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Estimating the Rivalry of National Defense Provision

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Abstract
Amid rising international tensions, notably the ongoing Russia-Ukraine and Hamas-Israel conflicts, countries around the world are reassessing their defense budgets with seriousness not seen since the Cold War. This paper investigates empirically whether national defense budgets align with actual security needs and underlying economic fundamentals. Using the framework of Borcherding and Deacon (1972) and Bergstrom and Goodman (1973), we estimate the determinants of national defense spending for a longitudinal panel of 150 countries from 1950 to 2016. Our findings reveal that national defense expenditures exhibit a high degree of rivalry, often being closer to 1 than 0 on the Samuelson Index. This suggests that governments, in practice, treat national defense as a rival rather than nonrival good, resulting in its estimated overprovision by 30 to 40 percent, on average. Our results call for a critical reassessment of defense allocation strategies and optimization of public resource management.

Keywords: public goods, publicness, private goods, rivalry, national defense, military
JEL Codes: H41; H42; H56

I. Introduction

National defense has long been a central theme in discussions regarding the basic functions of government. Virtually every economics textbook treats national defense as a quintessential example of a pure public good, highlighting the market's inability to adequately provide it because of the free-rider problem.[1] Although this assertion is

[1] We are unable to test the non-excludability feature of national defense because governments default to using taxes to overcome the free-rider problem that would allegedly threaten the private provision of national defense.

often attributed to Paul Samuelson (1954), it can be traced all the way back to Adam Smith.[2] Samuelson used national defense, along with lighthouses, to illustrate the nonrivalry and non-excludability of pure public goods.[3] However, Margolis (1955) soon contested this classification by pointing out private aspects of some alleged public goods. In response, Samuelson (1969) upheld his exemplars, emphasizing that few goods unequivocally fit the mold of a pure public good. The ensuing debate led to the recognition that goods exist on a rivalry continuum, now called the Samuelson Index, which ranges from 0 for a pure public good, perhaps a lighthouse, to 1 for a pure private good, like pizza. Goods may fall anywhere in between these two extremes depending on congestion externalities, such as those on a highway during rush hour.

It is not immediately obvious where national defense falls on the rivalry spectrum. It is possible that the deterrence effect of a missile defense system financed by national defense spending is completely nonrival: Once provided, the missile shield can defend any number of people within the system. The nonrival aspects of such a defense system or deterrence in general imply that population growth should have virtually no effect on national defense spending, holding everything else the same. However, public choice theory informs us that politicians and bureaucrats have incentives to grow government spending, which could explain, among other things, why national defense spending might grow with population and the tax base, not unlike the demand for rival private goods, such as pizza. This uncertainty begs an empirical inquiry.

To the best of our knowledge, this paper is the first to estimate the congestion (rivalry) parameter for national defense spending using the Samuelson Index derived from the popular median-voter demand models of Borcherding and Deacon (1972) and Bergstrom and Goodman (1973) (henceforth BD-BG). Our detailed analysis of temporal and cross-country variations in defense spending in a longitudinal panel of 150 countries for the 1950–2016 period shows a significant degree of rivalry in both military expenditure and military personnel (our alternative measure). The estimates are robust to the use

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[2] See book V, chapter 1, pages 2–3 in Smith (2000).

[3] Unlike public goods, pure private goods are both rival and excludable in consumption. Rivalry implies that consumption of a scarce, private good by one person reduces the amount available to another person. Excludability means that nonpayers can be easily and effectively excluded from consuming a private good (that is, there are no free-riders).

of additional control variables and different estimation techniques. The estimated Samuelson Index values (0.51 to 0.76) indicate the existence of congestion externalities in national defense spending, placing it closer to rival goods on the continuum. These rivalry estimates are in line with previous studies based on the BD-BG framework (Oates 2004). Our robust findings challenge the conventional textbook claim that national defense is a pure public good.

This paper is also the first to document general overprovision of national defense by showing that the average government would spend 30 to 40 percent less if it provided national defense as a nonrival good. While the question "Do governments overspend on national defense?" has been explored in prior studies, this study offers the first quantitative estimate of how much governments overspend on national defense by providing it as rival in consumption. Importantly, we do not estimate the amount of overprovision that would occur if the government spent more than the socially efficient quantity of a public good. Rather, our contribution is much more striking: We show that governments in practice provide national defense in a way that is more consistent with a rival (private) good rather than a nonrival (public) good. The misclassification of national defense as a pure public good has drastic implications for economic theory and public policy.

Finally, this paper provides actionable recommendations for policy makers, advocating defense budget reforms to reduce inefficiencies caused by lobbying and rent-seeking. By adopting performance-based budgeting, for example, governments can align defense spending more effectively with actual security needs.

