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Military spending and CO2 emissions: Empirical findings from countries with highest per capita military spending

Waldemar Tarczyński
University of Szczecin,
Poland
waldemar.tarczynski@usz.edu.pl
ORCID 0000-0003-0499-7680

Łukasz Roman
University of Justice,
Warsaw, Poland
lukasz.roman@swws.edu.pl
ORCID 0000-0002-4159-3557

Krzysztof Rejman
Rzeszow University of Technology,
Poland
k.rejman@prz.edu.pl
ORCID 0000-0001-6790-8775

Raufhon Salahodjaev
Akfa University, Uzbekistan,
Tashkent State University of Economics, Uzbeksitan
salahodjaev@gmail.com
ORCID 0000-0002-5578-811X

Sardor Azam
Akfa University,
Uzbekistan
sazam@wiut.uz

Abstract. This study aims to contribute to existing research on CO2 emissions by focusing on military spending. We use data from 47 countries with the highest levels of per capita military spending over the period from 2000 to 2015. The results from the two-stage GMM estimator suggest a positive relationship between defence spending and CO2 emissions: 1% increase in per capita military spending leads to a 0.05% increase in CO2 emissions per capita. GDP per capita has an inverted U-shaped relationship with CO2 emissions, which confirms the

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Environmental Kuznets Curve (EKC) hypothesis. Renewable energy is also found to mitigate CO2 emissions. Some policy implications of this study are discussed.

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1. INTRODUCTION

The global level of CO2 emissions increased by 45% between 2000 and 2018. This had significant health and social impacts on quality of life across high- and low-income countries. According to the World Health Organization (WHO), climate change costs 150,000 lives lost every year, and this figure is projected to rise to 300,000 in the next decade. Burke et al. (2018) posit that in such countries as the USA and Mexico climate change will result in an additional 21,000 suicides by 2050. CO2 emissions have been linked to health outcomes in Turkey (Erdogan et al., 2019), CIS (Rasoulinezhad et al., 2020), and developing countries (Ahmad et al., 2021). As a result, scholars are identifying the variables that affect CO2 emissions. Many studies are informed by the EKC hypothesis, which postulates that at the early stages of economic development, GDP growth increases CO2 emissions and after a certain threshold further rise in income mitigates CO2 emissions (Fujii et al., 2018). These studies explore the effects of trade, FDI, energy use, tourism, urbanization, globalization, and human capital (e.g., Ben Jebli et al., 2019; Nathaniel et al., 2021).

This paper contributes to the research on drivers of CO2 emissions in several important ways. We explore the effect of military spending on CO2 emissions. There is ample evidence that military spending has effect on economic growth (Farzanegan, 2014); fiscal deficit (Caruso & Di Domizio, 2017); exchange rate regime (Miyamoto et al., 2019); and the likelihood of involvement in environmental treaties (Carbonell, 2016). Therefore, we anticipated that military spending would influence CO2 emissions. We focus on countries with the highest share of military spending as a percentage of GDP and utilize a two-step GMM estimator that considers the problems of endogeneity and heteroskedasticity in the panel data. Section 2 reviews the relevant empirical research on CO2 emissions. Section 3 discusses data and methodology, and Section 4 provides the empirical results.

