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Research Article

The Relationship between Co2 emissions and Military Effort

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Abstract

In this paper, we study the relationship between pollution and military expenditure. A distinction is drawn between the indirect and direct impact of military expenditure on pollution which operates through the impact of military expenditure on income and the resultant impact of income on pollution. Using data of 120 countries covering the period 1980–2015, both indirect and direct effects of military expenditure on air pollution emissions are estimated. The results show that the military expenditure is estimated to have a positive direct effect on per capita emissions. Indirect effect is found to be positive, the total effect of military expenditure on emissions is positive.

Keywords: pollution, military effort, income and panel data.

Introduction

The relationship between environment and growth is a conventional theme in economics, (Stern (2004); Dinda (2004) and Dasgupta et al (2002)) so is the relationship between military effort and growth (Dunne and Birdi (2001); Dimitraki and Menla (2015); Dunne (2010)). However, there is almost no study that addresses the possible interactions between military effort, environment and growth. Although remarkable are the merits of the contributions proposed within these separate lines of studies, we argue that they don't get grip on all the aspects of military effort. This lack of connection in research leaves many empty spaces between these different aspects, yet closely interacted. This article intends to contribute to fill this gap.

The purpose of this paper is to provide a rigorous examination of the links between

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pollution, military effort and growth. From this perspective, we argue that there are two mechanisms through which military effort, measured here through military expenditure, may impact pollution.

The first is a direct mechanism through which military expenditure directly impacts pollution. The second is the "indirect" mechanism by which military expenditure affects income which in turn impacts pollution. We assert that the total effect of military expenditure on pollution is the result of these two effects. As far as we know, prior contributions have neglected this indirect effect, which might significantly affect pollution. To empirically investigate these direct and indirect effects of military expenditure on pollution, we use a sample of 120 countries covering the period 1981 to 2015.

The remainder of the paper is organized as follows: section 2 examines the previous literature, section 3 outlines the methodology used within this paper, section 4 provides the results, and section 5 provides the conclusion.

The Literature Review

While the empirical studies on the relationship between environment and military effort are very limited, studies on the relationship between economic growth and military effort abound.

Table 1 provides the main contributions related to the relationship between military effort and economic growth.

Table 1: Effects of military expenditure on economic growth

authors	Research question	Results
Aamer S. Abu-Qarn and Suleiman Abu Bader (2003)	Government spending causes economic growth or economic growth causes government spending in Israel, Syria and Egypt?	Existence of a bi-directional causality from government expenditure and economic growth with a negative long-term relationship between the variables .
Faek Menla Ali and Ourania Dimitraki and (2015)	Military spending causes economic growth or economic growth causes military spending in China over the period 1952–2010?	The economic power represented by the GDP drives any increases in military spending and not vice versa. A possible explanation for the result is that the increase in the military spending has been rapid primarily as a result of the country's economic development.
Luca Pieroni (2007)	The relationship between military spending and economic growth?	For the first group (high military expenditure level) the author finds a negative relationship between the share of military spending and economic growth. By contrast, countries with lower military burden show an insignificant relationship between economic growth and military burden.

J. Paul Dunne (2010)	Military expenditure causes economic growth or economic growth causes military expenditure in Sub Saharan Africa (SSA) (1988-2006)?	An unequivocal negative impact of military expenditure on economic growth for SSA.

The Effects of Economic Growth on Environment

A large body of literature posits a link between pollution and economic growth. The seminal work of Krueger's and Grossman (1991) detected the relationship known as the Environmental Kuznets Curve (EKC).

Table 2 examines the relation between pollution and economic growth.

