

CO₂ EMISSIONS, ENERGY MARKETS, AND GLOBAL CONFLICT: A RESOURCE POLICY PERSPECTIVE FROM MAJOR MILITARY SPENDERS

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Abstract. Climate change threatens national and international security, increasing conflicts and government spending. As economies grow in complexity, the need for public and military services, including environmental security, will rise. This study investigates the relationship among military spending, CO₂ emissions, energy prices, and international conflicts in the five largest defense-budgeting economies, including the USA, China, Russia, India, and Saudi Arabia. With the exception of Saudi Arabia, the other four economies rank among those with the largest CO₂ emissions. The study examines the factors influencing military expenditures (ME) in five countries using ARDL methodologies and Granger causality. Although increasing CO₂ emissions raises military expenditures, short-term economic growth reduces them. This evidence indicates the existence of climate-related security risks. Energy prices and prolonged external conflicts increase ME, while population growth and CO₂ emissions contribute to their decline. Granger causality tests indicate that military expenditures and population growth affect energy prices. CO₂ emissions highlight the need for a comprehensive approach to conflicts, energy, and climate, as they function as a short-term shield and a long-term constraint.

Keywords: *enviormental security, energy price shocks, defense budgeting, population dynamics cross-country analysis*

Introduction

Climate change threatens national and international security, increasing conflict and government spending. High levels of CO₂ increase climate change, causing droughts, floods, and resource shortages. This, in turn, led to the displacement of many rural people from Syria, which contributed to social issues that boosted the civil battle (Kelley et al., 2015). Such problems in the environment can lead to increased disputes between countries that need water and land, causing most governments to focus on making their militaries stronger. As the population of developing countries rises, the demand for energy

increases for residences, factories, and transportation. A rise in demand causes energy prices to go higher, especially if supply is unpredictable or depends on foreign markets (Sovacool, 2012). If energy prices go up, it might lead to inflation, create financial pressure, and disappoint people, which could increase the danger of unrest in countries that rely heavily on imported energy (Bazilian et al., 2012). In addition, nations boost their defence spending to secure oil supplies, invest in energy activities in other countries, or fight for strategic resources, mainly in places such as the Middle East and the South China Sea (Klare, 2012). As a result, changes in population and energy prices indirectly lead to higher military budgets due to both national and international security concerns.

Wagner's and Keynes' views illuminate this link. Wagner's law holds that government spending expands disproportionately with economic growth, but Keynesian theory emphasizes public sector investment may increase growth, especially during crises. Economic development, militarism, foreign wars, and environmental destruction all influence military spending. Military activities increase energy usage and CO₂ emissions, degrading the environment. Wealthy nations with high military spending have huge carbon footprints due to military activities, innovative technology, and industry. CO₂ levels in the air have been on the rise ever since the Industrial Revolution in the late 18th century, mostly because of the large-scale burning of fossil fuels for energy, manufacturing, and transportation (IPCC, 2021). Although there were stronger industries and more carbon dioxide during World War II, this did not start the rise in CO₂ levels in the atmosphere. As a result, an increase in economic activity after the war boosted the rising levels of greenhouse gas concentrations even further. Studies of long-term ice core samples and constant monitoring of levels in the air document that CO₂ levels increased with industrialisation and have been progressively rising again in the present era (Etheridge et al., 1996; NOAA, 2023). Therefore, when discussing CO₂ pollution and its effects on current topics.

These emissions are approaching key atmospheric limits, which might cause irreparable environmental damage. NASA aims to keep atmospheric carbon at 350 ppm to reduce dangers (Hansen, 2009). Despite this warning, CO₂ levels have risen to more than 420 ppm in the year 2023, which is much higher than what is considered safe, causing significant worry about the world's climate (NOAA, 2023). In parallel with environmental issues, another pressing area of study is the relationship between economic growth and public expenditure. Numerous researchers have sought to understand how economic development correlates with overall government spending (Mann, 1980; Islam, 2001; Babatunde, 2011; Demir and Balkı, 2019; Bazán et al., 2022). Furthermore, research is being conducted to examine the relationship between the categories of public expenditure (Samudram et al., 2009; Gül and Yavuz, 2011; Yürük and Acaroğlu, 2021; Balkı and Göksu, 2023). For instance, in the context of Turkey, Granger causality test results reveal that there is no causal link between economic development and defense (Görkem and Işık, 2008; Durgun and Timur, 2017). A substantial part of the federal budget is consumed by defence expenditures in numerous countries, which is considered a sign of power. In case of Turkey research finding indicate defence spending has positive impact on short-term economic growth. Moreover, defence expenditure and economic growth have a one-way causal relationship. The findings of the Granger causality test reveal that Wagner's law exists over a long time (Yağtu and Sezgin, 2019). Karakaya and Şahinoğlu (2020) investigated the viability of the economic theories related to Wagner's law.

