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Can We Have More Butter and Guns Simultaneously? An Endogeneity Perspective

Czy wzrost gospodarczy i wyższe wydatki na wojsko są możliwe jednocześnie? Perspektywa endogeniczności

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Abstract

Drivers and outcomes of military expenditures are an important topic in geopolitics and public debate. It is often argued that increases in the military budget can boost the economy through extended military equipment production. What should then be noticeable is a feedback relationship between military expenditures and the current state of the economy. This paper investigates this reverse relationship at the macro level using an unbalanced panel dataset of 173 countries over the period 1949–2020. Our empirical analysis implies that the claimed positive feedback loop between military expenditures and economic growth is either completely absent or, at most, very weak.

Słowa kluczowe:
rozwój gospodarczy, wydatki na wojskowość, wyścig zbrojeń, endogeniczność

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Streszczenie

Przyczyny i skutki wydatków na cele wojskowe pozostają jednym z kluczowych obszarów geopolityki i debaty publicznej. Często stwierdza się, że zwiększenie budżetu na obronność może pobudzić gospodarkę poprzez zwiększenie produkcji sprzętu wojskowego. To, co powinno wówczas wystąpić, to sprzężenie zwrotne pomiędzy wydatkami wojskowymi a stanem gospodarki. Zasadniczym celem artykułu jest zbadanie wskazanej odwrotnej relacji na poziomie krajów przy użyciu niezrównoważonego zestawu danych panelowych obejmującego 173 kraje w latach 1949–2020. Zaprezentowana analiza empiryczna wskazuje, że badana relacja sprzężenia zwrotnego między wydatkami wojskowymi a wzrostem gospodarczym jest albo całkowicie nieobecna, albo co najwyżej bardzo słaba.

Introduction

Military spending is undoubtedly an important and continuously explored issue, both in research and public debate [**d'Agostino et al., 2017**]. It even constitutes a political and economic controversy [**Nincic, Cusack, 1979**]. The available studies imply its relevance in various contexts. For instance, military spending matters for employment dynamics [**Hooker, Knetter, 1997**], poverty [**Henderson, 1998**], real exchange rates [**Miyamoto et al., 2019**], political systems [**Brauner, 2015**], and economic growth [**Dunne, 2012**; **d'Agostino et al., 2017**; **Zhao et al., 2017**; **Kollias, Paleologu, 2019**]. However, the issue of determinants of military spending and the impact of military spending on economic progress are persistent research challenges.

As the relevance of military spending for economic growth clearly should not be investigated in isolation from the impact of economic growth on military spending, what is particularly interesting is the presence of endogeneity in this context (feedback relationship). The current literature, more widely described in the next section, even if it provides detailed and valuable comments on the relationship between military spending and economic growth, mostly focuses on one-way influence instead of the above-mentioned interrelationships [**Capellen et al., 1984**; **Dunne, 2012**; **d'Agostino et al., 2017**; **Zhao et al., 2017**; **Kollias, Paleologu, 2019**]. Another essential point is that numerous studies expose the relevance of institutions as determinants of military spending as well as factors conditioning the influence of military expenditure on specific spheres [**Albalate et al., 2012**; **Compton, Paterson, 2016**]. However, research involving the interrelationships between military spending and economic growth and the institutional context of this feedback dependency seem to be an underexploited sphere.

In this study, we pose the following research questions: Considering that military expenditure is dependent on the economy, is a feedback relationship between military spending and economic progress observable? What are the institutional drivers of military expenditure? We aim to provide answers to these questions based on empirical techniques. A positive response to the first question would imply that it is possible to make military spending ("guns") and productive investment ("butter") simultaneously. Our contribution to the literature is multi-fold and refers to the scope of the study and the methods used. First, we rely on a global sample of 173 countries in the period 1949–2020 and a specification covering not only a range of economic, but also institutional factors, including an index of liberal democracy, political corruption and membership in international organisations. Second, we apply a variety of quantitative tools to address our research questions. Namely, we start with static panel econometric models, including instrumental variables, and then proceed with dynamic ones. The endogenous character of military expenditures is thus verified in both static and dynamic panel models. We also provide an extension focused particularly on countries leading the way in military technology.

The remainder of the article is as follows. Section 2 describes the determinants of the share of military expenditure in GDP. Then, in Section 3, our data, methodology, empirical results, model extensions and discussion are covered respectively. Finally, Section 4 concludes our study. Please note that the database used in this research, along with the replication codes, is available in the online appendix.

Determinants of military expenditures

The main subject of our study is the relationship between military spending and economic growth. But first it needs to be stressed that expenditures on armaments are of high geopolitical importance. Military expenditures can be generally attributed to security crises in the broad sense [**Mercille, 2008**; **Bove, Elia, 2014**] or uncertainty [**Gleditsch, 1992**; **George, Sandler, 2018**]. In this context, high military spending can be linked to maintaining national or regional security, deterrence, or planned involvement in armed conflicts.

Economic growth and military spending seem to be tightly connected. However, most of the literature focuses solely on the impact of economic development on military expenditure or vice versa, with some notable exceptions [**Dunne, Vougas, 1999**; **Desli et al., 2017**]. The overall portrayal is rather inconclusive. Meanwhile,

the available conclusions foster our motivation for investigating the feedback relationship between the two factors of key interest in this analysis. The effect of economic growth on military spending remains constant for various groups of countries, but cannot be taken for granted [**Chang et al., 2014**; **Pan et al., 2015**; **Desli et al., 2017**]. What is essential is that times of economic progress or recession bring asymmetric effects in terms of military spending increases and cuts [**Zielinski et al., 2017**]. The military Keynesianism claim states that military spending contributes to better economic conditions as it can be used like a countercyclical tool, which appears to be confirmed by the latest empirical research [**Borch, Wallace, 2010**]. It is often claimed that countries with a relatively high defence burden are characterised by a lower rate of economic growth, which has also been empirically verified [**Cappelen et al., 1984**; **Ward, Davis, 1992**; **Yakovlev, 2007**; **Mylonidis, 2008**]. It seems that only selected industries benefit from higher military spending [**Cappelen et al., 1984**]. In line with this finding, net arms exporters find military expenditure to be less detrimental to economic growth compared to other countries [**Yakovlev, 2007**]. If the positive impact of military spending on economic growth is noted, it is usually negligible or applies to a specific country rather than any broader trend [**Wijeweera, Webb, 2009**; **Farzanegan, 2014**]. Generally, in most countries, the individual impact varies over different time periods [**Desli, Gkoulgkoutsika, 2021**]. Below we elaborate on other determinants of defence spending.

Quite obviously, wars exponentially boost military expenditure [**Hwang, 2012**]. There is empirical evidence that higher military spending due to wars is rather temporary [**Cavicchioli, Pistoresi, 2016**]. In general, war can be assessed as one of the strategic factors affecting the scope of military spending [**Batchelor et al., 2002**]. Importantly, civil (domestic) wars also matter in this context, as they affect not only the countries involved, but also their neighbours [**Phillips, 2014**].