2. LITERATURE REVIEW

2.1. Environmental Kuznets Curve

One can identify two major streams of study on the EKC for CO2 emissions. A first group of studies confirms the EKC framework for single and groups of countries. For example, Adebayo (2020) investigates the relationship between GDP, trade, energy use, and CO2 emissions in Mexico between 1971 and 2016 and using ARDL, FMOLS, and DOLS estimators confirms the validity of the EKC. Moreover, the study shows bidirectional causality between economic growth and CO2 emissions. Ahmed and Long (2013) explore the EKC in Pakistan between 1971 and 2008. The authors' use ARLD bounds test indicate that, in the long run, there is inverted U-shaped relationship between GDP per capita and CO2 emissions. Saboori et al. (2012) investigated the links between real GDP per capita and CO2 emissions for Malaysia between 1980 and 2009 using ARDL method. The econometric findings also showed an inverted U-shaped relationship between GDP per capita and emissions exists, both in short- and long-term. Luo et al. (2017) tested for an EKC in G20 countries between 1960 and 2010. The study's fixed effects regression and GMM estimator validate a quadratic relationship between GDP per capita and CO2 emission. What is more, the authors found that in the case of developing countries, the turning point is not attainable in the short-term. Ahmad et al. (2017) tested the EKC hypothesis for Croatia between 1992 and 2011. The authors showed that the inverted U-shaped relationship between GDP per capita and CO2 emissions is robust using ARDL modelling, Granger causality test, and VECM methods. In addition, they found a unidirectional causality from economic growth to CO2 emissions in the long-term. In their study, the authors Rajkoomar et al. (2022) used PRISMA to simultaneously track carbon emissions versus economic growth in Africa from 2018 to 2022. The environmental Kuznets curve hypothesis explains the economic impact of carbon emissions over a certain period of time. According to the study results, economic growth's impact on the environment is dominant. Supriyanto et al., (2022) investigated the interaction between CO2 emissions, economic expansion, and national health policies among 10 ASEAN countries from 2011 to 2020. Empirical research data demonstrate a causal relationship between economic expansion and CO2 emissions.

A second stream of research fails to confirm either the EKC relationship or the hypothetical economic turning point. For example, Musolesi et al. (2010) applies a hierarchical Bayesian model to a sample of 109 economies between 1959 and 2001. The results for high-income countries suggest an N-shaped specification between GDP and CO2 emissions, whereas there is direct linear relationship between income and emissions for low-income countries. Weak evidence for the EKC hypothesis was documented in a study by Baek (2015) using data for 7 Arctic countries from 1960 to 2010. The ARDL modelling results show that energy consumption increases emissions and economic growth mitigates CO2 emissions only in some of the countries. Hasanov et al. (2019) explores the relationship between economic growth and CO2 emissions in Kazakhstan between 1992 and 2013 using several cointegration techniques to find that GDP per capita has an inverted U-shaped relationship with CO2 emissions. The turning point, however, exceeds existing data for Kazakhstan. Minlah and Zhang (2021) test the presence of an EKC pattern for CO2 emissions in Ghana using a rolling window Granger causality test. The results contradict the predictions of the EKC: GDP per capita has a positive impact on CO2 emissions in Ghana throughout the period of analysis. Iwata et al. (2012) explores EKC for 11 OECD countries using data from between 1960 and 2003. The results from their ARDL modeling show that although EKC hypothesis is confirmed in Finland, Japan, Korea, and Spain, the turning point is meaningful only for Finland. Therefore, the EKC theory has little economic meaning for OECD members states. Beşe and Kalayci (2021) explores the EKC hypothesis for the UK, Denmark, and Spain between 1960 and 2014. Using the ARLD bounds technique and cointegration, the study fails to confirm the EKC for these countries. The authors document a neutrality hypothesis for these countries.

Arouri et al. (2012) uses cointegration method to explore the relationship between GDP and CO2 emissions for 12 MENA countries between 1981 and 2015. Their results show an inverted U-shaped link for these variables in the region, but the separate turning points are very high in several countries. Leal and Marques (2020) assess the EKC for the 20-highest CO2 emitters from the OECD region between 1990 and 2016. The results from Driskoll-Kraay standard error approach and ARDL estimators suggest that the significance of the EKC hypothesis depends on the level of globalization. The study finds quadratic relationship between GDP and CO2 emissions only for high-globalized countries.

