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# The Relationship between Military Expenditure, Military Personnel, Economic Growth, and the Environment

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***Abstract*—**In this paper, we study the relationship between the military effort and pollution. A distinction is drawn between the direct and indirect impact of the military effort (military expenditure and military personnel) on pollution, which operates through the impact of military effort on per capita income and the resultant impact of income on pollution. Using the data of 121 countries covering the period 1980–2011, both the direct and indirect impacts of military effort on air pollution emissions are estimated. Our results show that the military effort is estimated to have a positive direct impact on per capita emissions. Indirect effects are found to be positive, the total effect of military effort on emissions is positive for all countries.

***Keywords*—**Military expenditure, military personnel, income, emissions of CO2 and panel data.

## I. Introduction

THE relationship between growth and environment is a conventional theme in economics [12], [15], [27] so is the relationship between growth and military effort [8], [14], [16]. However, there is almost no study that addresses the possible interactions between environment, military effort and growth. Although remarkable are the merits of the contributions proposed within these separate lines of studies, we argue that they do not grasp all the aspects of the military effort. This lack of connection in the research leaves many empty spaces between these different, yet closely interacted, aspects. This article intends to contribute to filling this gap.

The purpose of this paper is to provide a rigorous examination of the links between military effort, growth and pollution. From this perspective, we argue that there are two mechanisms through which military effort, measured here through military expenditure and military personnel, may impact pollution.

The first is a direct mechanism through which military effort directly impacts pollution. The second is the "indirect" mechanism by which military effort affects per capita income, which in turn impacts pollution. We assert that the total effect of military effort 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 and military personnel on pollution, we use a sample of 121 countries covering the period 1980 to 2011.

The remainder of the paper is organized as follows; Section II examines the previous, literature; whilst Section III outlines the methodology used within this paper; Section IV provides the results; and Section V provides the conclusion.

## II. The Literature Review

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

Reference [7] was the first who empirically tested the relationship between economic growth and defense spending. He found strong evidence suggesting that defense spending encouraged economic growth, especially in a less developed country [6].

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

A large body of literature posits a link between economic growth and pollution. The seminal work of [18] detected the relationship known as the Environmental Kuznets Curve (EKC). Table II examines the relation between economic growth and pollution.

## III. Data and Methodology

### *A. The Data*

The data sample includes 3,751 observations describing 121 different countries in a balanced panel covering 31 years (from 1980 to 2011).

Two indicators of the military effort (MIL) are used in this paper: the military personnel in armed conflict (MILper) and the military expenditure per capita (MILexp). These indicators are collected from the World Bank. [9], [13], [17], [19], [26] used the military expenditure variable to study the link between economic growth and military effort.

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TABLE I
EFFECTS OF MILITARY SPENDING ON GROWTH

| Authors | Research question | Results |
|---|---|---|
| [8] | The relationship between military spending and economic growth in Africa | The existence of a positive long run relationship between military spending and manufacturing output, and a negative short run effect of the growth of military spending on the growth of manufacturing output. |
| [1] | Government expenditure causes economic growth or economic growth causes government expenditure in Egypt, Israel and Syria? | The existence of a bi-directional causality from government spending and economic growth with a negative long-term relationship between the two variables. |
| [25] | The relationship between military expenditure and economic growth? | For the first group (high military spending level) the author find a negative relationship between the share of military expenditure and economic growth. By contrast, countries with lower military burden show an insignificant relationship between military burden and growth. |
| [15] | Military spending causes economic growth or economic growth causes military spending in Sub Saharan Africa (SSA) (1988-2006)? | An unequivocal negative impacts of military spending on growth for SSA. |

TABLE II
EFFECTS OF GROWTH ON POLLUTION

| Authors | Research Question | Results |
|---|---|---|
| [3] | Is economic growth related to emission of CO2? | The CO2 emission trajectory is closely related to the income time path. Pollutant emissions elasticity on income has been declining over time. |
| [4], [5] | Does economic growth cause the emission of CO2 or emission of CO2 causes economic growth? | The economic development has a negative effect on gas emissions. |
| [2] | Does economic growth cause the emission of CO2 or emissions of CO2 cause economic growth in Malaysia? | CO2 emissions cause economic growth in long-term. |

The effect on the environment is captured through the variable emissions per capita, precisely through Carbon dioxide emissions (ECO2). References [11], [28] used the variable Carbon dioxide emissions (ECO2) to study the relationship between the environment and the corruption.