Their Analysis using ARDL limits to test and Johansen cointegration analysis indicates that defense expenditures adversely impact economic growth. Results for Sub-Saharan African nations show that administration spending significantly affects financial growth when fixed-effect and random-effect estimate methodologies are used (Yasin, 2003). Chletsos and Kollias (1997) examined data from 1958 to 1993 within the Greek sample. The cointegration study indicates that Wagner's law is applicable to defense spending. Dritsakis (2004) examined the correlation between GDP Progress and defence expenditure in Türkiye and Greece from 1960 to 2001. Johansen's cointegration analysis indicates the not having cointegration between the two variables. The Granger causality test results indicate a correlation Between defence and economic growth expenditures. Shaaba Saba and Ngepah (2019) analyzed the correlation between military expenditures and economic 35 African countries development between 1990 and 2015. Panel causality outcomes indicate that defense spending adversely impacts economic growth.

The demand for substantial energy in contemporary military equipment has led to a rise in fossil fuel use since World War II. Advanced Every mile, helicopters use five gallons of fuel., but F-15 and F-16 aircraft require 1,500 to 1,700 gallons an hour (Clark and Jorgenson, 2010). Air pollution resulting from nuclear weapons testing comprises radioactive isotopes (Commoner, 1971; Jorgenson et al., 2012; Givens, 2014). Nuclear fallout has global consequences, intensifying the environmental impacts of militarism (Renner, 1991). Military and economic activities deteriorate the environment, impacting global warming and the carbon cycle. This results in health complications, ecological degradation, and severe meteorological conditions. To maintain economic growth and mitigate health issues, politicians must emphasize environmental preservation.

Research has identified several factors contributing to pollution, and econometric studies have expanded the analysis to incorporate more variables and other countries (Commoner, 1971). Global military expenditure increased by 76% during the Cold War, constituting 2.1% of global GDP in 2018. This indicates that national budgets prioritize defense expenditures (Shaw, 1988; Kentor and Kick, 2008).

Advances in transportation, especially in military logistics, enable the rapid deployment of supplies and personnel; thus, they intensify the environmental impacts of military activities (Collins, 1981). Globalization is seen as a catalyst for war and instability, with the military industry often shaping national policy and undermining the political capacity to mitigate the negative impacts of free-market forces (Staples, 2000; Gupta et al., 2001).

Urbanization trends may potentially provoke an increase in military expenditure due to the heightened demand for security in densely inhabited areas. Wealthy nations with urban centers generally invest significant resources in their military capabilities to achieve regional and global power. As economies progress and industrial activity increases, CO₂ emissions rise, intensifying climate change and presenting security challenges related to resource scarcity and geopolitical instability. The impact of global conflicts, oil prices, and CO₂ emissions on defense budgets is highlighted by the United States, China, Russia, India, and Saudi Arabia. Climate change forces nations to increase military readiness, necessitating greater spending on supplies, manpower, and logistics. Nations obligated to reduce CO₂ emissions may concurrently adopt energy-efficient military technology, necessitating more investment in renewable energy research and development.

Homer-Dixon (1999), as an environmental security expert, affirms that CO₂ increases and their associated environmental issues can weaken social and political stability, mainly

impacting places that are easily affected. The connection between climate-related disruptions and military spending is not widely known; more studies are required to comprehend the possible effects of such disruptions on security matters. As an illustration, drought, shortage of food, and migration caused by climate in the Sahel, Afghanistan, and South Asia often lead to conflicts. Although these areas are not the main topic here, they give useful background on the possible effects of climate and energy problems on military budget decisions worldwide. Thus, this research investigates the broader connection among environmental stress, energy prices, and military expenditure in countries with the highest defense budgets. These nations play key roles in energy production, consumption, or strategic control (e.g., oil reserves, pipeline routes, naval control over energy trade). Large military powers do decide the bigger global trends. These countries are now paying more attention to climate change-related pressures, energy safety, and political risks in their defense preparation and budgets (U.S. Department of Defense, 2014; NATO, 2021). This study explores the relationship between CO₂ emissions, energy consumption, and war spending to understand how environmental pressures influence the policies of large nations.