Table 2: Effects of growth on pollution

authors	Research question	Results
Dipankor Coondoo Soumyananda Dinda (2002)	Does Economic growth causes the emission of CO2 or emission of CO2 causes economic growth from 1960 to 1990)?	The existence of a bi-directional causal relationship between CO2 emissions and GDP for America, Africa and Europe.
Nguyen Van Phu and Théophile Azomahou (2001)	CO2 emissions cause economic growth or economic growth causes the emission of CO2?	The economic growth has a negative effect on emissions of CO2.
James B and Ang (2008)	Emissions of CO2 cause economic growth or economic growth causes the emission of CO2 in Malaysia?	Emissions of CO2 cause economic growth in long-term.
Hsiao-Tien Pao and Chung-Ming Tsai(2010)	The type of causality between economic growth, emissions of CO2 and consumption of energy in BRIC countries over the period 1971-2005?	The panel causality results indicate there are emissions- energy consumption bidirectional strong causality and output -energy consumption bidirectional long-run causality, along with unidirectional both strong and short-run causalities from emissions of CO2 and consumption of energy, respectively, to output.
Coondoo and Dinda (2002)	The type of causality between economic growth and emission of CO2 in the world?	Three different types of causality for different country groups. For the developed country groups of Western Europe and North America, the causality is found to run from emission of CO2 to income. For the country groups of South and Central America,

		Japan and Oceania causality from income to CO2emissions is obtained. Finally, for the country groups of Africa and Asia, the relationship of causality is bi-directional.

Methodology and data

Econometrically, the use of the multivariate cointegration is much recommended since it offers the opportunity to verify the existence of the relationship and the sense of causality among variables. It presents an extremely powerful empirical framework to deal with the issue raised in this paper.

In this study we will study the relationship between military expenditure and CO2emissions and specify the direct and indirect effect of military expenditure on the emissions of CO2.

Data

The data sample includes 4200 observations describing 120 different countries covering 35 years (from 1981 to 2015). We have used these countries because they have complete data for military expenditure variable and CO2emissions.

The indicator of military endeavour used in this paper is the military expenditure per capita (MILexp). Biswas and Ram (1986); Deger and Sen (1983); Faini Annez and Taylor (1984) and Leontief and Duchin (1983) used the military expenditure variable to study the link between military effort and economic growth.

The Empirical Strategy

Presentation of the Model

To handle both the indirect and direct effects of the military expenditure on pollution, we use the joint estimation of two equations. Estimation equations are defined as:

$$ECO2_{it} = \gamma_i + \kappa_t + \alpha_1 Y_{it} + \alpha_2 (Y_{it})^2 + \alpha_3 MIL + \alpha_4 Z_{it} + \mu_{it} \quad (1)$$

$$Y_{it} = \lambda_i + \tau_t + \beta_1 X_{it} + \beta_2 MIL + \varepsilon_{it} \quad (2)$$

Where subscripts i and t denote country and year. In eq (1) emissions of CO2 per capita (ECO2) as a function of per capita income (GDP) and a quadratic income. Equation (1) also includes Z, a vector of additional explanatory variables. These include the share of exportation in GDP and the share of industry in GDP. Finally, γi and κ_t represent country and year specific effects, and ε_{it} and μ_{it} denote error terms.

Eq. (2) expresses per capita income as a function of year and country specific effects (τ_t and λ_i), military expenditure (MILexp) and X, a vector of other explanatory variables.

Instrumental variables

In equation (2) income is a function of military expenditure ; consequently this equation may suffer from a problem of endogeneity. To deal with this potential endogeneity, in this equation MILexp is instrumented. The instrumental variable solution is to find another variable; this variable is highly correlated with MILexp, and not correlated with the error term. We use the Human Development Index.

Table 3 presents the descriptive statistics of these variables

Table3: Definition of the variables and descriptive statistics

Variable (abbreviation)	Mean	Std. Dev	Min	Max
CO2 emissions per capita **(ECO2)**	0.900	1.505	-3.218	3.529
Military expenditure per capita in armed conflict **(MILexp)**	4.039	1.699	0.120	10.084
Gross Domestic Product per capita **(GDP)**	8.016	1.555	5.225	10.940
Gross capital formation **(GCF)**	23.226	2.079	18.561	28.621
Exports of goods and services **(EXP)**	3.536	0.574	1.638	5.455
Inflation rate **(INF)**	1.562	1.309	-3.912	10.102
Annual growth of population **(POPgr)**	1.340	1.269	-3.820	13.180
Share of industry in GDP **(ind sh)**	3.420	0.314	2.197	4.343
Human Development Index **(HDI)**	-0.403	0.282	-2.134	-0.030