2.2. Military spending and other drivers of CO2 emissions

Considering the mixed evidence for the EKC hypothesis, another large stream of research has emerged that incorporates other variables into the EKC framework. For example, Disli et al. (2016) uses a sample of 69 different countries and finds that cultural values have an impact influence on the relationship between GDP and CO2 emissions. Katircioglu (2017) test the relationship between GDP, oil prices, and CO2 emissions in Turkey using cointegration analysis, and their empirical results not only confirm the EKC hypothesis, but also indicate that oil prices have a negative impact on CO2 emissions. Liu et al. (2020) utilise a semi-parametric fixed effects model to show that globalization has an inverted U-shaped relationship with CO2 emissions in a sample of G7 countries between 1979 and 2015. Zhang et al. (2016) applied quantile regression estimator for panel data and found an inverted U-shaped relationship between corruption and CO2 emissions in APEC countries. Indeed, the overall impact of corruption on CO2 emissions is positive (Lyeonov et al., 2023, Vasylieva et al., 2019).

Other studies explore the relationship between tourism (Paramati et al., 2017), renewable energy (Zoundi, 2017; Naumenkova et al., 2022), nuclear energy (Saidi & Omri, 2020), digital transformations (Melnyk et al., 2021), and remittances (Yang et al., 2020; Versal and Sholoiko, 2022) and CO2 emissions, but few focus on the military spending and CO2 emissions nexus. Bildirici (2019) examined the relationship between military spending, energy use, GDP, and CO2 emissions in G20 countries between 1965 and 2016 using panel cointegration and PARDL methods to reveal a unidirectional causality from military spending to CO2 emissions. Ahmed et al. (2020a) tested the relationship between military spending, GDP, and ecological degradation in Pakistan between 1971 and 2016. The results from the cointegration technique and bootstrap causality test show that military spending has causal effect and increases environmental degradation, while reducing GDP growth rates. Ahmed et al. (2020b) assesses the relationships between military spending, energy consumption, and CO2 emissions in Myanmar between 1975 and 2014. The ARDL regression results indicate not only that military spending increases CO2 emissions and inhibits GDP growth rates, but also a bi-directional causality between energy consumption and CO2 emissions. Isiksal et al. (2021) examines the militarization-CO2 emissions nexus in the 10 countries with the highest levels of military spending between 1993 and 2017. The results from the common correlated effects mean group estimator show that military spending worsens air quality. Erdogan et al. (2022) investigates the relationship between military spending and CO2 emissions in four Mediterranean countries using a global VAR model between 1965 and 2019. The results indicate that reducing military spending should not be overlooked as a carbon mitigation strategy.

3. METHODOLOGY

Our study examines data from a sample of the 47 countries with the highest levels of military spending between 2000 and 2015. After discarding missing observations, our sample includes Australia, Austria, Azerbaijan, Belgium, Bahrain, Brunei Darussalam, Canada, Switzerland, Chile, Colombia, Cyprus, Germany, Denmark, Algeria, Spain, Estonia, Finland, France, United Kingdom, Greece, Croatia, Ireland, Iraq, Israel, Italy, Japan, Korea, Rep., Kuwait, Lebanon, Luxembourg, Namibia, Netherlands, Norway, New Zealand, Oman, Poland, Portugal, Russian Federation, Saudi Arabia, Singapore, Slovak Republic, Slovenia, Sweden, Seychelles, Turkey, Uruguay and United States. The data for the variables was obtained from the World Bank's Development Indicators portal.

The dependent variable in our study is tCO2 emissions per capita as reported by the Carbon Atlas Database. In our sample, tCO2 emissions per capita range from between 0.91 in Namibia to 31.35 in Kuwait. The main independent variable is military spending per capita, a figure that includes all current and capital expenditures on the armed forces, including peacekeeping forces; defence ministries and other government agencies engaged in defence projects; paramilitary forces; and military space activities. In our sample, military spending per capita ranges from 14.85 USD in Azerbaijan to 2748 USD in Saudi Arabia. Fig. 1 plots the visual association between military spending and CO2 emissions for 2015. The relationship between defence spending and GHG is positive.