Interestingly, military expenditures in neighbouring countries appear to be one of the drivers of military spending in a given country [**Phillips, 2014**]. This is mostly due to the aggregate military spending of the "security web" or "potential enemies" [**Dunne, Nikolaidou, 2001**; **Dunne et al., 2008**], which perfectly fits the concept of the arms race. The effect of military expenditures in neighbouring countries matters for the level of military spending, but only in selected cases and depending on the set of control variables [**Yesilyurt, Elhorst, 2017**]. In general, countries tend to adapt their military spending to that of others, even if these countries are not neighbours [**Yesilyurt, Elhorst, 2017**]. This finding is in line with the concept of horizontal interactions between governments [**Brueckner, 2003**]. Given this context, recent studies imply that there is convergence in military spending, mostly into three groups, where both advanced and developed economies are present [**Clements et al., 2021**]. The first group of countries stands for more than 90% of global military spending and represents a trend of military expenditures of around 2% of GDP. The second group covers countries in which military spending amounts to approximately 5% of GDP, mostly because of armed conflicts. Finally, there are also developing countries where military spending accounts for around 1% of GDP.

Another factor that may play a role in military spending is being embargoed, for instance due to military coalitions or treaties. An international arms embargo is usually designed to limit the expansion of military forces, which is obviously linked with military expenditure. In the long run, embargoed countries may try to develop military technology on their own, but this strategy may prove pointless given the effort necessary in the case of advanced equipment. Even more importantly, given our focus, an international arms embargo can be violated by arms exporting states. It appears that such violations may be driven more by political interests than economic ones [**Moore, 2010**]. Problems such as adverse selection or moral hazard have been identified in military trade as well [**Deger, Sen, 1991**]. Military spending may be also constrained by various sanctions [**McNamara, 1991**; **Ringsmose, 2009**; **Dizaji, 2019**]. More intense sanctions decrease military expenditure in both the short and long term [**Dizaji, Farzanegan, 2021**]. Additionally, a special role in this context is played by multilateral sanctions [**Dizaji, Farzanegan, 2021**], which may target specific military sectors [**Veebel, 2020**].

The available empirical studies show that membership in military alliances matters for the level of military spending. One channel of impact may be spatial spillovers [**Dudley, Montmarquette, 1981**; **Douch, Sol-**

omon, 2014], but their significance is questioned in the case of NATO [**George, Sandler, 2018**]. More importantly, the effect of free-riding is observable among the allies in the context of military expenditures [**George, Sandler, 2018**]. Some members of the alliance, due to their strategic location, may be expected to play a key role in maintaining the structures of some treaties, as in the case of Cyprus and CENTO [**Dimitrakis, 2009**]. Although it is justified to expect that alliances influence military spending, the issue of sharing burdens within alliances remains unclear [**Thies, 1987**; **Alley, 2021**].

Additionally, the literature reveals that the significance of corruption for military spending is not negligible [**Gupta et al., 2001**; **d'Agostino et al., 2020**]. Political corruption affects military budgets – more corruption corresponds with increased spending on the military [**Farzanegan, 2018**]. Political corruption imposes extra costs on the functioning of the military [**Beliakova, Perlo-Freeman, 2018**], contributing to overall higher military spending. The impact of corruption on military spending has been confirmed in various dimensions: military expenditure as a share of GDP, share of total government spending, as well as arms procurement related to GDP and total government spending [**Gupta et al., 2001**].

Other institutional and political factors may also be relevant for military expenditure. Political regimes are important in this aspect. It is possible to observe differences not only between the impact of democracy and autocracy on military spending, but also across various levels of democracy [**Biddle, Long, 2004**; **Yildirim, Sezgin, 2005**; **Lskavyan, 2011**; **Albalte et al., 2012**; **Bove, Brauner, 2016**]. It also appears that the presence and strength of populist political parties affects defence cooperation between countries and may cause a shift in domestic attitudes in the context of military issues [**Henke, Maher, 2021**]. Interestingly, the literature shows that there have been military reactions against populists, even those that ended in coups d'état [**Kuehn, Trinkunas, 2017**]. It is well worth noting that empirical studies claim the presence of both leftist and rightist populist regimes in the last few decades [**Leon, 2014**; **Kuehn, Trinkunas, 2017**]. Moreover, it appears that party ideology influences defence spending as it more or less shapes the composition of the budget. In general, military spending is higher under right-wing administrations [**Whitten, Williams, 2011**; **Bove et al., 2017**; **Welzenburger, Böller, 2019**]. The personal characteristics of political leaders may have a crucial impact on public spending priorities, in practice affecting military expenditure [**Hayo, Neumeier, 2012**; **Holman, 2014**; **Mavisakalyan, 2014**].

Empirical analysis

Data and empirical design

The SIPRI military expenditure database constitutes the foundation of this research. It consists of an unbalanced panel data set of 173 countries over the 1949–2020 period. We decided to use two alternative measures of GDP growth to verify the existence of endogeneity. The average elevation was supposed to be a proxy of whether the country is mountainous, and as such easier to defend, and in consequence requiring a smaller defence budget. Additionally, the landlocked dummy variable should affect the military budget in a similar way to the average elevation. It can be argued that for a country without access to international waters no funds are allocated to the navy, thus lowering expenditures. Table 1 presents descriptive statistics and data sources.

We assumed military expenditures to be a function of the neighbouring countries' military budgets. For this reason, we calculated the maximum of the neighbours' expenditures using both land and maritime borders. A similar approach was employed by **Baltagi and Levine** [**1986**] to use the minimum price of cigarettes in any neighbouring state in a dynamic demand model for cigarettes. Our approach was extended to include information on the military expenditures of any hostile country that was at war with the analysed country at some point in time. Three different scenarios were considered: that the effect of the international conflict lasts 10 years, 20 years or indefinitely. To be specific, the list of neighbours was extended to include all countries that were at war with the analysed country during the last 10 years (in scenario 1), 20 years (in scenario 2) and

indefinitely (in scenario 3). Information on conflicts, derived from the UCDP database, was used to determine whether a specific country remained at war or dealt with an internal conflict. Notably, the *at war* and *domestic war* variables almost exclusively take values of zero and one. For a limited number of country-year pairs, the variables take on higher values, indicating more than one war or conflict.