Identifying the effect of the military expenditure on pollution

The total effect of military expenditure per capita on emissions of CO2 (dECO2/ dMILexp) decomposes into a direct and an indirect effect. The direct effect is defined as the impact of military expenditure on emissions of CO2. The indirect effect is expressed as the product of the impact of military expenditure on income (δY/ δMILexp) and the impact of income on emissions of CO2 (δECO2/ δY). These effects can be expressed as:

$$\frac{dECO2}{MILexp} = \frac{\delta ECO2}{\delta MILexp} + \frac{\delta ECO2}{\delta Y}\frac{\delta Y}{\delta MILexp} \quad (3)$$

Where ECO2, Y and MILexp denote emissions of CO2, income and military expenditure, respectively.

Empirical Results

Estimation Results

Table 4 provides estimates of per capita income equation.

Table 4: The impact of military expenditure per capita on per capita income

	exogenous **MILexp**	(Y1)	(Y2)	(Y3)	(Y4)
MILexp	0.116* (0.0079)	0.900* (0.057)	1.012* (0.496)	0.890* (0.042)	0.893* (0.027)
POP gr	-0.022* (0.001)	-0.166* (0.569)	-0.159* (0.057)	-0.166* (0.050)	-0.160* (0.046)
GCF	0.231* (0.001)	-0.032 (0.360)	-0.050 (0.033)	-0.029 (0.025)	
INFL	-0.004** (0.017)	0.016 (0.329)	0.0109 (0.033)		
EXP	0.191* (0.011)	0.0962 (0.080)			
R^2	within =0.660 between=0.857	within = 0.028 between=0.864	within = 0.011 between=0.857	Within= 0.054 Between=0.899	within= 0.070 between=0.866

F-test on IVs		1439.200 (0.000)	1320.09 (0.000)	1589.20 (0.000)	1739.00 (0.000)
endog		618.00 (0.000)	588.01 (0.000)	706.12 (0.000)	1395.98 (0.000)

In the first column, military expenditure is treated as being exogenous with regard to income and is therefore not instrumented. In models Y1 to Y4 Military expenditure is instrumented using 2SLS. All models use a random effects specification.* and ** denote significance at 5% and 10% respectively.

Table 4 provides estimates of per capita income equation. In the first column, MIL which is treated as being exogenous with regard to income is not instrumented, but in all subsequent columns MIL is instrumented. Model (Y4) begins by expressing per capita income simply as a function of population growth and military expenditure. Models (Y1) to (Y3) include explanatory variables used by many studies (Levine and Zervos (1993); Mankiw et al (1992) and Levine and Renelt (1992)).These variables are the population growth rate (POPgr), the rate of inflation (INFL), and the share of exports in GDP.

In Table 4, Military expenditure is found to have a statistically positive impact on income in all models. This result is justified by Benoit (1973) but contradicts with other contributions (Leontief and Dutchin (1983); Deger and Sen (1983) and Taylor et al (1984)).

The correlation between MILexp and the instrument (IDH) is high whereas the correlation between the residuals of the model (Y1) and the instrument is very low (See table A2). The first stage regression results validate the use of variables "IDH" as instruments (See table A3) . The obtained F value is high and the first stage estimates are significant (see Table A3). This gives extra support to the validity of the instrument (IDH).

Table 5: Estimates of per capita pollution emissions based on model (Y1)

	(Y1a)	(Y1b)
MILexp	0.446* (0.027)	0.521* (0.025)
GDP	0.401* (0.025)	0.523* (0.024)
GDP^2	-0.003 (0.008)	-0.006 (0.024)
Pind sh	0.189* (0.039)	
EXP	0.137* (0.024)	
R^2	within =0.2401 between=0.763	within 0.2031 between=0.713
Hausman FE.v.RE	103.33 (0.000)	150.81 (0.000)

Standard errors in parentheses.* denotes significance at 5% respectively. All models use a fixed effect

Table 5 provides estimates of per capita CO2 emissions, utilizing the results of the 'full' income models (Y1) (see table3). A 'basic' equation is estimated (models Y1b) where pollution is expressed simply as a function of per capita income and military expenditure. In all models MILexp has a positive and statistically significant effect

on emissions of CO2. Industry share (INDsh) and export of goods and services (EXP) are found to be positive, significant determinants of pollutant emission. In this direction, Managi (2004) shows that trade liberalization causes the increase of emissions of CO2. In the same context, Tubb and Magnani (2007) and Cole (2004) argue that trade affects negatively emissions of many pollutants (CO2, SO2, NO2 etc...) in OECD countries.