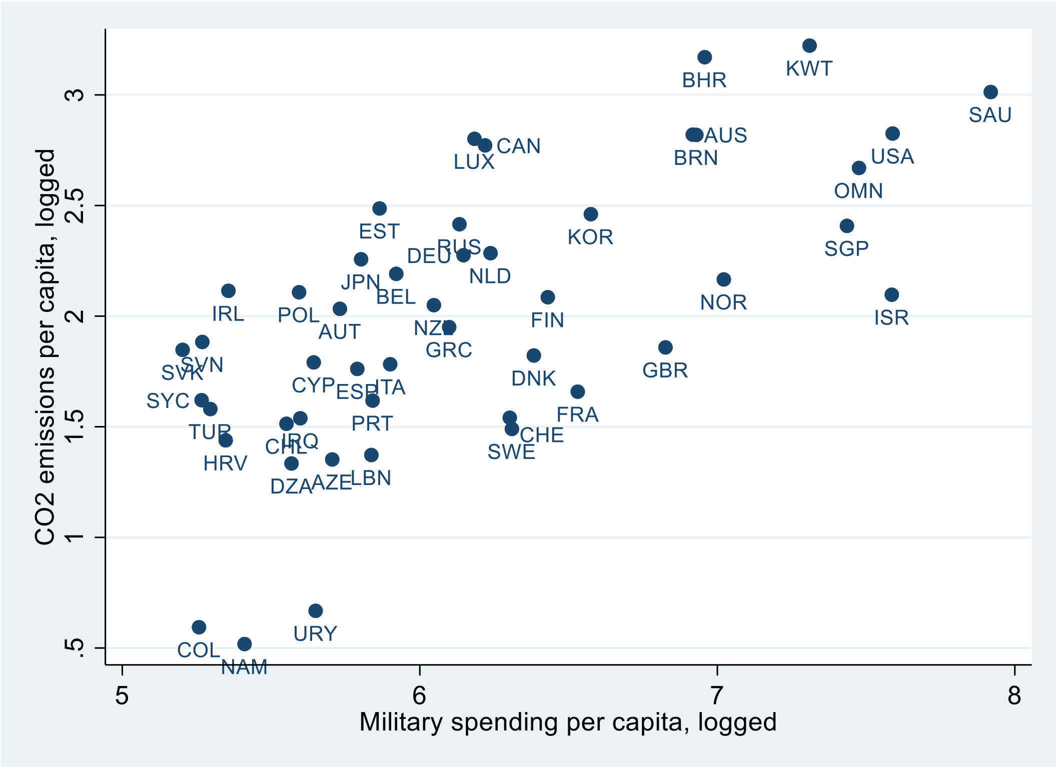

Figure 1. Scatterplot between CO2 emissions and military spending in 2015

We explore the relationship between military spending and CO2 emissions with a revised STRIPAT model. The STRIPAT model explores the stochastic impact of population, affluence, and technology on environmental outcomes. In this model, affluence is measured as GDP per capita, population is proxied by urbanization rate or population density, and technology is measured using the indicators of the energy sector. In its linear form, the model can be represented as:

$$CO2_{i,t} = a_0 + a_1 GDP_{i,t} + a_2 URBAN_{i,t} + a_3 ENERGY_{i,t} + \varepsilon_{i,t} \qquad (1)$$

The STRIPAT model can be extended by including other variables. For the goals of our study, it can be expressed as:

$$CO2_{i,t} = a_0 + a_1 GDP_{i,t} + a_2 GDP_{i,t}^2 + a_3 URBAN_{i,t} + a_4 TRADE_{i,t} + a_5 ENERGY_{i,t} + a_6 RE_{i,t} + a_7 MILITARY_{i,t} + \varepsilon_{i,t} \qquad (2)$$

where GDP is GDP per capita, URBAN is the urbanization rate (%), TRADE is trade as a % of GDP, ENEGY is the energy intensity level of the primary energy measured, RE is the share of renewable energy consumption, MILITARY is military spending per capita, and ε is an error term. We include GDP per capita and its squared term to account for the quadratic relationship between income and CO2 emissions (Cole et al., 1997). Because trade openness and renewable energy have been widely assessed in the EKC framework (e.g., Zafar et al., 2019), we also include these variables in the revised STRIPAT model. The summary statistics are reported in Table 1.