Specifically, it focuses on the five countries with the largest defense budgets. According to the list published by (Stockholm International Peace Research Institute (SIPRI, 2023)) USA, China, Russia, India and Saudi Arabia are the five major economies with the largest defense budgets of \$ 916 billions, \$330 billions, \$130 billions, \$83.6 billion and \$75.8 billion respectively. It means that USA is a leader in this group. Similarly, five countries that emit highest CO₂ emissions are; China, USA, India, Russia and Saudi Arabia. China tops the list of Carbon Dioxide emitting nations with 11397 million metric tons, USA emits 5057 million metric tons, India emits 2830 million metric tons, Russia emits 1652 million metric tons. In 2023 the economic growth rates of these largest defense budgeting economies USA, China, Russia, India and Saudi Arabia were recorded 2.9%, 5.2%, 3.6%, 8.2%, and 3.7%.

Objective of the study

Examine how environmental, economic, conflict-related, and demographic factors influence military expenditure in the five largest defense spending nations.

Specific objectives of the study

1. To evaluate the effect of CO₂ emission on military spending.
2. To analyze the relationship between external conflicts and defense spending.
3. To measure the effect of GDP growth on military expenditure in major military spending countries.
4. To explore how energy prices contribute to variations in military expenditure.
5. To determine the role of population size in shaping defense spending priorities.

Review of literature

Military spending has been normally viewed either through a strategic or an economic prism, in terms of defense potential and budgetary allocation. The environmental impacts of defense operations, including greenhouse gas emissions, resource extraction, and land degradation, however, are rapidly being understood as an important yet underexamined studied area of global security policy (Belcher et al., 2020). These impacts are further

intensified as greenhouse gas emissions, military logistics and exercises consume vast amounts of natural resources, including fossil fuels, metals, and water, intensifying ecological strain. Armed conflicts and military infrastructure also cause direct damage to ecosystems by disrupting land use, polluting soil and water, and destroying habitats. These environmental impacts pose long-term risks to biodiversity and human health. According to Wezeman (2019), despite the growing recognition of such issues, military spending continues to prioritize defense capabilities with little integration of sustainability goals, highlighting the need for policies that address the environmental footprint of defense sectors.

Hsiang et al. (2013) has shown that changes in climate variables, including temperature and precipitation, strongly contribute to the incidence of interpersonal and intergroup violence, especially in sensitive areas, which are liable to conflict. Their findings highlight how climate stress can be a driver of conflicts which in most cases lead to military implications. Mach et al. (2019) reveal the existence of certain conflict zones whereby environmental degradation, attributed to the environmental change, has aggravated the competition over the limited resources, in turn extending or escalating armed conflicts. These findings highlight the fact that the environment context in conflict prone regions should be incorporated in the quest to understand the issue of military expenditures and security policies. Tarczyński et al. (2023) studied 47 high spenders countries using GMM estimator in two stages and concluded that each percentage increase in per-capita military spending results in a 0.05 percent growth in CO₂ emissions, and renewable energy implementation alleviates these impacts.

Husnain and Ali (2023) utilized ARDL techniques on Pakistan, India, and China and confirmed that military spending and economic growth drive emissions upward, whereas renewable energy helps reduce them.

Markó (2024) analysis in *The Green Peace Dividend* demonstrates that a percentage point rise in military spending leads to a 0.9–2% increase in emissions and a 10–25% reduction in green patenting, highlighting the crowding-out effect on renewable innovation.

These findings have been used as a basis to advance research on sustainable development that has, in turn, focused on complicated relationships between economic growth and environmental degradation, commonly using the Environmental Kuznets Curve (EKC). The Environmental Kuznets Curve (EKC), based on Kuznets 1955 research, suggests a relationship with an inverted U shape in which the quality of the environment declines with early expansion of the economy but then improves after attaining a specific income threshold. Significant research, notably by Grossman and Krueger (1991) has identified curvilinear relationships among industrial pollution, agricultural land utilization, and deforestation. Still, studies have shown that the Environmental Kuznets Curve isn't always accurate. For example, Hoffmann (2004) and Roberts and Grimes (1997) show that slightly better environmental conditions may happen when GDP per capita goes up.

Although research indicates a correlation between GDP and environmental pollution, the lack of an absolute threshold for pollution reduction complicates the results (Hettige et al., 2000; Hoffmann, 2004). Research has examined the correlation between emissions of CO₂, GDP, as well as energy usage (Jalil and Mahmud, 2009) highlighting the necessity for more investigation into the impact of energy use regarding the environment deterioration.

Another significant topic of study is the connection between militarism and the degradation of the environment. Bildirici (2015) explored the dynamic relationship between China's GDP, energy consumption, and militarism, which supported the destructive cycle argument.

The defense sector's reliance on fossil fuels, along with military actions, adds significantly to CO₂ emissions (Bildirici, 2017a). The Treadmill of Destruction Theory (Hooks and Smith, 2012) explores the environmental consequences of militarism and conflict. Jorgenson and Clark (2009) found a clear association between military spending per soldier and environmental impact, and later research has connected militarization to higher CO₂ emissions in the United States and G7 countries (Bildirici, 2017b).