II. Literature Review

While Samuelson's lighthouse example of a pure public good has largely been undermined by the property rights work of Coase (1974) and Peacock (1979), national defense continues to be highlighted as a prime example of a pure public good in many, if not most, economics textbooks.[4] However, a deeper dive into the specialized literature on public versus private goods reveals a contentious debate. Like the Margolis (1955) and Samuelson (1969) debate, Ostrom's (1990) seminal analysis of common pool resources also underscores

[4] Coyne and Lucas (2016) analyze fifty undergraduate textbooks and find that the overwhelming majority present national defense as a public good and rarely mention the possibility of government failure.

the existence of a continuum between purely public and purely private goods. Common pool resources, such as fisheries or groundwater, are characterized by rivalry in consumption, meaning use by one individual diminishes their availability to others in the presence of non-excludability—that is, when access cannot be easily restricted. Ostrom identifies the necessity of institutional frameworks to mitigate overuse and depletion of such resources, addressing a critical gap left unexamined in the Samuelson model of public goods.

Complementing this perspective, Hardin (1968) introduces the notion of the tragedy of the commons, illustrating how unrestricted access to rival and non-excludable goods often precipitates resource exhaustion. While Ostrom emphasizes the role of governance in resolving these issues, Hardin focuses on the systemic vulnerabilities stemming from inadequate management. Although the nonrival deterrence benefit of national defense spending does not conform to the archetype of a common pool resource, it may face inefficiencies and tendencies toward overprovision due to political and institutional factors. Our paper contends that despite its conceptually nonrival deterrence benefit, national defense spending, in practice, exhibits characteristics of rivalry shaped by political considerations, bureaucratic mechanisms, and consumption dynamics.

A review of the literature shows that the publicness feature of national defense has been contested on empirical, conceptual, and implementational grounds. Empirically, the publicness of nearly every locally provided public good has been scrutinized by numerous studies as detailed in Reiter and Weichenrieder's (1997) critical review of the literature. The predominant approach for testing the rivalry of public goods via the Samuelson Index relies on median-voter demand models, particularly the BD-BG approach. The popularity of this approach stems from its rather simple theoretical model that enables the use of measures of public expenditures in lieu of the quantity and quality of public goods, which are difficult to measure. Most studies employing this approach find a rather high degree of rivalry in locally provided public goods.

When it comes to empirically testing the rivalry of national defense, to our knowledge only one published study comes close, and even it does so only tangentially. This rather dated study, by Dudley and Montmarquette (1981), estimates the international spillover effects of military expenditures using separate cross-sectional regressions for a limited sample of thirty-eight developed and developing countries in the years 1960, 1970, and 1975. Their findings suggest that economies

of scale (which entails some degree of nonrivalry) characterized national defense provision in 1960 but appeared to diminish over time. However, their analysis is constrained by several factors: The small sample size and limited degrees of freedom reduces the robustness of their estimates, and the lack of critical socioeconomic controls beyond the basic demand model limits the explanatory power of their results. Moreover, their reliance on cross-sectional data inherently excludes unobserved, country-specific factors and temporal dynamics that are essential for understanding the evolving nature of national defense spending.

Our study addresses these limitations by using the BD-BG framework with a large, longitudinal panel data set encompassing 150 countries over the period 1950 to 2016. This comprehensive data set enables us to account for both cross-country differences and temporal dynamics in defense spending, offering a more detailed and nuanced analysis. Additionally, the application of fixed-effects and median regression techniques enhances the robustness of our findings, mitigating the impact of unobserved heterogeneity and outliers.

Two notable empirical studies take completely different approaches to testing the publicness of national defense. Goff and Tollison (1990) examine US House of Representatives votes on aid to the Contras in 1985 and 1988. They find that the distance of a representative's district from Managua, Nicaragua, is inversely related to the likelihood of voting for aid, leading them to conclude that national-security spending does not behave like a pure public good. Hudson and Jones (2005) take another approach: measuring voters' perceptions of public goods in Britain with a telephone survey. Their method involves discerning variations in perceived individual utility at both the country and household levels in response to changes in taxation and public service expenditure. A notable facet of this study is its emphasis on individuals' subjective perceptions of public goods. For instance, a homeowner's flower garden remains a public good as long as it imparts aesthetic pleasure to neighbors, an aspect that is lost if the perceived value diminishes. Remarkably, when Hudson and Jones create an ordinal ranking of public goods from their survey, national defense emerges as having the highest degree of public good characteristics. This finding highlights an important distinction: While national defense or its deterrence effect may be viewed as a pure public good by the public, the government may choose to provide it like a rival (private) good. While Hudson and Jones's findings emphasize the *perception* of national defense as a pure public good,

theoretical and empirical literature suggests significant nuance.