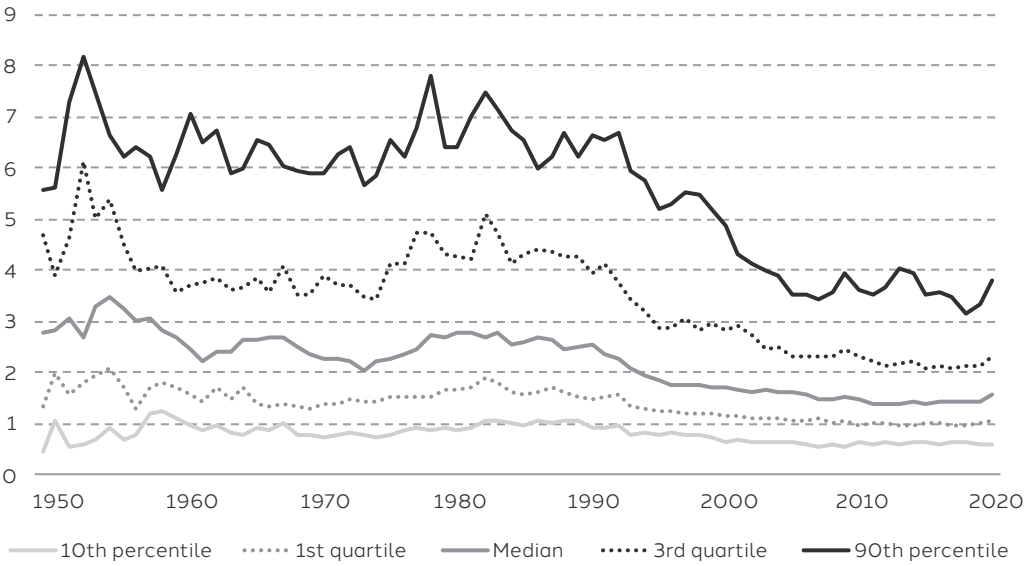
Table 1. Data descriptive statistics

Variable	Source	Unit	Obs	Mean	Std. Dev.	Min	Max
Dependent variable							
Military expenditures	SIPRI	% GDP	7,684	0.0277	0.0321	0	1.1735
Regressors							
GDP annual growth	World Bank	%	7,903	3.8150	6.4461	−64.0471	149.9730
GDP per capita growth	World Bank	%	7,900	1.9724	6.2788	−64.9924	140.3670
Average elevation	Atlas Big	Feet	11,952	1.8572	1.6516	0.0317	9.6916
Landlocked	Wikipedia	Dummy	11,952	0.2349	0.4240	0	1
At war	UCDP	Dummy	11,952	0.0211	0.1488	0	3
Domestic war	UCDP	Dummy	11,952	0.1933	0.5814	0	6
United Nations embargo	SIPRI	Dummy	11,952	0.0239	0.1528	0	1
Additional European Union embargo	SIPRI	Dummy	11,952	0.0200	0.1400	0	1
Military expenditures max {neighbours, conflicts}	SIPRI	% GDP	7,526	0.0478	0.0468	0	1.1735
Military expenditures max {conflicts}	SIPRI	% GDP	6,468	0.0431	0.0426	0	1.1735
Military expenditures max {neighbours}	SIPRI	% GDP	7,479	0.0472	0.0462	0	1.1735
Trade sanctions [number of countries imposed]	GSDB	Number	11,952	3.5826	20.5181	0	192
Financial sanctions [number of countries imposed]	GSDB	Number	11,952	4.8485	26.2077	0	193
Military alliance	Wikipedia	Dummy	11,952	0.2474	0.4315	0	1
NATO	Wikipedia	Dummy	11,952	0.1031	0.3041	0	1
CENTO	Wikipedia	Dummy	11,952	0.0084	0.0911	0	1
CSTO	Wikipedia	Dummy	11,952	0.0157	0.1241	0	1
TIAR	Wikipedia	Dummy	11,952	0.1204	0.3254	0	1
SEATO	Wikipedia	Dummy	11,952	0.0181	0.1332	0	1
Liberal democracy index	V-dem	Own scale	10,675	0.3116	0.2733	0.0050	0.8920
HOS = HOG	V-dem	Dummy	10,804	0.4257	0.4945	0	1
HOS female	V-dem	Dummy	10,746	0.0444	0.2060	0	1
Political corruption index	V-dem	Own scale	10,696	0.4747	0.2889	0.0020	0.9680
Illiberalism	V-party	Own scale	6,965	0.5631	0.3585	0.0120	1
Populism	V-party	Own scale	6,965	0.3967	0.2520	0.0170	0.9930
Economic left-right scale	V-party	Own scale	6,965	−0.2278	1.5781	−4.2840	4.0530
Instrumental variables							
Arms producers [Wiki]	Wikipedia	Number	11,952	2.6084	7.2429	0	79
Arms producers [SIPRI]	SIPRI	Number	11,952	1.5904	8.4921	0	101
Human Capital	Penn World Table	Value	8,347	2.0786	0.7332	1.0070	4.3516
Total factor of productivity	Penn World Table	Value	6,189	0.7171	0.2794	0.0349	3.6964
Gross capital formation [%GDP]	Penn World Table	% GDP	9,119	0.2109	0.1154	−0.1011	3.1650
Government consumption [%GDP]	Penn World Table	% GDP	9,119	0.1877	0.1023	0.0052	2.1113
Rule of law index	V-dem	Own scale	10,777	0.5117	0.3022	0.0040	0.9990

Source: Authors' own elaboration.

Information on United Nations and European Union arms embargoes was enriched with trade and financial sanctions derived from the Global Sanctions Database. We believe that the impact of sanctions can depend on the number of countries that imposed restrictions of any sort on a specific country instead of a dummy variable approach. We decided to exploit information on the dominant religion. However, preliminary analysis indicated no impact of religion on military expenditures. Various political indicators were extracted out of the Varieties of Democracy V–DEM [**Coppedge et al., 2021**] and V-Party [**Lührmann et al., 2020**] data sets. The liberal democracy index refers to a country as a whole, while the illiberalism variable characterises the ruling party. Figure 1 presents the percentiles of military expenditures over time.

Figure 1. Percentiles of military expenditures over the period 1949–2020 (in %)



Source: Authors' own elaboration.

The standard approach to panel data is the linear model of the form

$$y_{i,t} = \boldsymbol{z}'_{i,t}\boldsymbol{\delta} + u_i + \varepsilon_{i,t} \tag{1}$$

in which u_i is the individual effect attributable to an individual and considered to be time-invariant. Assuming a lack of correlation between the individual effect and the vector of covariates $\boldsymbol{z}_{i,t}$ leads to the random effects (RE) model. Allowing for non-zero correlation between u_is and covariates results in the fixed effects (FE) estimator. However, the price is that the parameters of the time-invariant variables cannot be estimated. The Hausman test is usually employed to distinguish between the FE and RE estimators, although Baltagi (2013) presented a wider discussion on the selection between the fixed effects and the random effects. The correlated random effects (CRE) framework combines the benefits of the two approaches. It involves Mundlak's device to be included in the model. A comprehensive description of the RE, FE and CRE models is presented in **Wooldridge** [**2013**].

The above-mentioned models assume that the independent variables are exogenous. One key assumption in the RE, FE and CRE models is the exogeneity of the explanatory variables. The presence of at least one endogenous regressor leads to inconsistent estimates. Controlling for endogeneity involves a panel model of the form

$$y_{i,t} = \boldsymbol{x}'_{i,t}\boldsymbol{\beta} + \boldsymbol{w}'_{i,t}\boldsymbol{\theta} + u_i + \varepsilon_{i,t} \tag{2}$$

where $\boldsymbol{w}$ is the vector of the endogenous variables, which is correlated with the error term, while vector $\boldsymbol{x}$ contains the exogenous variables. The two-stage estimation of (2) employs additional variables, namely the instruments. The instrumental variables satisfy two conditions. Specifically, the instruments cannot be correlated with the error term and should be at least weakly correlated with the endogenous variables.