### *B. The Empirical Strategy*

1. Presentation of the Model

To handle both the direct and indirect effects of the military effort on pollution, we use the joint estimation of two equations. Formally, 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. Equation (1) draws upon the environmental Kuznets curve literature, expressing pollution emissions 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 industry in GDP, in order to capture the composition of a country's output and the share of exportation in CDP to investigate whether openness to trade influences emissions. Finally, $\gamma i$ and $\kappa_t$ represent country and year specific effects, and $\mu_{it}$ and $\varepsilon_{it}$ denote error terms.

Equation (2) expresses per capita income as a function of country and year specific effects ($\lambda_i$ and $\tau_t$), military effort (MIL), which is captured in this study by the military expenditure per capita (MIL exp) and military personnel (MIL per) and X, a vector of other explanatory variables.

2. Instrumental Variables

In (2) income is a function of military effort[1], yet military effort is itself likely to be a function of income; consequently (2) may suffer from an endogeneity problem. To deal with this potential endogeneity, MIL is instrumented in (2). The instrumental variable solution is to find another variable that is highly correlated with MIL, but not correlated with the error term ($\varepsilon_{it}$). We use the Human Development Index.

3. Identifying the Impact of the Military Effort on Pollution

The total effect of the military effort on pollution (dECO2/ dMIL) decomposes into a direct and an indirect effect. The direct effect is defined as the impact of the military effort on pollution emission. The indirect effect is expressed as the product of the impact of military effort on income (δY/ δMILexp) and the impact of income on pollution emission (δECO2/ δY). Formally, these effects can be expressed as:

$$\frac{dE}{dMILI} = \frac{\delta E}{\delta MILI} + \frac{\delta E}{\delta Y}\frac{\delta Y}{\delta MILI} \quad (3)$$

where E, Y and MIL denote pollution emissions, income and military effort, respectively.

## IV. EMPIRICAL RESULTS

### *A. Estimation Results*

Tables III and IV provide estimates of the per capita income equation. In the first column of the Tables III and IV, MIL 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 effort. Models (Y1) to (Y3) include additional explanatory variables used by previous studies [20], [21], [24]. These

[1] Military effort is expressed by military expenditure per capita and military personnel.

variables are the rate of inflation (INFL), the population growth rate (POPgr), and the openness of the economy (TRADE), defined as the share of exports in GDP.

In Table III, the military effort is expressed in terms of military personnel. In all models military personnel is found to have a statistically negative impact on income, except in model 4.

The signs of the other explanatory variables are positive and statistically significant in both Tables III and IV, except the inflation rate (INFL), which is found insignificant in Table IV and the population growth which is negative in Table IV.

The correlation between MIL and the considered instruments (IDH) is high, whereas the correlation between the residuals of the model (Y1) and the instruments is very low (Table VIII). The first stage regression results (reported in Tables IX and X in the appendix) validate the use of variables "IDH" as instruments. Indeed, the obtained F value is high and the first stage estimates are significant (Tables IX and X in the appendix). This gives extra support to the validity of the instruments used.

Table V provides estimates of per capita CO2 emissions, utilizing the results of the 'full' income models (Y1) (Tables III and IV). For each pollutant a 'basic' equation is estimated (models Y1b and Y1d) where pollution is expressed simply as a function of per capita income and military effort. In all models MIL has a positive and statistically significant effect on CO2 emissions. In addition, Industry share (INDsh) and Export of goods and services (EXP) are found to be positive, significant determinants of pollutant emission. In this direction, [23] shows that trade liberalization causes the increase of CO2 emissions. In the same context, [9], [10], [22] 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 effort on pollutant emission. Firstly, Table VI provides the direct, indirect and total effect of military expenditure and military personnel on pollution for each of the four models presented in Table V.