Despite these findings, there has been limited research on the economic implications of militarism's environmental effects. Historical settings of colonialism show how military and commercial objectives converged to create unequal economic relations (Cohen, 1973).

Studies have found a significant link between energy consumption and militarism, underscoring the fundamental reliance of military activities on fuel (Givens, 2014). The continuous environmental repercussions of militarism, such as pollution and resource depletion, demonstrate its negative influence on ecological health (York, 2008).

Although the literature has thoroughly investigated the social, ecological, and economic aspects that influence expansion, The connection between militarism and, energy usage, and CO₂ emission levels has received little attention (Jorgenson et al., 2012; Givens, 2014). Recent research has mostly focused on energy consumption, but the connection between militarism, economic development, and environmental repercussions needs additional exploration (Pascale et al., 2016; Aung et al., 2017). Addressing this gap can help us better understand how the military affects environmental sustainability while promoting economic growth.

Numerous issues, including economic, political, strategic, psychological, and moral components, complicate the appraisal of military spending. As a result, doing a theoretical study on this topic involves major challenges. Several theories examine the process of determining decisions and the effects Of different political, military, and financial elements, despite the classification of military expenditure as a separate economic activity. External factors that impact a country's willingness to boost military spending include military variables, such as defense spending by prospective adversaries or allies. In this setting, arms race models can help explain the necessity of military spending (Richardson, 1960), important work on arms races in addition to Brito and Intriligator (1995); Concerning surveys on the concept of arms races or alliance models, as well as innovative research on the economics of agreements Murdoch and Sandler (1982), and Hansen et al. (1990).

Despite some past research on the role of a large number of factors related to economy and politics and to some extent strategy, the combined role of militarism, energy use, CO₂ emissions and economic growth has not yet been sufficiently studied especially within the group of the largest military-spending countries in the world. Filling this gap is of key importance in the interactivity of economic, environmental, political and bureaucratic forces which it can be seen are fundamental in influencing the military expenditure and resource policy. strategic This paper is been contributed to the literature by examining these associations in the USA, China, Russia, India, and Saudi Arabia to provide an inclusive view of these interconnections between defense expenditure, environmental sustainability, and economic growth.

Based on the literature discussed, this study proposed the following hypothesis:

H1: CO₂ emission has positive impact on Military Expenditure

H2: Economic Growth Are positively Associated with Military Expenditure

H3: Energy Price Positive impact on the Military Expenditure

H4: Eternal Conflicts Increase the Military Expenditure

H5: Population growth Contribute to increase Military Expenditure

Material and method

According to Smith (1980, 1989) and Dunne and Mohammed (1995), expenditure on defence is based on economic competency, security needs, and sociopolitics. This study applies a neoclassical military expenditure demand model as foundational of the frame work. while public choice and bureaucratic behaviour theories describe how political and institutional dynamics affect expenditure decisions, Strategic Resource Theory and Environmental Security Theory highlight that CO₂ emission and Energy prices as Significant Security theart. These classical and contemporary model illustrate the complexity of military expenditure in the five main defence-budgeting countries.

Model specification

It consequently, the need for a nation's military spending might be modeled as

$$ME = D(GDP, CO_2, EC, EP, PoP) \quad (\text{Eq.1})$$

where ME stands for Military Expenditure, GDP stands for Gross Domestic Product, CO₂ means Carbon emission, EC stands for External Conflicts, EP stands for Energy Price and PoP stands for Population.

Econometric specification of the model is as follows:

$$ME_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 CO_{2it} + \alpha_3 EC_{it} + \alpha_4 EP_{it} + \alpha_5 PoP_{it} + u_{it} \quad (\text{Eq.2})$$

We convert this equation in to loglinear form

$$\ln ME_{it} = \alpha_0 + \alpha_1 \ln GDP_{it} + \alpha_2 \ln CO_{2it} + \alpha_3 \ln EC_{it} + \alpha_4 \ln EP_{it} + \alpha_5 \ln POP_{it} + u_{it} \quad (\text{Eq.3})$$

where,

$\ln ME_{it}$ = The Natural log of military expenditure as a percentage of GDP,

$\ln GDP_{it}$ = GDP per capita expressed as a natural logarithm,

$\ln CO_{2it}$ = The natural log of carbon dioxide emissions (metric tons per capita),

$\ln EC_{it}$ = Natural log of External Conflicts,

$\ln EP_{it}$ = Natural log of Energy Prices as share of GDP(measured by oil rents),

$\ln POP_{it}$ = Population's natural log.