Introduced by **Anderson and Hsiao [1982]**, dynamic panel models facilitate the establishment of the autoregressive effect. A more efficient method was proposed in **Arellano and Bond [1991]**. It led to two further developments by **Arellano and Bover [1995]** and **Blundell and Bond [1998]**. In the literature, these developments are often described as the Arellano-Bover-Blundell-Bond estimator. The estimator relies on the general method of moments estimation and allows both autoregression and endogeneity. The form of the model is

$$y_{i,t} = \alpha_1 y_{i,t-1} + \boldsymbol{x}'_{i,t}\beta + \boldsymbol{w}'_{i,t}\theta + u_i + \varepsilon_{i,t} \tag{3}$$

in which the vector of covariates $\boldsymbol{x}$ comprises exogenous regressors, while $\boldsymbol{w}$ is the vector of endogenous variables.

The share of military expenditures in GDP can be seen as a limited dependent variable. This stems from the fact that its values are naturally limited by zero. As a consequence, a tobit model can be exploited. Although the number of zeros in the data set is limited and therefore the estimated basic fixed effects estimator and the tobit CRE model should be comparable.

Empirical results and discussion

The endogeneity in the share of military expenditures in GDP modelling arises from the GDP growth rate variable. The expenditures seem to be a function of economic growth. At the same time, it can be argued that increased military equipment acquisition may lead to faster growth, especially if the purchases are made within the economy. The emerging feedback relationship is one form of endogeneity. For that reason, we applied the instrumental variables approach. As potential instruments, we identified the number of major arms producers within the country, the human capital index, total factor productivity, gross capital formation as a percentage of GDP, the share of government consumption in GDP, and the rule of law index as an instrument. The variable would constitute a valid instrument only if the number of major arms producers has no direct effect on military expenditures while being correlated with GDP growth. The number of major arms producers can be associated with the technological advancement of the economy and the possibility of absorbing offsets, and it would therefore be correlated with GDP growth. For instance, in the context of Russia's invasion of Ukraine, increased military budgets transmit to military equipment acquisition. Modern military warfare contains many technological advances and requires research and development expenditures. To produce modern military equipment, physical input and intellectual contribution are needed. As a consequence, modern warfare production requires the cooperation of many sectors of the economy. Increasing demand in this context may lead to higher production and consequently faster GDP growth. The selection of the remaining instruments was justified in **Barro [1998]**, where these variables were presented as growth determinants.

Table 2 presents the results of the static panel data models. It contains models with the GDP growth rate treated as endogenous and exogenous. The findings remain consistent across the presented models. Surprisingly, although they are statistically significant and there is a negative effect of the GDP growth rate, the findings simultaneously appear to be economically insignificant. While even a ten-thousandth of the GDP growth rate can be millions, the fact remains that modelling military expenditures as a percentage of GDP seems practically irrelevant. Wars or internal conflicts have a positive impact on military expenditures. Considering the possible effect of external or internal conflict on GDP, further analysis should focus on this indirect path of causality.

The positive estimate of the United Nations embargo can be attributed to the timing of the restriction. The embargo does not apply to previously ordered equipment, so even after it is imposed, there may still be expenses related to previous orders. As it appears, the more liberal the democracy, the smaller the share of the military budget in comparison to GDP. This can be associated with both a more stable external environment and higher GDP *ceteris paribus*. Similar explanations can be identified for the effect of political corruption. The corruption problem may involve the lack of competencies to identify military needs. The results indicate that populist governments reallocate resources to non-military sectors. Unanticipated estimates of the economic left-right scale indicate that it is the left that tends to spend more. Surprisingly, participation in a trans-border defence alliance does not affect military spending.

Table 2. Static panel data model results

	Military expenditures as a share of GDP								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GDP annual growth	−0.0002*** (0.0000)	−0.0002*** (0.0000)	−0.0002*** (0.0000)	−0.0002*** (0.0000)	−0.0002*** (0.0000)	0.0014*** (0.0004)	0.0014*** (0.0004)	0.0013*** (0.0004)	0.0026*** (0.0007)
Average elevation [feet]		0.0011 (0.0009)	0.0007 (0.0008)	0.0011 (0.0010)	0.0007 (0.0009)			−0.0002 (0.0007)	
Landlocked		− 0.0065* (0.0036)	−0.0026 (0.0033)	− 0.0065* (0.0038)	−0.0027 (0.0035)			0.0018 (0.0030)	
At war	0.0074*** (0.0014)	0.0078*** (0.0014)	0.0077*** (0.0015)	0.0077*** (0.0014)	0.0077*** (0.0014)	0.0082*** (0.0019)	0.0081*** (0.0019)	0.0082*** (0.0019)	
Domestic war	0.0027*** (0.0004)	0.0027*** (0.0004)	0.0027*** (0.0004)	0.0027*** (0.0004)	0.0027*** (0.0004)	0.0022*** (0.0006)	0.0022*** (0.0006)	0.0022*** (0.0006)	
United Nations Embargo	0.0080*** (0.0015)	0.0082*** (0.0015)	0.0081*** (0.0015)	0.0082*** (0.0015)	0.0081*** (0.0015)	0.0052*** (0.0020)		0.0052*** (0.0020)	0.0067** (0.0026)
Military expenditures max {neighbours, conflicts}	0.1252*** (0.0063)	0.1282*** (0.0063)	0.1244*** (0.0063)	0.1279*** (0.0062)	0.1245*** (0.0063)	0.0922*** (0.0079)	0.0917*** (0.0078)	0.0921*** (0.0078)	0.1124*** (0.0102)
Trade sanctions [number of countries imposed]	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000** (0.0000)	0.0000*** (0.0000)	0.0000** (0.0000)	0.0001** (0.0000)
Financial sanctions [number of countries imposed]	−0.0000** (0.0000)	−0.0000** (0.0000)	−0.0000*** (0.0000)	−0.0000** (0.0000)	−0.0000*** (0.0000)	−0.0000*** (0.0000)	−0.0000** (0.0000)	−0.0000*** (0.0000)	−0.0001*** (0.0000)
Military alliance	−0.0004 (0.0010)	−0.0005 (0.0010)	−0.0004 (0.0010)	−0.0005 (0.0010)	−0.0004 (0.0010)	−0.0014 (0.0013)		−0.0012 (0.0013)	
Liberal democracy index	−0.0287*** (0.0017)	−0.0289*** (0.0017)	−0.0290*** (0.0017)	−0.0289*** (0.0017)	−0.0289*** (0.0017)	−0.0325*** (0.0020)	−0.0330*** (0.0018)	−0.0322*** (0.0020)	
HOS = HOG	−0.0006 (0.0008)	−0.0006 (0.0008)	−0.0005 (0.0008)	−0.0006 (0.0008)	−0.0005 (0.0008)	0.0013 (0.0011)		0.0012 (0.0011)	0.0002 (0.0015)
HOS female	0.0005 (0.0009)	0.0004 (0.0009)	0.0004 (0.0010)	0.0004 (0.0009)	0.0004 (0.0009)	0.0011 (0.0010)		0.0010 (0.0010)	0.0002 (0.0014)
Political corruption index	−0.0202*** (0.0020)	−0.0203*** (0.0019)	−0.0209*** (0.0020)	−0.0203*** (0.0019)	−0.0208*** (0.0020)	−0.0269*** (0.0030)	−0.0273*** (0.0030)	−0.0259*** (0.0030)	
Illiberalism	0.0004 (0.0009)	0.0005 (0.0009)	0.0003 (0.0009)	0.0005 (0.0009)	0.0003 (0.0009)	−0.0000 (0.0011)		−0.0001 (0.0011)	0.0062*** (0.0014)
Populism	−0.0029*** (0.0010)	−0.0028*** (0.0010)	−0.0029*** (0.0010)	−0.0028*** (0.0010)	−0.0029*** (0.0010)	−0.0037*** (0.0011)		−0.0036*** (0.0011)	−0.0019 (0.0015)
Economic left-right scale	−0.0006*** (0.0002)	−0.0006*** (0.0002)	−0.0006*** (0.0002)	−0.0006*** (0.0002)	−0.0006*** (0.0002)	−0.0010*** (0.0002)	−0.0007*** (0.0002)	−0.0009*** (0.0002)	−0.0010*** (0.0002)