For all models, Table VI indicates a positive direct impact of military effort on $CO_2$ emissions. This result reflects the estimated coefficients on CONF reported in Table V. For CO2 emission, the indirect effect is positive, providing a positive total effect. This positive sign of indirect effect reflects the same sign of the relationship between $CO_2$ emissions and income ($\delta E/ \delta Y$) and the relationship between military effort and income ($\delta Y/ \delta CONF$). Consequently, a military effort-induced reduction in income leads to a reduction in $CO_2$ emissions and vice versa.

Figs. 1 and 2 plot the direct, indirect and total effects of military effort on CO2 emissions against per capita income using the results from models Y1a and Y1c.

TABLE III
THE IMPACT OF MILITARY PERSONNEL ON PER CAPITA INCOME

| | exogenous MILper | (Y1) | (Y2) | (Y3) | (Y4) |
|---|---|---|---|---|---|
| MILper | -0.0039 (0.007) | -2.437068* (0.701) | -1.834494* (0.204) | -1.86716* (0.292) | 3.706304* (0.826) |
| POP gr | -0.024218* (0.000) | -0.327385* (0.147) | 0.1738056 (0.138) | -0.1452864 (0.096) | 0.2447925 (0.416) |
| GCF | 0.018* (0.005) | 1.1088* (0.226) | 1.508531* (0.130) | 1.033687* (0.110) | |
| INF | -0.0053* (0.005) | 0.1387314* (0.068) | 0.2401534* (0.083) | | |
| EXP | 0.187* (0.011) | -0.5066363 (0.333) | | | |
| $R^2$ | within =0.6736 between=0.8456 | within=0.2164 between =0.6264 | within = 0.3760 between = 0.5164 | within = 0.3652 between =0.2701 | within = 0.0001 between =0.0211 |
| Sargan | | (0.000) | (0.000) | (0.000) | (0000.) |
| F-test on IVs | | 52.04 (0.000) | 245.53 (0.000) | 124.17 (0.000) | 27.84 (0.000) |
| endog | | 19.10 (0.0018) | 132.43 (0.000) | 55.23 (0.000) | 26.66 (0.000) |

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

TABLE IV
THE IMPACT OF MILITARY EXPENDITURE PER CAPITA ON PER CAPITA INCOME

| | **exogenous** MILexp | **(Y1)** | **(Y2)** | **(Y3)** | **(Y4)** |
|---|---|---|---|---|---|
| **MILexp** | 0.117* (0.008) | 0.975* (0.059) | 1.013* (0.494) | 0.982* (0.041) | 0.943* (0.026) |
| POP gr | -0.024* (0.000) | -0.168* (0.575) | -0.158* (0.059) | -0.165* (0.048) | -0.162* (0.045) |
| GCF | 0.234* (0.000) | -0.030 (0.357) | -0.050 (0.031) | -0.028 (0.027) | |
| INFL | -0.004** (0.015) | 0.017 (0.333) | 0.011 (0.034) | | |
| EXP | 0.193* (0.011) | 0.096 (0.083) | | | |
| $R^2$ | within = 0.673 between = 0.845 | within = 0.028 between = 0.864 | within = 0.011 between=0.857 | within = 0.053 between = 0.861 | within = 0.078 between = 0.865 |
| Sargan | | (0.000) | (0.000) | (0.000) | (0.000) |
| F-test on IVs | | 1438.34 (0.000) | 1318.06 (0.000) | 1591.54 (0.000) | 1738.65 (0.000) |
| endog | | 617.90 (0.000) | 587.98 (0.000) | 704.05 (0.000) | 1400.63 (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 V
ESTIMATES OF PER CAPITA POLLUTION EMISSIONS BASED ON MODEL (Y1)

