the relative size of armed forces systematically increase carbon emissions in these countries. The development, production, and long-run use of high-tech military infrastructure, along with continuous maintenance requirements, structurally raise fossil fuel consumption and deepen environmental degradation, as predicted by the Treadmill of Destruction theory (Hooks & Smith 2004, 2005; Clark & Jorgenson, 2012; Jorgenson et al., 2010; Crawford, 2022). In contrast, the short-run effects of military expenditures are more limited, as personnel costs or defense-related spending do not immediately generate observable increases in emissions. However, these limited short-run effects create path dependencies over time due to the extensive military base networks and weapons systems, reinforcing carbon-intensive production and consumption patterns (Kentor et al., 2012; Jorgenson et al., 2023; Smith & Lengefeld, 2020). Consequently, in these Eastern European countries, ME has limited short-run effects but produces persistent and systematic environmental degradation in the long-run. However, the direct and indirect environmental impacts of regional conflicts such as the Russia-Ukraine war are noteworthy. However, the environmental impacts caused by such conflicts, such as carbon emissions from military activities, infrastructure destruction, land degradation, and loss of natural resources, often involve long-run, multidimensional, and difficult-to-measure dynamics, and may not be reflected in the short-run causal nexus between the two variables. (ii) Causality from EF to EC has been identified. This finding suggests that a rise in the EF reflects heightened environmental pressures and resource consumption, which may consequently drive an increase in EC. (iii) It has been concluded that the EF is the cause of TO. In line with this conclusion, it can be said that environmental degradation has been influential in shaping foreign trade policies in Eastern Partnership countries and Russia. Indeed, the increase in environmental degradation is leading countries in the region to adopt policies that encourage the import and export of environmentally friendly technologies, goods, and services in line with sustainable development goals.

Although the cointegration test results reveal a positive and statistically significant long-run nexus between ME and the EF, the lack of clarity regarding the direction of causality necessitates a cautious and multidimensional policy evaluation. Military spending is typically linked to intensive fossil fuel consumption and is frequently undertaken without yielding substantial technological advancements. Operational activities of land, naval, and air forces involve considerable use of petroleum-based fuels for vehicles such as tanks, ships, and aircraft. Notably, even in peacetime, the military sector maintains high levels of fossil EC, contributing persistently to environmental pressures (Bildirici, 2017c). In cases where military spending cannot be reduced for strategic reasons, it is necessary to restructure the existing oil-based energy structure by redirecting it toward more sustainable sources. In this context, policymakers are advised to meet the energy needs of navies with environmentally friendly alternatives such as nuclear energy and renewable energy sources instead of fossil fuels. For example, increasing the use of alternative fuels such as biodiesel, a clean energy source, instead of fossil fuels in military vehicles, plays an important role in reducing the environmental degradation caused by military activities. In the long-run, the Eastern Partnership countries and Russia need to develop strategic plans similar to the green defense strategies implemented by the US in 2014 and NATO in 2021 (Radich,2014; NATO Climate Initiative, 2021). In addition, policymakers are advised to evaluate military expenditures in terms of environmental sustainability. In this regard, prioritizing investments that are capital-intensive and support the integration of innovative, environmentally friendly technologies into the defense sector, rather than current expenditures, will both encourage military modernization and contribute to reducing environmental impacts. In addition, it is recommended that policymakers direct a portion of defense sector investments toward environmental R&D efforts.

On the other hand, while the study identifies a statistically significant long-run effect between GDP and the EF, the absence of established causality direction underscores the need for policymakers to formulate economic growth strategies that adequately account for environmental sustainability. In this context, the adoption of green growth strategies grounded in environmental sustainability, alongside regular monitoring and evaluation of the ecological impacts of economic activities, is strongly recommended. Considering that the EF affects EC in the Eastern Partnership countries and Russia, it is recommended that policymakers prioritize energy efficiency and conservation, accelerate the transition to renewable energy sources, and limit energy use with high environmental impact. At the same time, control mechanisms based on efficiency and needs analysis should be established for military spending, and unnecessary spending should be limited. In this way, the environmental and social impacts of growth can be controlled.

Although the findings of the study point to the importance of the environmental impacts of ME, the fact that human casualties and physical destruction are the most urgent and pressing issues in the ongoing war conditions, especially for Ukraine and Russia, should not be ignored. This study considers environmental impacts in the long-run and structural policy framework without subordinating the humanitarian dimension of war.

Considering the damage caused to the environment by the defense sector's heavy use of fossil fuels, it is of great importance to increase the number of studies examining the environmental impacts of ME in the context of environmental sustainability. In this context, it is recommended that future studies focus on specific countries or groups of countries. The findings obtained in this way will encourage policymakers to develop strategic plans for the development of an environmentally friendly defense industry and to strengthen existing plans.

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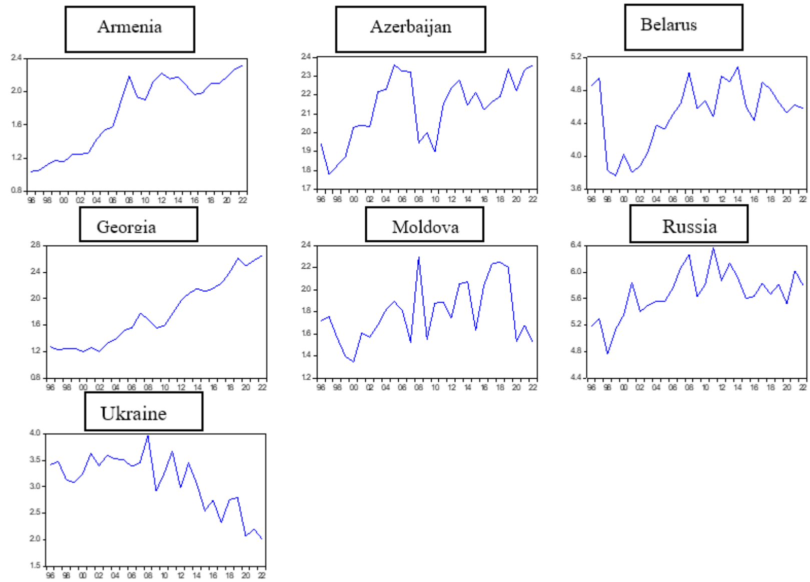
APPENDIX

Table A1. Ecological footprint and military expenditures by country

EF



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