cont. Table 2

	Military expenditures as a share of GDP								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mundlak device[#]	No	No	Yes	No	Yes	No	No	Yes	Yes
Constant	0.0402*** (0.0018)	0.0404*** (0.0027)	0.0092 (0.0121)	0.0404*** (0.0028)	0.0091 (0.0130)	0.0409*** (0.0022)	0.0399*** (0.0019)	0.0424*** (0.0108)	0.0009 (0.0044)
Method[$]	FE	RE	CRE	TBTRE	TBTCRE	IVFE	IVFE	IVCRE	IVCRE
sigma_u	0.0187	0.0170	0.0144	0.0179	0.0155	0.0115	0.0113	0.0102	0.0106
sigma_e	0.0127	0.0127	0.0127	0.0127	0.0127	0.0129	0.0129	0.0129	0.0175
Observations	5594.0000	5594.0000	5594.0000	5594.0000	5594.0000	4165.0000	4173.0000	4165.0000	4181.0000
Groups	152.0000	152.0000	152.0000	152.0000	152.0000	108.0000	108.0000	108.0000	108.0000
R^2 overall[&]	0.2673	0.2702	0.3274			0.1413	0.1471	0.2177	0.0657
R^2 between[&]	0.3620	0.3550	0.4750			0.2440	0.2703	0.4306	0.3351
R^2 within[&]	0.1793	0.1792	0.1792			.	.	0.0690	0.0030

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

[#] The Mundlak device constitutes an integral part of the correlated-random effects model.

[&] R-squared statistics for models with endogeneity cannot be subjected to standard interpretation.

[$] Abbreviations for the used methods: FE – fixed effects, RE – random effects, CRE – correlated random effects, TBTRE – tobit model with random effects, TBTCRE – tobit model with correlated random effects, IVFE – fixed effects with instrumental variables, IVCRE – correlated random effects with instrumental variables.

Source: Authors' own elaboration.

Table 3 presents the results of the Hausman and Sargan tests. What emerges from the results is that, for the fixed-effects estimator, we have identified endogeneity, which we relate to the feedback relationship between GDP growth and military expenditures. In fact, the CRE models appear quite inconclusive in this context. Model (8) of Table 3 contains a negative (inconclusive) test statistic of the Hausman test, while model (9) of the same table fails the Sargan test and thus makes the Hausman statistic unreliable.

Table 3. First-stage regressions for models (6)–(9) from Table 2

	GDP growth			
	(6)	(7)	(8)	(9)
Total factor of productivity	3.5548*** (0.5492)	3.5395*** (0.5416)	3.3695*** (0.5269)	3.5505*** (0.5278)
Rule of law index	8.4644*** (1.7895)	8.0484*** (1.7833)	8.4175*** (1.7121)	0.6059 (0.6325)
Constant	−7.9097*** (1.4071)	−6.6535** (1.3496)	−3.8428 (3.7197)	3.0700 (1.9138)
Exogenous variables	Yes	Yes	Yes	Yes
Observations	4165	4173	4165	4181
F statistic	7.81***	10.24***	134.00	284.00
Hausman test#	99.04***	81.99***	−697.90	8.07
Sargan-Hansen test	0.7900	0.5510	0.7940	20.7480***
Sargan-Hansen test p-value	0.3741	0.4579	0.3730	0.0000

Notes: * p<0.10, ** p<0.05, *** p<0.010
Negative value for the Hausman test denotes inconclusive result.
Source: Authors' own elaboration.

The endogenous character of GDP growth can be tested with the Hausman test. The idea of the test is to compare two sets of estimates and evaluate whether the differences are significant. If the estimates obtained from the consistent model are close to those of the efficient model, a conclusion on the lack of endogeneity is drawn. We found no endogeneity in model (6) compared to model (3). However, the Hausman test used for model (7) yielded an inconclusive result.

In view of the fact that some major military acquisitions involve enormous financial costs, the payment is often divided into instalments. In consequence, a positive autocorrelation of military expenditures should be observed. For this reason, we decided to refer to dynamic panel data models. As mentioned in the previous section, the endogeneity of GDP growth can be incorporated within dynamic panel data models.

Table 4. Dynamic panel model results

	Military expenditures as a share of GDP					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged military expenditures	0.6184*** (0.0202)	0.6201*** (0.0197)	0.6900*** (0.0151)	0.6901*** (0.0219)	0.6772*** (0.1038)	0.6168*** (0.0212)
GDP annual growth	−0.0003*** (0.0001)	−0.0003*** (0.0001)			−0.0003* (0.0001)	−0.0003*** (0.0001)
GDP per capita growth			−0.0002* (0.0001)	−0.0002* (0.0001)		
Arms producers [Wiki]	−0.0004 (0.0005)				−0.0008 (0.0007)	−0.0004 (0.0005)
Arms producers [SIPRI]		−0.0002 (0.0004)	−0.0002 (0.0004)	−0.0001 (0.0004)		
Average elevation [feet]	0.0011 (0.0014)	0.0010 (0.0013)	0.0003 (0.0013)	0.0003 (0.0013)	0.0001 (0.0036)	0.0012 (0.0014)
Landlocked	−0.0011 (0.0055)	−0.0007 (0.0061)	0.0018 (0.0055)	0.0021 (0.0053)	0.0069 (0.0062)	−0.0017 (0.0060)