The debate over national defense's publicness also continues to evolve along conceptual and implementational dimensions. Conceptually, Sandler (1977) argues that the military serves the public good mainly as a deterrent to conflict, but actual engagement in conflict diminishes its nonrivalry aspect. For example, actually defending borders on two fronts creates an opportunity cost for a nation's rival resources. Hoppe (1989) further notes that public goods' marginal units can exhibit private good characteristics. While national defense aims primarily at providing deterrence, military branches such as the Coast Guard also capture drug smugglers. This interdiction can be a bad for citizens who consume illicit drugs and a good for those who earn higher incomes by providing legal substitutes.

On the implementational level, Leeson et al. (2014) argue that if the free-rider problem plagues the private provision of defense, it equally plagues private provision of offense. Since national offense necessitates national defense, supposedly underprovided national defense is just sufficient to counter underprovided offense in a free market world, undermining the claimed need for government intervention. Coyne (2015) further questions the idealistic assumptions behind the claim that benevolent policy makers can maximize social welfare by optimally providing national defense as a pure public good. Makovi (2017) posits that defense provision, best characterized as a natural monopoly with increasing returns to scale and various externalities, might be best managed at the subnational or polycentric level, allowing for increased private provision. Coyne and Goodman (2020) further contend that in actuality government-provided national defense not only fails to be purely protective but also neglects the varied impact of threats across the population and suffers from public choice issues, leading to imperfect security provision.

Even if we assume that national defense conceptually fits the definition of a pure public good, the odds of its efficient provision by self-interested, fallible policy makers are slim. Coyne and Hall (2019), for instance, argue that state provision of national defense suffers from public choice issues such as rent-seeking, rent extraction, and bureaucratic dysfunction. These issues often result in inefficiently large or small defense spending. In the aptly titled book *In Search of Monsters to Destroy*, Coyne (2022) exposes the cronyism and corruption in the US military sector, which seems perpetually engaged in war with little incentive to scale back its power and scope. In Weingast and colleagues' (1981) seminal model, the incentives of distributive

politics lead to an overprovision of government projects, including national defense.

Several studies have since documented the role of political incentives in military contract provision (Krehbiel 1992; Arnold 1979; Ray 1980; Roberts 1990). Specifically, Rundquist and colleagues (1996) find that congressional representatives on the House and Senate Armed Services Committees do channel significant military spending to their districts. Similarly, Carsey and Rundquist (1999) argue that politicians on defense-related committees generate benefits for their constituents by securing additional military spending for their home states. This suggests that military spending decisions are often driven by local pecuniary gains rather than national-security concerns. The Department of Defense's Base Realignment and Closure (2005) website admits to considering "the economic impact on existing communities" when recommending base closures. The announcement in 2005 to close thirty-three bases raised concerns about the economic effects, spurring numerous studies of local economic impact. These redistributive pecuniary concerns add a private good dimension to national defense provision, explaining why policy makers have incentives to increase defense spending even if the supposed deterrence benefits are truly nonrival.

III. Theoretical Model

The commonly used method for estimating the Samuelson Index (our rivalry measure) relies on the median-voter demand models developed by Borcherding and Deacon (1972) and Bergstrom and Goodman (1973), referred to as the BD-BG approach by Reiter and Weichenrieder (1997). While the two models are similar theoretically, they differ in their specification of the public good's tax price. According to Reiter and Weichenrieder, the Bergstrom and Goodman model yields more consistent estimates, which explains our choice to employ it below.

We present a condensed version of the median-voter demand model from Bergstrom and Goodman (1973), in which the median voter's disposable income Y is allocated between a numeraire private good x and the total cost of a public good (military spending M in our case), which is multiplied by the voter's tax share t times the tax price p of national defense:

$$Y \geq x + tpM \tag{1}$$

The median voter's individual consumption of national defense m is then determined by the divisibility of M over population N, where γ is a congestion parameter:

$$m = MN^{-\gamma} \tag{2}$$

If $\gamma = 0$, then $m = M$ and there is no crowding out (or rivalry) in the consumption of national defense (or rather its security benefit). If $\gamma = 1$, then the median voter receives only M/N amount of defense, which now becomes rival in consumption like a pure private good. Finally, the median voter maximizes utility with respect to x and m subject to equations (1) and (2):

$$U = U(x, m) \tag{3}$$

This results in a demand function that represents combinations of N and M for a given level of utility. With constant price (δ) and income (η) elasticities, the demand function for m is as follows:

$$m = c[tpN^{\gamma}]^{\delta}Y^{\eta} \tag{4}$$

After substituting this into equation (2), it can be rewritten as follows:

$$M = c(tp)^{\delta}Y^{\eta}N^{\gamma(1+\delta)} \tag{5}$$

One assumption in the BD-BG approach is that the tax price *p* paid by the consumer with median income is proportional to their tax share *t*. Therefore, equation (5) can be simplified and expressed in a log-linear model as follows:

$$ln(M) = ln(c) + \rho ln(N) + \delta ln(t) + \eta ln(Y) \tag{6}$$

Here, $\rho = \gamma(1 + \delta)$. Equation (6) serves as the foundation for our empirical model, which we extend to control for other relevant factors when we estimate the rivalry of national defense spending.