Variables and data sources

Table 1 lists together with their explanations and linked data sources all the dependent and independent variables. As the table for five main military budgeting countries over the period 1990–2020 shows, data is gathered from several different source.

Table 1. *Variables description and data sources*

Variable Name	Type of Variable	Definition of Variable	Data Source
Military Expenditure	Dependent Variable	Military spending (% of GDP)	Stockholm International Peace Research Institute (SIPRI)
GDP	Independent Variable	Real GDP per capita (current us dollar)	World Development Indicator World Bank (WDI)
CO ₂ emissions	Independent Variable	CO ₂ emissions (metric tons per capita)	Climate Watch Historical GHG Dataset
External Conflicts (EC)	Independent Variable	External Conflicts (EC) The indicator is measured on a scale that goes from 0 to 12. When a country ranks 0, war, force by other militaries across borders, and threats of terrorism against it come from foreign countries and allied groups. 12 mean no outside threats or problems are shown	International country Risk Guide(ICRG)
Energy Prices (EP)	Independent Variable	Oil rents(% of GDP)	World Development Indicator World Bank (WDI)
Population (pop)	Independent Variable	Total population 65 years of age or older	World Development Indicator World Bank (WDI)

We use general models inside an integrated framework to evaluate defense expenditure proposals using the Engle-Granger two-step approach. For NATO countries (Gadea et al., 2004); for Spain (Gadea and Montañes, 2001); for Turkey (Chletsos and Kollias, 1995); for Greece (Kapopoulos and Lazaretou, 1993); or the Johansen (1991) maximum likelihood method for cointegration (see Gadea et al., 2004 for Canada). These approaches require continuous evaluation and consideration to be effective. If not, they should use alternative variables and undertake unit root testing. To evaluate long-term effects without depending on the series to be stationary, Pesaran and Pesaran (1997) created the autoregressive distributed lag (ARDL) model. For data from Greece, Spain, and Portugal, Dan and Al. (2003) used this approach. This approach was also applied to Turkey. Solomon (2005) conducted research on Canada, while Gadea et al. (2004) focused on NATO members. Considered a public service, security does not match the rate of population increase. Public spending (G) has nothing to do with military operations. We want to apply this model, which reflects the postponed advantages of defense by combining negative values with its economic expenses.

Econometric techniques

Unit root test

Panel unit root tests assess variable integration. *Tables 2 and 3* show each variable's IPS and Fisher-ADF panel unit root tests. We evaluate both the variable levels and the starting difference. Examining the variables at the strictest level we reject the null hypothesis. The variables have both individual and common unit roots. After the initial distinction, almost all variables meet the study's specifications.

ARDL

The ARDL co-integration method, created by Pesaran et al. (2001), is used to study the long-term relationships between military spending and its influencing factors. This method is powerful even for small sample sizes, as it can handle variables that are integrated in different orders, thereby addressing various degrees of influence.

Panel cointegration test

This study applied Pedroni (2004) and Kao (2003) approach. To assess the long-term relationships between military spending, GDP, population, and CO₂ emissions in the five countries with the highest military spending, we used panel data approaches. In order to determine stationarity, we have assumed a mixed order of integration, indicating the existence of both stationary and non-stationary series. However, by including a long-term bond, we have been able to track the effects over time. Interpersonal error variability may affect the accuracy of parameter estimations in a cross-sectional investigation. The results of the panel cointegration test are shown in the table in our study. The variables have a long-term relationship, as evidenced by four of the six statistical measures that The null hypothesis that there is no cointegration is strongly rejected. However, neither the panel nor the group rho statistics provided sufficient evidence to rule out the null hypothesis. The presence of a long-term link is usually confirmed by the panel figures, which are valid for all chosen countries. The majority of tests show a believable co-integration between military spending, GDP, population, and carbon dioxide emissions, rejecting the null hypothesis at a 5% significance level. *Tables 4 and 5* demonstrate that every statistical parameter of the Kao residual cointegration test is significant. This demonstrates that the factors under investigation have a lasting relationship. The optimal selection among levels, logarithms, or variable shares remains ambiguous (Solomon, 2004). Utilizing shares can reduce conversion issues; nonetheless, the interpretation of the outcomes remains ambiguous. Furthermore, Hartley and Sandler (1995) assert that the level variable more accurately explains the need for military expenditure.

Result

Unit root test

External conflicts (EC), (GDP), and (CO₂) are not significant at the level but significant at the first difference (*Table 2*). Military expenditure (ME), Energy prices (EP) and population (Pop) are significant at the specified level. Here, we determine the mixed order of integration. Result justifies the use of ARDL Co-integration.