cont. Table 4

	Military expenditures as a share of GDP					
	(1)	(2)	(3)	(4)	(5)	(6)
At war	0.0122*** (0.0045)	0.0119*** (0.0043)	0.0122*** (0.0040)	0.0127*** (0.0043)	0.0049* (0.0025)	0.0122*** (0.0043)
Domestic war	−0.0013 (0.0012)	−0.0012 (0.0012)	−0.0016 (0.0012)	−0.0016 (0.0013)	−0.0038* (0.0021)	−0.0014 (0.0013)
United Nations embargo	−0.0024 (0.0055)	−0.0024 (0.0059)	−0.0024 (0.0053)	−0.0025 (0.0052)	0.0144 (0.0200)	−0.0020 (0.0047)
Additional European Union embargo						0.0032 (0.0033)
Military expenditures max {neighbours, conflicts}	0.0580*** (0.0094)	0.0564*** (0.0105)	0.0555*** (0.0113)	0.0509*** (0.0094)		0.0567*** (0.0111)
Military expenditures max {conflicts}					−0.1052 (0.1641)	
Military expenditures max {neighbours}					0.1577 (0.1691)	
Trade sanctions [number of countries imposed]	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0001)	−0.0000 (0.0000)
Financial sanctions [number of countries imposed]	−0.0000 (0.0000)	−0.0000 (0.0000)	0.0000 (0.0000)	−0.0000 (0.0000)	0.0000 (0.0000)	−0.0000 (0.0000)
Military alliance	−0.0018 (0.0025)	−0.0022 (0.0020)	−0.0015 (0.0031)		0.0106* (0.0057)	−0.0018 (0.0027)
NATO				−0.0028 (0.0035)		
CENTO				0.0038 (0.0066)		
CSTO				−0.0035 (0.0104)		
TIAR				−0.0007 (0.0040)		
SEATO				0.0012 (0.0033)		
Liberal democracy index	−0.0276*** (0.0036)	−0.0285*** (0.0043)	−0.0262*** (0.0025)	−0.0258*** (0.0025)	−0.0119 (0.0230)	−0.0277*** (0.0027)
HOS = HOG	0.0042*** (0.0012)	0.0040*** (0.0013)	0.0040 (0.0030)	0.0037 (0.0031)	0.0043 (0.0056)	0.0041 (0.0027)
HOS female	0.0001 (0.0022)	0.0001 (0.0016)	0.0008* (0.0005)	0.0008* (0.0004)	−0.0439 (0.0357)	0.0002 (0.0019)
Political corruption index	−0.0211*** (0.0035)	−0.0205*** (0.0031)	−0.0182*** (0.0044)	−0.0181*** (0.0033)	−0.0300 (0.0202)	−0.0219*** (0.0031)
Illiberalism	0.0021 (0.0013)	0.0022 (0.0019)	0.0009 (0.0016)	0.0007 (0.0015)	0.0031 (0.0071)	0.0026* (0.0016)
Populism	−0.0015 (0.0015)	−0.0017 (0.0013)	−0.0015 (0.0010)	−0.0009 (0.0011)	0.0074 (0.0112)	−0.0014 (0.0015)
Economic left-right scale	−0.0003** (0.0001)	−0.0003** (0.0001)	−0.0002 (0.0001)	−0.0002 (0.0001)	−0.0011 (0.0012)	−0.0003** (0.0001)
Constant	0.0271*** (0.0033)	0.0263*** (0.0031)	0.0234*** (0.0030)	0.0232*** (0.0029)	0.0271 (0.0196)	0.0272*** (0.0034)
Observations	5483	5483	5480	5480	1570	5483
Groups	152	152	152	152	48	152
g_avg	36.0724	36.0724	36.0526	36.0526	32.7083	36.0724
AR (1) residuals autocorrelation test stat.	−2.0855**	−2.0859**	−2.0868**	−2.0803**	−1.2511	−2.0829**
AR (2) residuals autocorrelation test stat.	0.9725	0.9764	1.0762	1.0764	1.0214	0.9910
Sargan test statistic	133.0288	132.0629	132.9244	132.0112	13.2966	136.3214

Notes: * p<0.10, ** p<0.05, *** p<0.010

Source: Authors' own elaboration.

Table 3 presents estimations of the dynamic panel data models. In fact, we observe a positive and highly significant lag of the military expenditures, indicating the superiority of the dynamic approach over static models. Within the dynamic framework, the United Nations embargo appears to be insignificant, contrary to previous results. The fact that the head of state is female or concurrently serves as head of government may be significant in some models, but has no practical effect on defence spending. The remaining results were consistent with those in the static models. The use of alternative measures of GDP growth and of the number of producers yields comparable findings. Even altering the military alliance with a set of dummies for each defence bloc had no effect on the conclusions.

For models (1), (2), (3) and (6), the endogenous character of GDP growth has been confirmed. In the case of models (4) and (5), it was impossible to obtain valid test statistics of the Hausman test. The results seem to prove the existence of a feedback relationship between military spending and GDP growth. As a result, the models that handle endogeneity enable valid estimations. Although the effect exists, it appears to be limited and on the edge of practical significance. The results of dynamic models with more lags remain consistent with those presented above. These results are included in the online appendix.

Model extensions

On the whole, we scrutinised the main arms producing countries. Having identified the existence of the feedback relationship between GDP growth and military expenditures in the previous section, we decided to verify the stability of the results. The question was whether the effect observed for the entire population would be more pronounced for countries leading in military technology. The following analysis can be understood as a confirmatory analysis.

Of the 154 countries included in the base analysis, only 72 could be classified as leading in military production. Additionally, due to data availability limitations, only up to 69 countries constitute the data sets for the following analysis. Table 4 presents the results of the dynamic models for the panels of main producers of military equipment.

The estimate of the lagged military expenditures is higher in comparison to the previous results. We identified NATO membership to be negatively correlated with military expenditures. However, the variable seems to be slightly significant, indicating the joint insignificance of all defensive treaties. Despite similar estimates, the economic left-right scale variable turned out to be statistically insignificant. By and large, conclusions drawn on the arms producing countries data set remain consistent with the results of the dynamic models for the entire set of countries.

The Hausman test for endogeneity yielded inconclusive results for models (1)–(6). The Hausman test statistics for models (7) and (8) were 17.1548 and 9.6637 respectively (p-values of 0.8016 and 0.7863 respectively), indicating no endogeneity.

Table 5. Dynamic panel data models for countries leading in military technology

	Military expenditures as a share of GDP							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged military expenditures	0.8789*** (0.0380)	0.8222*** (0.0455)	0.8589*** (0.0419)	0.8218*** (0.0322)	0.8209*** (0.0262)	0.7965*** (0.0316)	0.7911*** (0.0412)	0.8304*** (0.0220)
GDP annual growth	−0.0001* (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0001)	−0.0000 (0.0000)	−0.0001 (0.0000)	−0.0000 (0.0001)	−0.0001* (0.0000)	−0.0000 (0.0000)
Arms producers [Wiki]	−0.0000 (0.0001)	0.0000 (0.0001)	−0.0001 (0.0001)	−0.0000 (0.0001)	0.0001 (0.0001)	0.0000 (0.0001)	−0.0001 (0.0001)	0.0001 (0.0001)
Average elevation [feet]	0.0003 (0.0009)	0.0004 (0.0006)	−0.0001 (0.0009)		0.0011 (0.0008)	0.0004 (0.0007)	0.0005 (0.0011)	0.0005 (0.0006)
Landlocked	0.0004 (0.0034)		−0.0014 (0.0033)		−0.0028 (0.0019)	−0.0013 (0.0020)	0.0017 (0.0027)	