| | (Y1a) | (Y1b) | | (Y1c) | (Y1d) |
|---|---|---|---|---|---|
| MILper | 0.317* (0.031) | 0.346* (0.031) | MILexp | 0.446* (0.027) | 0.524* (0.026) |
| GDP | -0.103* (0.011) | -0.122* (0.011) | GDP | 0.436* (0.026) | 0.522* (0.025) |
| GDP² | -0.003* (0.011) | -0.001 (0.001) | GDP² | -0.003 (0.008) | -0.006 (0.023) |
| Pind sh | 0.163* (0.041) | | Pind sh | 0.190* (0.038) | |
| EXP | 0.252* (0.025) | | EXP | 0.136* (0.023) | |
| $R^2$ | within = 0.139 between=0.251 | within = 0.068 between=0.039 | $R^2$ | within =0.2404 between=0.765 | within 0.203 between=0.716 |
| Hausman FE.v.RE | 53.56 (0.000) | 44.86 (0.000) | Hausman FE.v.RE | 102.34 (0.000) | 151.85 (0.000) |

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

TABLE VI
THE IMPACT OF MILITARY EFFORT ON POLLUTION (ELASTICITIES)

| Pollutant Mode | δE/ δMIL | δE/ δYδY/ δMIL | dE/dMIL |
|---|---|---|---|
| | Direct effect | Indirect effect | Total effect |
| (Y1a) | 0.317 | 0.253 | 0.570 |
| (Y1b) | 0.346 | 0.299 | 0.646 |
| (Y1c) | 0.446 | 0.425 | 0.871 |
| (Y1d) | 0.524 | 0.509 | 1.033 |

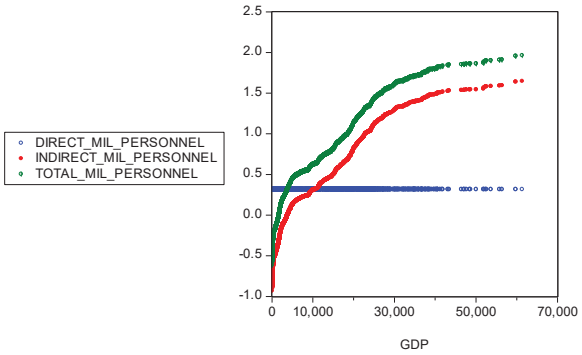


Fig. 1 The marginal effect of military personnel on carbon dioxide emissions

Fig. 1 presents the marginal effect of military personnel on carbon dioxide emissions, and Fig. 2 presents the marginal effect of military expenditure on carbon dioxide emissions. For both models, the indirect effect of military effort on CO2 emissions increases as per capita income increases. As, has already been established, the direct effect is positive and does not vary with income. The resulting total effect of both military efforts on emissions of carbon is generally positive, but increasing with income.

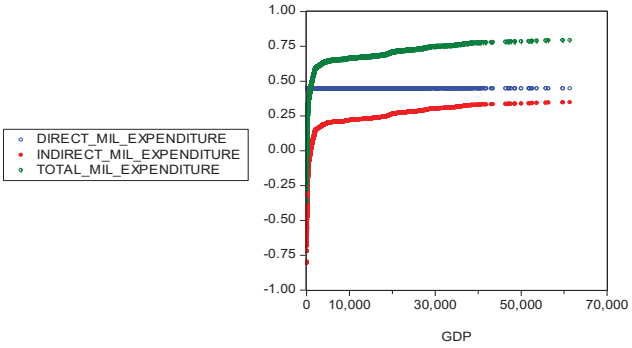


Fig. 2 The marginal effect of military expenditure on carbon dioxide emissions

## V. DISCUSSIONS AND CONCLUSIONS

The aim of this paper is to study the linkages between military effort and pollution with a detailed empirical examination.

Empirical results show that military effort has a positive direct and indirect effect on per capita emissions of CO2. This positive relationship was found to increase statistical significance when military effort was instrumented as a determinant of income. A direct consequence of our results is that a reduction of military effort entails a reduction of pollution.