Table 2. *Im, Pesaran and Shin W-Stat*

Variable	1(0)	1(1)
lnEC	--0.69784(0.2426)	-6.11342(0.0000)
lnGDP	0.81583(0.7927)	-3.68566(0.0001)
lnCO ₂	1.33573(0.9092)	-2.10306(0.0177)
lnME	-3.14626(0.0008)	
lnEP	-1.56095(0.0593)	
lnPop	-5.43039(0.0000)	

The following *Table 3* gives the test statistics and p-values (listed in parentheses) for each variable's level [I(0)] and first difference [I(1)]. This test using ADF helps find out if a time series follows a stationary pattern. The null hypothesis means that the variable does not show stationarity. If the p-value comes out to be lower than 0.05, the null will be rejected and we will state that the series is stable.

Table 3. *Augmented Dickey-Fuller*

Variable	1(0)	1(1)
lnEC	11.6475(0.3093)	54.1213(0.0000)
lnGDP	4.6454(0.9136)	31.4773(0.0005)
lnCO ₂	6.65651(0.7574)	22.9691(0.0109)
lnME	27.4010(0.0022)	
lnEP	19.4377(0.0350)	
lnPop	51.2106(0.0000)	

External conflicts (EC), Military expenditure (ME), energy prices, (EP), and population (Pop) are significant at the level. In contrast, GDP and CO₂ are significant at the first difference. These Result indicating a mixed order of integration. Result justifies the use of ARDL Co-integration.

Panel cointegration tests

This investigation employed the approach of Kao (2003) and Pedroni (2004). We used panel data approaches to analyze the long-term relationships among military expenditures, GDP, population, and CO₂ emissions in the five nations with the greatest military spending. We have assumed a mixed order of integration to ascertain stationarity, signifying the presence of both stationary and non-stationary series. Nonetheless, the presence of a long-term bond has enabled us to assess the impact over time. In a cross-sectional investigation, interpersonal error variability can influence the precision of parameter estimations. The table in our research presents the outcomes of the panel cointegration test. Four of six statistical indicators strongly reject the null hypothesis of no cointegration, indicating a long-term relationship. However, the group rho statistics and panel did not reject the null hypothesis. Panel figures from all selected nations frequently confirm a long-term relationship. Most tests reject the null hypothesis at 5%; military spending, GDP, population, and CO₂ emissions are likely co-integrated.

As shown in *Tables 4 and 5*, all Kao residual cointegration test statistical values are significant. This suggests a long-term link between both of them.

Table 4. The Pedroni Residual a Cointegration test

	Statistics	Prob	Statistics	Prob
The v-Statistic of the Panel	-2.679623	0.9963	-3.332492	0.9996
Rho-Statistic of the panel	3.152456	0.9992	2.901987	0.9981
PP-Statistic of the panel	-4.243808	0.0000	-28.62203	0.0000
ADF-Statistic of the Panel	-1.631677	0.0514	-3.559258	0.0002
Individual AR coefficients serve as an alternative hypothesis (between dimensional)	-	-	-	-
Rho-Statistic of Group	4.039737	1.0000	-	-
PP-Statistic of Group	-34.28546	0.0000	-	-
ADF-Statistic of group	-1.990904	0.0232	-	-

Table 5 presents the results of the Kao residual cointegration test. The t-statistic for the ADF is -3.542747, and the probability value is 0.0002, proving that the outcome is highly significant. Since the null hypothesis is rejected at the 1% level, it means that the results favor the idea of cointegration among the variables. The evidence suggests the long-term relationship between military expenditure and GDP, population (Pop), CO₂ emissions, and the external conflicts (EC) across five countries with the highest defense budgets. Because the residual and HAC variances are low, it can be seen the model is stable and reliable. All in all, the findings prove the presence of cointegration and make it appropriate to use the ARDL bounds test.

Table 5. Kao residual cointegration test

ADF	t-Statistic	Prob
	-3.542747	0.0002
Residual variance	0.001741	
HAC variance	0.001395	

Note: Kao residual co-integration panel co-integration process has no co-integration source as its null hypothesis: Authors' estimation

Table 6 shows the correlation analysis: all statistics are statistically significant, with no problem of multicollinearity. External Conflicts (EC) GDP and Energy prices (EP) are strongly influenced by military expenditure (ME). Military expenditure (ME) shows a negative relationship between population growth (POP) and CO₂ emissions. This result supports the theory that military expenditure rises with external conflicts (EC) and energy prices (EP) and decreases with the population and CO₂ emissions.

D(lnCO₂) show a significant and positive impact at 5% level (0.9236, p=0.0288) military Expenditure in short run CO₂ emission are linked to higher military expenditure. This indicate increased environmental insecurity or a shift in governmental priorities towards defense in reaction to environmental pressures (Table 7).