cont. Table 5

	Military expenditures as a share of GDP							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
At war	0.0043** (0.0018)	0.0052*** (0.0011)	0.0042** (0.0020)	0.0038*** (0.0012)	0.0048** (0.0020)	0.0036*** (0.0009)	0.0040* (0.0023)	0.0050*** (0.0008)
Domestic war	−0.0001 (0.0007)		0.0003 (0.0005)	0.0000 (0.0004)	0.0001 (0.0008)		0.0002 (0.0008)	
Embargo_UN	−0.0057 (0.0035)	−0.0012 (0.0024)	−0.0041 (0.0039)	−0.0024 (0.0038)	−0.0005 (0.0052)		−0.0095 (0.0070)	−0.0029 (0.0031)
Military expenditures max {neighbours, conflicts}	0.0129 (0.0094)	0.0251** (0.0123)					0.0283** (0.0121)	0.0242*** (0.0074)
Military expenditures max {land and maritime neighbours}			0.0137 (0.0120)	0.0215*** (0.0077)	0.0361 (0.0231)	0.0484*** (0.0108)		
Trade sanctions [number of countries imposed]	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0001** (0.0000)	0.0000 (0.0000)
Financial sanctions [number of countries imposed]	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)	−0.0000 (0.0000)
Military alliance	0.0002 (0.0009)	0.0012 (0.0013)	0.0008 (0.0012)	0.0004 (0.0013)	0.0005 (0.0014)			
NATO							−0.0037* (0.0022)	
CENTO							0.0082 (0.0088)	
CSTO							0.0018 (0.0053)	
TIAR							−0.0002 (0.0041)	
SEATO							0.0011 (0.0050)	
Liberal democracy index	−0.0137*** (0.0039)	−0.0141*** (0.0027)	−0.0148*** (0.0036)	−0.0134*** (0.0039)	−0.0096*** (0.0036)	−0.0120*** (0.0030)	−0.0092 (0.0063)	−0.0127*** (0.0028)
HOS = HOG	−0.0004 (0.0021)		0.0003 (0.0019)		0.0014 (0.0023)		0.0020 (0.0037)	
HOS female	0.0008 (0.0022)	0.0014 (0.0020)	0.0019 (0.0028)	−0.0008 (0.0032)	0.0047 (0.0034)		−0.0020 (0.0023)	
Political corruption index	−0.0093*** (0.0031)	−0.0100*** (0.0022)	−0.0083*** (0.0029)	−0.0098** (0.0038)	−0.0076* (0.0042)	−0.0105*** (0.0039)	−0.0189*** (0.0070)	−0.0104*** (0.0033)
Illiberalism	−0.0016 (0.0019)	−0.0007 (0.0012)	−0.0022 (0.0019)	0.0003 (0.0011)	0.0011 (0.0018)	0.0010 (0.0012)	0.0012 (0.0013)	−0.0000 (0.0010)
Populism	−0.0008 (0.0007)	−0.0010 (0.0011)	−0.0026 (0.0024)	−0.0012** (0.0006)	−0.0006 (0.0018)	−0.0029** (0.0015)	−0.0011* (0.0006)	−0.0013 (0.0014)
Economic left-right scale	−0.0000 (0.0001)		−0.0001 (0.0002)	−0.0000 (0.0001)	−0.0000 (0.0001)	−0.0001 (0.0001)	−0.0001 (0.0001)	−0.0001 (0.0001)
Constant	0.0134*** (0.0040)	0.0131*** (0.0028)	0.0152*** (0.0040)	0.0142*** (0.0033)	0.0066* (0.0039)	0.0131*** (0.0032)	0.0156*** (0.0055)	0.0125*** (0.0031)
Observations	2777	2777	2730	2730	2526	2534	2777	2785
Groups	69	69	68	68	62	62	69	69
AR (1) residuals autocorrelation test stat.	−3.3010***	−3.3102***	−3.2807***	−3.2339***	−3.0464***	−3.0099***	−3.2366***	−3.2735***
AR (2) residuals autocorrelation test stat.	−0.1599	−0.1705	−0.1900	−0.1647	−0.2638	−0.1888	−0.0785	−0.1466
Sargan test statistic	56.4444	60.0984	56.6998	57.9099	49.0547	54.1057	54.2635	58.9072

Notes: * p<0.10, ** p<0.05, *** p<0.010

Source: Authors' own elaboration.

Conclusions

There is a continuous and lively public debate on the matter of military expenditure and the topic itself appears to be very complex. Depending on the actual needs of politicians and rent-seeking groups, various advantages of arms races may be claimed. One of the points often raised is the positive interrelationship with economic growth. We decided to address this issue empirically with advanced economic apparatus applied on a global sample of countries.

The core goal of our research was to investigate the drivers of arms races, with a particular focus on the relationships between military expenditures and economic growth. The results of our static econometric models generally suggest a lack of endogeneity in this context. The output of dynamic models, in turn, proves the existence of a feedback relationship between military spending and GDP growth, but the effect appears to be limited. Last but not least, our empirical extensions in terms of endogeneity analysis provide inconclusive results about the impact of military spending on economic growth or no such effect. At the same time, we are aware that national defence plays a crucial role in various dimensions and we do not underestimate this fact. It simply appears that the claimed positive feedback loop between military expenditures and economic growth is not valid. In our empirical study, we identified a robust statistical significance of factors such as GDP growth, being at war, military expenditures in neighbouring countries, state of democracy, as well as political corruption in the context of military spending.

Overall, our study sheds new light on the issue of military expenditures, providing added value to the literature. Our results can also be of practical relevance to policymakers and governments. Of course, there are limitations of the methods we apply and the data we rely on. There are multiple directions for future research in the area. One option is to include more information about the existing alliances between countries and direct or indirect sanctions imposed. Another perspective would be to focus on selected countries to obtain a portrayal for a particular context.

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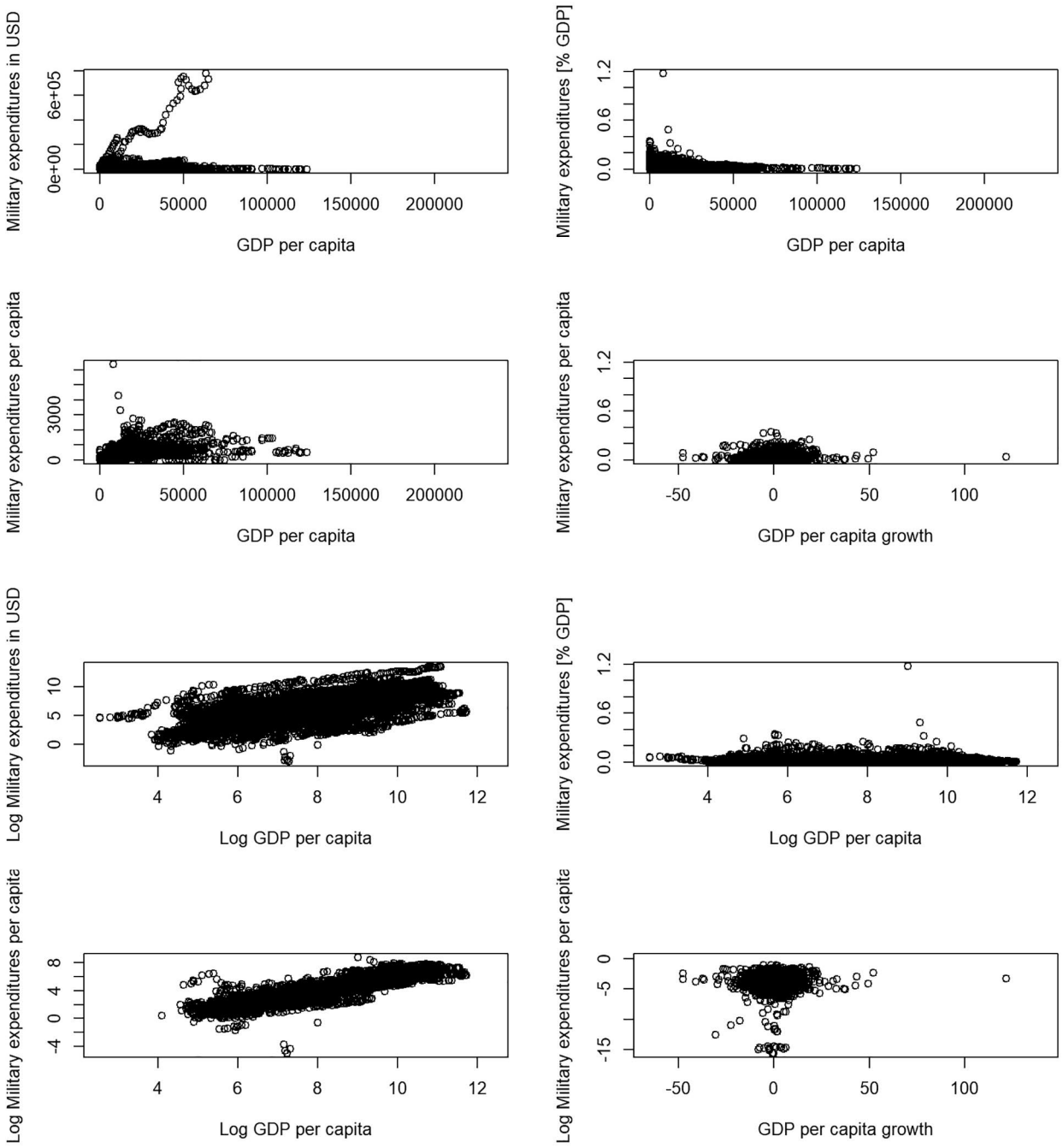
Appendix