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## APPENDIX

TABLE VII
DATA INFORMATION

| Variable | Definition | Source |
|---|---|---|
| GCF | Gross capital formation (% of GDP) (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. | World Bank |
| GDP | Gross Domestic Product per capita ($US constant 2000) is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. | World Bank |
| ECO2 | CO2 emissions per capita, They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. | World Bank |
| MILper | military personnel | World Bank |
| MILexp | Military expenditures per capita include current and capital expenditure of the armed forces. Military expenditures are presented as a percentage of Gross Domestic Product (GDP) | World Bank |
| IND sh | share of industry in GDP, Industry includes manufacturing. mining, manufacturing, construction, electricity, water, and gas. | World bank |
| INFL | Inflation rate (annual%), Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals. | World Bank |
| EXP | The share of exports of goods and services in GDP. Exports of goods and services represent the value of all goods and other market services provided to the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services | World Bank |
| POPgr | Annual growth of population (%of total population) | World Bank |
| Human Development Index | Human Development Index is an index that measures the quality of life of the average population of a country t, theoretically the index is between 0 and 1. | World Bank |

TABLE VIII
CORRELATION MATRIX

| | MILexp | Eco2 | GDP | EXP | IND sh | GCF | POPgr | INFL | HDI | LE | LMILexp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MILexp | 1.000 | | | | | | | | | | |
| Eco2 | 0.826 | 1.000 | | | | | | | | | |
| GDP | 0.911 | 0.840 | 1.000 | | | | | | | | |
| EXP | 0.226 | 0.362 | 0.258 | 1.000 | | | | | | | |
| IND sh | 0.136 | 0.273 | 0.034 | 0.315 | 1.000 | | | | | | |
| GCF | 0.635 | 0.626 | 0.666 | -0.106 | 0.136 | 1.000 | | | | | |
| POPgr | -0.316 | -0.506 | -0.364 | -0.105 | -0.049 | -0.316 | 1.000 | | | | |
| INFL | -0.431 | -0.279 | -0.455 | -0.055 | 0.097 | -0.333 | 0.044 | 1.000 | | | |
| HDI | 0.772 | 0.829 | 0.827 | 0.220 | 0.114 | 0.606 | -0.504 | -0.380 | 1.000 | | |
| LE | 0.700 | 0.744 | 0.747 | 0.179 | 0.037 | 0.623 | -0.510 | -0.383 | 0.852 | 1.000 | |
| LMIL exp | 0.996 | 0.825 | 0.913 | 0.223 | 0.131 | 0.635 | -0.312 | -0.430 | 0.755 | 0.658 | 1.000 |

TABLE IX
FIRST STAGE ESTIMATIONS OF MILITARY EXPENDITURE

| | (Y1) | (Y2) | (Y3) | (Y4) |
|---|---|---|---|---|
| **HDI** | 3.740* | 4.607* | 4.345 * | 4.483 * |
| | (0.322) | (0.236) | (0.188) | (0.171) |
| EXP | 0.089 * | 0.104* | -0.131 | -0.078 |
| | (0.105) | (0.033) | (0.098) | (0.091) |
| INF | -0.082 * | -0.025* | -0.105 * | |
| | (0.048) | (0.006) | (0.042) | |
| POP gr | -0.015** | -0.008 | | |
| | (0.008) | (0.008) | | |
| GCF | 0.150 | | | |
| | (0.042) * | | | |
| **F** | 673 | 668 | 674 | 777 |
| | (0.000) | (0.000) | (0.000) | (0.000) |

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

TABLE X
FIRST STAGE ESTIMATIONS OF MILITARY PERSONNEL

| | (Y1) | (Y2) | (Y3) | (Y4) |
|---|---|---|---|---|
| **HDI** | -1.191* | 1.527* | 1.152 * | 1.196 * |
| | (0.345) | (0.266) | (0.227) | (0.213) |
| EXP | -0.681* | 0.104* | -0.353* | -0.445* |
| | (0.114) | (0.033) | (0.090) | (0.089) |
| INF | -0.019* | -0.025 | -0.007 | |
| | (0.035) | (0.006) | (0.022) | |
| POP gr | -0.071 ** | -0.008 | | |
| | (0.079) | (0.008) | | |
| GCF | 0.421* | | | |
| | (0.045) | | | |
| **F** | 145 | 64 | 31 | 41 |
| | (0.000) | (0.000) | (0.000) | (0.000) |

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

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