D(lnGDP) show statistically significant and negative impact at 1% (-0.4060, p=0.0051) in short run GDP increase is associated with reduction of Military Expenditure, due to improve the economic condition need to reduced the excessive military expenditure.

Table 6. Correlation matrix

Variables	lnME	ln GDP	lnEC	lnCO ₂	LnEP	lnPoP
lnME	1.000000					
lnGDP	0.476767	1.000000				
lnEC	0.0000	-0.174230	1.000000			
lnCO₂	-0.106184	0.0395	0.2118	1.000000		
lnEP	0.519694	0.0000	0.0000	-0.071907	1.000000	
lnPoP	0.532894	-0.299963	-0.059700	-0.167654	0.0477	1.000000
	0.0000	0.0003	0.4835	0.400676	-0.198349	0.0188
	-0.275728	0.298743	-0.055838	0.0000		
	0.0010	0.0003	0.5123			

Table 7. Short run ARDL

Dependent Variable = lnME				
Variable	Coefficient	Std. Error	t-Statistic	Prob.values
D(lnGDP)	-0.406002***	0.141046	-2.878512	0.0051
D(lnEC)	-0.127451	0.108271	-1.177144	0.2426
D(lnCO ₂)	0.923615**	0.414753	-2.226905	0.0288
D(lnEP)	-0.051759	0.053493	-0.967592	0.3362
D(lnPoP)	-11.89862	12.02162	-0.989769	0.3253
ECM _{t-1}	-0.151227	0.133417	-1.133494	0.2604
Mean dependent var	S.E. of regression	Sum of squared resid	Schwarz criterion	Log likelihood
-0.000902	0.030358	0.073728	-2.446000	319.4693
S.D. dependent var	Akaike info criterion	Hannan-Quinn criter		
0.044171	-3.706704	-3.194391		

Notes: *denotes significance at 10%; **at 5%; and***at 1% respectively

D(lnEP) (energy prices), D(lnPoP) (population) and D(lnEC) (external conflicts) are statistically insignificant in short run change in variable have no effect on military expenditure.

1% increase the CO₂ emission is associated 0.78% decrease the Military Expenditure. This unexpected sign reflect a shift toward environmentally sustainable military technologies. Surprisingly CO₂ emission exhibit a negative relationship with Military Expenditure (-0.775290*) (Table 8). There is positive and significant relationship between GDP and Military Expenditure 1% increase the GDP associated with 0.49% increase the Military Expenditure, government have more resources as economy grow provide more fund to the defence. A 1% increase in Energy Prices lead to increase to the 0.39% Military Expenditure, increasing cost of the Energy Price also push the Military budget. Similarly, 1% increase the External Conflicts lead to increase 2.21% increase the Military Expenditure. External conflicts trigger the military expenditure. Finally, 1% increase the population associated with the 1.54% decrease Military Expenditure.

Table 8. Long run results

Dependent Variable= LnME				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnGDP	0.494473**	0.192147	2.573410	0.0119
lnEC	2.214125***	0.388897	5.693339	0.0000
lnCO ₂	-0.775290*	0.430088	-1.802631	0.0752
lnEP	0.391774***	0.046936	8.347057	0.0000
lnPoP	-1.537857***	0.384487	-3.999762	0.0001

Notes: *denotes significance at 10%; **at 5%; and***at 1% respectively

Dumitrescu and Hurlin panel causality

As a robustness check, the Dumitrescu and Hurlin (2012) panel causality test was employed to explore short-run causal relationships among the variables (*Table 9*). The results indicate no short-run causality from CO₂ emissions to military expenditure (Prob = 0.9755) and from energy prices to military expenditure (Prob = 0.4402), suggesting that the influence of environmental concerns and energy markets on defense budgeting may be more long-term in nature. This complements the ARDL long-run results, where CO₂ emissions and energy prices showed significant effects, highlighting that policy shifts driven by environmental security and energy shocks are gradual rather than immediate. Therefore, the short-run causality tests support the notion that the response of military expenditure to these variables is not contemporaneous, reinforcing the structural nature of such relationships.