Table 1

Summary statistics

Variable	Description	Mean	SD	Min	Max
CO2	tCO2 per capita, log	2.07	0.68	-0.09	3.45
GDP	GDP per capita, adjusted for PPP	10.39	0.60	8.31	11.66
TRADE	Trade as % of GDP	94.47	64.67	19.80	437.33
URBAN	Urbanization rate (%)	75.07	13.84	32.37	100.00
ENERGY	Intensity level of primary energy measured in MJ/$2011 PPP GDP, log	1.53	0.34	0.67	2.58
RE	Renewable energy consumption (%)	13.31	13.64	0.00	60.19
MILITARY	Military spending per capita, log	6.02	0.87	2.70	7.92

Following extant research on the antecedents of CO2 emissions (Kuldasheva & Salahodjaev, 2022; Salahodjaev et al., 2022; Huang et al., 2021; Mentel et al., 2022) we use the two-step GMM estimator. A two-step GMM estimator has numerous advantages over such methods as random effects, fixed effects, and generalized least squares of panel corrected standard errors. This method is more efficient for panel data studies when the number of countries exceeds the number of years of data. In addition, the two-step GMM estimator solves the problems of endogeneity, omitted variable bias, heteroskedasticity, and simultaneity in cross-country research (Omri et al., 2014).

4. EMPIRICAL RESULTS AND DISCUSSION

The main results are reported in Table 2. Column 1 estimates conventional STRIPAT model as expressed in Eq. (1), whereas column 2 estimates the revised STRIPAT model as in Eq. (2). First, we find that GDP per capita has quadratic (inverted U-shaped) relationship with CO2 emissions, which confirms the EKC hypothesis. The turning point in Column 2 is 15,620 international dollars, and this is consistent with some of the studies on the EKC for CO2 emissions. For example, Ozatac et al. (2017) documents the turning point for Turkey between 1960 and 2013 as approximately 16,600 USD. Halkos and Tzeremes (2009) use data from 17 OECD member states between1980 and 2002 and identify a turning point at nearly 16,000 USD. We find that energy intensity has a positive impact on CO2 emissions. In column 1, a 1% increase in energy intensity leads to a 0.60% increase in per capita CO2 emissions. We also confirm that renewable energy mitigates CO2 emissions (Radmehr et al., 2021; Kuzior et al., 2023). For example, a 1% increase in RE consumption leads to a 0.79% decrease in CO2 emissions. Turning to our main variable of interest, we find that military spending has a significant positive effect on CO2 emissions in both columns 1 and 2. The results in the revised STRIPAT model (column 2) indicate that a 1% increase in per capita military spending leads to a 0.05% increase in CO2 emissions per capita. The instruments used in the two-step GMM system are credible and reliable: the Hansen p-values are not statistically significant in Table 2.

Table 2

Main results

	I	II
$CO2_{t-1}$	0.5092 (14.26)***	0.3919 (13.27)***
GDP	1.1435 (1.75)*	1.1308 (3.19)***
GDP^2	-0.0396 (1.29)	-0.0362 (2.14)**
URBAN	-0.0031 (1.85)*	0.0019 (1.71)*
ENERGY	0.5954 (9.93)***	0.6303 (12.16)***
MILITARY	0.0691 (3.18)***	0.0509 (3.09)***
TRADE		-0.0001 (0.70)
RE		-0.0079 (7.30)***
Constant	-7.6599 (2.28)**	-7.8609 (4.29)***
AR (1)	0.001	0.000
AR (2)	0.435	0.432
Hansen p-value	0.216	0.319
EKC turning point	14,400	15,620
N	702	702