It is now possible to quantify the impact of military expenditure on emissions of CO2. Firstly, Table 6 provides the indirect, direct and total effect of military expenditure on pollution for each of the two models presented in Table 5.

Table 6: The impact of military expenditure on pollution

Pollutant Model δECO2/ δMILexp δECO2/ δY δY/ δMILexp dECO2/dMILexp			
	Direct effect	Indirect effect	Total effect
(Y1a)	0.446	0.360	0.8069
(Y1b)	0.521	0.4707	0.9917

Table 6 indicates a positive direct impact of military expenditure on emissions of CO2. For emissions of CO2, the indirect effect is positive, providing a positive total effect. This positive sign of indirect effect reflects the same sign of the relationship between income and emissions of CO2 income (δECO2/δY) and the relationship between income and military expenditure (δY/ δMILexp). Consequently, a military expenditure - induced reduction in income leads to a reduction in emissions of CO2 and vice versa.

Discussions and conclusions

The aim of this paper is to study the relationship between emissions of CO2 and military endeavor with a detailed empirical examination.

Empirical results show that military expenditure has a positive indirect and direct effect on per capita CO2emissions. This positive linkage between the two variables was found to increase statistical significance when military endeavor was instrumented as a determinant of income.

A direct consequence of our results is that a reduction of military endeavor entails a reduction of emissions of CO2 and vice versa.

Appendix

Table A1. Data Information

Variable	**Definition**	**Source**
GCF	Gross capital formation (% of GDP)	World Bank
GDP	Gross Domestic Product per capita ($US constant 2000)	World Bank
ECO2	CO2 emissions per capita	World Bank

MILexp	Military expenditures per capita	World Bank
IND sh	Share of industry in GDP	World bank
INFL	Inflation rate (annual %)	World Bank
EXP	The share of exports of goods and services in GDP	World Bank
POPgr	Annual growth of population (% of total population)	World Bank
Human Development Index	Human Development Index	World Bank

Table A2: Correlation matrix

	MILexp	**Eco2**	**GDP**	**EXP**	**IND sh**	**GCF**	**POPgr**	**INFL**	**HDI**	**LE**
MILexp	1.00									
Eco2	0.82	1.00								
GDP	0.91	0.84	1.00							
EXP	0.22	0.36	0.25	1.00						
IND sh	0.13	0.27	0.03	0.31	1.00					
GCF	0.63	0.62	0.66	-0.10	0.13	1.00				
POPgr	-0.31	-0.50	-0.36	-0.10	-0.04	-0.31	1.00			
INFL	-0.43	-0.27	-0.45	-0.05	0.09	-0.33	0.04	1.00		
HDI	0.77	0.82	0.82	0.22	0.11	0.60	-0.50	-0.38	1.00	
LE	0.70	0.74	0.74	0.17	0.03	0.62	-0.51	-0.38	0.85	1.00

Table A3: First stage estimations of military expenditure

	(Y1)	**(Y2)**	**(Y3)**	**(Y4)**
HDI	3.700* (0.325)	4.606* (0. 235)	4.340 * (0.186)	4.479 * (0.169)
EXP	0. 090 * (0.103)	0.105* (0.033)	-0.130 (0.101)	-0.080 (0.093)
INF	-0.080 * (0.050)	-0.023* (0.007)	-0.104 * (0.040)	
POP gr	-0.016** (0.007)	-0.0079 (0.0081)		
GCF	0.152 (0.040)*			
F	670	669	673	775

	(0.000)	(0.000)	(0.000)	(0.000)
Standard errors in parentheses. * and ** denote significance at 5% and 10%, respectively.				

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