Table 9. Dumitrescu-Hurlin (DH) panel causality

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
lnGDP does not have a consistent effect on lnME	7.89402	0.81506	0.4150
lnEC does not have a consistent effect on lnME	6.59619	0.25656	0.7975
lnCO ₂ does not have a consistent effect on lnME	6.07149	0.03077	0.9755
lnEP does not have a consistent effect on lnME	4.20642	-0.77184	0.4402
lnME does not have a consistent effect on ln EP	12.2405	2.68548	0.0072
lnPoP does not have a consistent effect on lnME	10.6807	2.01424	0.0440
lnGDP does not have a consistent effect lnCO ₂	11.2150	2.24417	0.0248
lnEP does not have a consistent effect on lnGDP	7.21718	0.52379	0.6004
lnGDP does not have a consistent effect on lnEP	25.7840	8.51368	0.0000
lnPoP does not have a consistent effect on lnGDP	12.0878	2.61979	0.0088
lnGDP does not have a consistent effect on lnPoP	9.20246	1.37812	0.1682
lnCO ₂ does not have a consistent effect on lnEC	9.86396	1.66278	0.0964
lnEP does not have a consistent effect on lnEC	28.7923	9.80824	0.0000
lnPOP does not have a consistent effect on lnEC	13.4411	3.20212	0.0014
lnEP does not have a consistent effect on lnCO ₂	8.98231	1.28338	0.1994
lnCO ₂ does not have a consistent effect on ln EP	10.3869	1.88784	0.0590
lnPoP does not have a consistent effect on ln CO ₂	12.0627	2.60898	0.0091
lnCO ₂ does not have a consistent effect on lnPoP	13.7191	3.32176	0.0009
lnPoP does not have a consistent effect on lnEP	15.4217	4.05444	5.E-05
ln EP does not have a consistent effect on lnPoP	17.0951	4.77456	2.E-06

Discussion

Military spending is negatively impacted by GDP in the short term at a statistically significant level (coefficient = -0.4060, $p = 0.0051$). This shows that higher economic output is linked to lower military spending, most likely as a result of better economic conditions that lessen the perception of the need for disproportionate defense spending. According to Deger and Sen (1983) and Berthélemy et al. (1995), economic progress can cause priority to shift toward social and economic sectors, and this finding supports their claims.

In the short run, CO₂ emissions have a positive and significant effect, indicating either a shift in government priorities toward defense in response to environmental concerns or increased environmental insecurity (Homer-Dixon, 1999). But in long run, there is a negative correlation between military spending and CO₂ emissions (coefficient = -0.7753, $p = 0.0752$). This finding is consistent with Lin and Zhu (2019), which suggests that governments may eventually use non-military means to deal with environmental issues. Additionally, this result leads us to reject H1, which hypothesized a positive correlation between military spending and environmental degradation.

In the meantime, short-term changes in population ($D(\ln PoP)$), energy costs ($D(\ln EP)$), and external conflicts ($D(\ln EC)$) are statistically insignificant, suggesting that they do not immediately impact military spending (Collier and Hoeffler, 2004).

In the long run GDP Show significant and positive impact on the Military Expenditure. In the long run 1% increase the GDP associated with 0.49% increase the Military Expenditure, government have more resources as economy grow provide more fund to the defence.

Energy price strong and positive impact on the millitary Expenditure a 1% increase in energy prices results in a 0.39% increase in military spending (coefficient = 0.3918, $p < 0.001$). This supports H3 and demonstrates the strategic significance of energy security in determining defense budgets and the most significant long-term driver of military expenditures is external conflict; for every 1% increase in conflict, military spending increases by 2.21% (coefficient = 2.2141, $p < 0.001$). The results of Gurr (1994) and Collier and Hoeffler (2002), who emphasized that geopolitical instability necessitates quick military reactions and greater defense burdens in conflict-prone areas, are echoed by this finding, which supports H4.

In the long run there is negative relationship between population and Military Expenditure, more old age people mean government spending more towards the social services and reduce the defence budget Dunne and Perlo-Freeman (2003) larger population decrease the external threat and spending shift for other public periorities finding reject the hypothesis.

Conclusion and policy recommendation

This paper aims to fill the knowledge gap on how geopolitical conflicts, environmental challenges, and economic development together shape military expenditures. Evaluating the interaction between CO₂ emissions, energy prices, and economic performance in defense spending is crucial, espically considering global concern about sustainability and security.

The finding suggest that while CO₂ emissions increase military spending in the long run, economic development reduced it in the short term. Energy price, and population

growth minimal immediate effects. However, with a minor error correction term, long-term equilibrium seems to be reached gradually.

In long-term military expenditure is positively influenced by economic development, energy consumption, and energy prices. This implies wealthier, energy-intensive nations dedicate more resources to defense, the negative long run impacts of CO₂ emissions on defense spending over time point to environmental issues perhaps influencing budgetary choices eventually. Population increase reduces military budget as well, implying a more focus on social development.

These results highlight the complex relationship between defence strategies, environmental challenges and economic performance. Policymakers in energy-dependent nation need to strike balance between security needs and financial sustainability future studies examining the shifting dynamics between military spending and economic cycle and geopolitical factor would offer valuable insight for adaptive policy making.

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