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

We next test whether quality of institutions can influence the relationship between military spending and CO2 emissions. Indeed, several studies assess the interplay between governance, military spending, and economic growth (d'Agostino et al., 2020). We included interaction terms between corruption perceptions index (CPI) and military spending (column 1), between economic freedom (EF) and military spending (column 2), and between rule of law (RL) and military spending (column 3). While indicators of the quality of institutions have a negative impact on CO2 emissions, only economic freedom influences the military spending and CO2 emission nexus. The interaction term is negative and significant, which suggests that in countries with more economic freedom the effect of military spending on CO2 emissions less.

Table 3

The role of institutional quality

	I	II	III
$CO2_{t-1}$	0.3798 (9.94)***	0.3505 (10.44)***	0.3783 (13.33)***
GDP	0.8449 (1.34)	0.2440 (0.44)	1.0253 (2.42)**
GDP^2	-0.0193 (0.63)	0.0123 (0.47)	-0.0243 (1.16)
TRADE	0.0002 (0.92)	0.0003 (1.70)*	0.0001 (0.97)
URBAN	0.0020 (1.49)	-0.0002 (0.11)	0.0013 (1.16)
ENERGY	0.6823 (15.09)***	0.7081 (16.80)***	0.6615 (15.69)***
RE	-0.0055 (4.70)***	-0.0060 (3.45)***	-0.0065 (5.75)***
MILITARY	0.0576 (2.13)**	0.0777 (3.40)***	0.0358 (1.62)
CPI	-0.0022 (3.11)***		
CPI*MILITARY	-0.0008		

	(1.53)		
EF		-0.0038 (3.14)***	
EF*MILITARY		-0.0023 (2.49)**	
RL			-0.0029 (2.90)***
RL*MILITARY			-0.0000 (0.02)
Constant	-6.7921 (2.08)**	-3.7595 (1.32)	-7.7817 (3.61)***
AR (1)	0.009	0.007	0.001
AR (2)	0.471	0.401	0.436
Hansen p-value	0.463	0.639	0.501
N	674	669	702

* p<0.1; ** p<0.05; *** p<0.01

5. CONCLUSION

The role of military spending in economic growth has received considerable attention from scholars, but the research on the relationship between military spending and GHG is in its infancy. This study explored the relationship between defence spending and CO2 emissions using a sample the countries with the highest levels of per capita CO2 emissions over the period 2000-2015. The results from the two-step GMM estimator suggest that military spending has a positive impact on CO2 emissions even after accounting for the other antecedents of environmental degradation.

The study offers policy implications in light of these empirical findings. First, it is important to foster economic progress to achieve the turning point such that further increase in GDP leads to environmental improvement. Channels suggested by extant research include investment in human and social capital (Obydenkova et al., 2016) and increase in human capital (Omanbayev et al., 2018). Another avenue to increase GDP per capita with little harm to environment is by promoting R&D spending and patenting (Chen & Lee, 2020). Second, renewable energy is an important tool to mitigate CO2 emissions considering rising demand for energy from developed and emerging economies. Policymakers should rely on such various tools as tax benefits, low interest loans, and subsidies to offer incentives for households and the private sector to shift to renewable energy consumption. Third, it is crucial to strengthen the quality of institutions by adopting anti-corruption policies, reducing the burden for economic activities, and increasing rule of law because these are significant predictors of CO2 emissions. Finally, since military spending has a detrimental impact on CO2 emissions, it is important to shift resources from the defence sector to such other industries as innovation, education, ICT, and infrastructure.

Prospective studies can extend our main results by testing whether the effect of military spending on such other environmental indicators as deforestation is significant and exploring the influence of military spending on energy consumption. Indeed, it will be important to assess whether other variables not considered in this study can influence defence spending-CO2 emissions nexus.

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