Figure A1. Military expenditures and GDP per capita (1949–2020 averages)



Source: Authors' own elaboration.

Table A1. Patterns of data availability

```
country: 1, 2,…, 166 n=166
year: 1949, 1950,…, 2020 T=72
Delta (year)=1 unit
Span (year)=72 periods
(country*year uniquely identifies each observation)
Distribution of T_i:    min     5%      25%     50%     75%     95%     max
                          6      16      30      49      62      71      72
Freq.   Percent    Cum.      Pattern
8       4.82        4.82     ........................................1111111111111111111111111111
8       4.82        9.64     ...........1111111111111111111111111111111111111111111111111111111111111111111111
7       4.22       13.86     .1111111111111111111111111111111111111111111111111111111111111111111111111111111
6       3.61       17.47     ........................................1111111111111111111111111111
6       3.61       21.08     1111111111111111111111111111111111111111111111111111111111111111111111111111111
5       3.01       24.10     ..................1111111111111111111111111111111111111111111111111111
4       2.41       26.51     ................................1111111111111111111111111111111111111
4       2.41       28.92     ............................1111111111111111111111111111111111111111
4       2.41       31.33     ........1111111111111111111111111111111111111111111111111111111111111111111111
4       2.41       33.73     .......1111111111111111111111111111111111111111111111111111111111111111111111
4       2.41       36.14     ....1111111111111111111111111111111111111111111111111111111111111111111111111
3       1.81       37.95     ..................................................1111111111111111111111
3       1.81       39.76     .........1111111111111111111111111111111111111111111111111111111111111111111111
3       1.81       41.57     ..1111111111111111111111111111111111111111111111111111111111111111111111111111
2       1.20       42.77     ..........................................................1111111111111111
2       1.20       43.98     ....................................1111111111111111111111111111111111
2       1.20       45.18     ....................................1111111111111111111111111111111111
2       1.20       46.39     ........................1111111111111111111111111111111111111111111111
2       1.20       47.59     ........................1111111111111111111111111111111111111111111111
2       1.20       48.80     ......................1111111111111111111111111111111111111111111111
2       1.20       50.00     ................1111111111111111111111111111111111111111111111111111
2       1.20       51.20     ..............1111111111111111111111111111111111111111111111111111111
2       1.20       52.41     ............1111111111111111111111111111111111111111111111111111111111
2       1.20       53.61     ....1...1111111111111111111111111111111111111111111111111111111111111
1       0.60       54.22     ..........................................................1111111111..
1       0.60       54.82     ..........................................................111111111111.
1       0.60       55.42     ..........................................................111111111111111111
1       0.60       56.63     ..........................................................1111111111111111.....
1       0.60       57.23     ..........................................11...........111....111111.
1       0.60       57.83     ..........................................1111.11111.............1..
1       0.60       58.43     ..........................................111111.....................
1       0.60       59.04     ..........................................1111111111.................
1       0.60       59.64     ..........................................11.11111111111111111111111
1       0.60       60.24     ..........................................111111111111...11111.1111111
1       0.60       60.84     ..........................................1111111111111111111.......
1       0.60       61.45     ........................................111111.....1111.11111111111111
1       0.60       62.05     ........................................11111111111111111111111111111
1       0.60       62.65     ........................................1111111111111111111111......
1       0.60       63.25     ....................................11111111.................11111111
1       0.60       63.86     ....................................11111111........1111111111111111..
1       0.60       64.46     ....................................11111111111111111111111111111111111
1       0.60       65.06     ....................................1111111111111111111.11..111111111
1       0.60       65.66     ....................................11111...11111111111111111111111111
1       0.60       66.27     ....................................1111111111111.1....11111111111111111
1       0.60       66.87     ....................................11111111111111111111111111111111111
1       0.60       67.47     ....................................11111111.1111111111111111111.11111111
1       0.60       68.07     ....................................11111111111111111111111..1111..111
1       0.60       68.67     ................................111111.1....11111.1111.1...111111111111
1       0.60       69.28     ................................11111...111111111..1111111111111111111
1       0.60       69.88     ................................111........1111..11111111.......111111111
1       0.60       70.48     ................................111111.11111..........111111111..........
1       0.60       71.08     ..............................11111111111111111111111111111111111111111
1       0.60       71.69     ..............................111111.......1111111111...11111.............
1       0.60       72.29     ..............................11...11111111111111111111111111111111111111
1       0.60       72.89     ..........................1111111...11111111111111111111111111111111111
1       0.60       73.49     ..........................1111111111111......111111111111..1111111.11111
1       0.60       74.10     ..........................11111111111111111111111111111111111111111111
1       0.60       74.70     ..........................11111111111111111111111111111111111111111111
1       0.60       75.30     ........................1111111111111111111111...1111111111111111111
1       0.60       75.90     ......................111111111111111111111111111111111111111111111111
1       0.60       76.51     ......................111111111111111111111111111111111111111111111111
```

cont. Table A1

1	0.60	77.11	.....1..11111.....1111111111111111
1	0.60	77.71	.....11111..1111111111111111111111111111111111111111
1	0.60	78.31	.....111111111111.11.1....11.......11111111.1..11.11111
1	0.60	78.92	.....1111111111111...........11......1111111111111111111
1	0.60	79.52	.....1111111111111.........1111111111111111111111111111
1	0.60	80.12	11111111111111111111111111111111111111111111111111
1	0.60	80.72	.....11111111111.11111111.............1111111...11111111111
1	0.60	81.33	11111111111111111111111111111111111111111111111111
31	18.67	100.00	(other patterns)
166	100.00		xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Source: Authors' own elaboration.