Equation (6) implies that military spending should rise with population and income[5] but fall with the tax price. If the government

[5] Hendrickson et al. (2018) argue that higher national income or wealth should increase the external threat of plunder, resulting in higher domestic military spending to deter it. This argument is consistent with the BD-BG model, which uses the median voter's income as a demand shifter. A positive income elasticity of demand would indicate that national defense or its deterrence benefit is a normal good.

provides a normal good, then the elasticity coefficients ρ and η should be positive and δ negative, implying rising demand with higher population *N* and median income *Y* but falling demand with higher tax share *t*. Conversely, if the government is providing a pure public good, then the elasticity coefficient ρ should be 0 since increases in population do not deplete or crowd out the availability of this nonrival good. However, population also has an indirect effect on quantity demanded via economies of scale: As the number of taxpayers rises with population size for a given quantity of a good, the individual tax share or price paid falls and quantity demanded rises. Since population effects on the demand function manifest themselves through both δ and ρ, the estimated elasticity coefficients from equation (6) can be used to calculate the rivalry parameter γ (measuring congestion or crowding out) as follows:

$$\gamma = \frac{\rho}{1+\delta} \tag{7}$$

The rivalry parameter γ is known in the literature as the Samuelson Index, which ranges from 0 (nonrival good) to 1 (rival good). For context, locally provided public services such as fire departments, police, and roads typically exhibit γ values ranging from 0.3 to 0.7. Our estimates of national defense's rivalry parameter, obtained in the next section, range from 0.51 to 0.76. This implies that national defense spending behaves more like a congested private good than a pure public good.

IV. Empirical Model

We estimate the national-defense rivalry parameter (that is, γ) with an extension of the basic model in equation (6) that accounts for the longitudinal nature (country *i* and year *t*) of our data set by including country-level fixed effects[6] and additional time-variant control variables that may affect national defense spending:

$$ln(M_{it}) = \rho ln(N_{it}) + \delta ln(t_{it}) + \eta ln(Y_{it}) + (X_{it})\beta + \alpha_i + \varepsilon_{it} \tag{8}$$

[6] The presence of unobserved heterogeneity is very common in this type of international data, which we confirm with the Breusch-Pagan Lagrange-multiplier test. The commonly used method of controlling for this type of unobserved heterogeneity is through within fixed effects rather than random effects, which we confirm with the Hausman test. Country-level or within fixed effects allow us to control for time-invariant factors such as geography, long-standing traditions or culture, a country's nuclear-weapons status, and other unobserved sticky factors.

Here, M is the dependent variable measuring annual resources dedicated to national defense, N is total national population, t is the tax share, Y is real income (GDP) per capita, X is a vector of control variables, α is country-level fixed effects, and ε is the error term. Two measures of M are used: total real military spending in a given year and number of military personnel in a given year. While total fiscal expenditure is the most commonly used measure of a latent public good, it is constrained by the model's assumption that the good's price is constant across observations. The military-personnel measure does not depend on this assumption, so using it serves as a robustness check.

Building on previous research, we considered and tested an extensive list of control variables ranging from economic, institutional, and political factors to international alliances.[7] We relied on multiple criteria in selecting our final control variables: (1) theory, (2) previous studies, and (3) empirical tests. With respect to the last criterion, a viable control variable should (1) be statistically significant and have a consistent sign in all model specifications, (2) improve the model's explanatory power without raising multicollinearity concerns, and (3) not cost us too many degrees of freedom through lost observations. We settled on two control variables that consistently correlate with military spending in all of our model specifications and estimation techniques without creating multicollinearity problems.[8] These variables are the Polity IV democracy index and total-armed-conflict intensity in a country in a given year. Like Goldsmith (2003), we find democracy and conflict to be among the few statistically significant determinants of military spending, while many other factors, such as alliances and rivalries, are not statistically significant. In table 1, we present descriptions and summary statistics for the variables used in our regression analysis. The next section provides a detailed description of the variables used in this study and their sources.

[7] See, for instance, empirical studies by Goldsmith (2003), Yakovlev (2007, 2008), and Yakovlev and Spleen (2022).

[8] All of our reported models' mean and individual variance inflation factors are below 4, confirming the absence of multicollinearity.

Table 1. Variable description and data

Variable name	Description	Mean	Std. dev.	Min	Max
Military expenditure[a]	Total military expenditures (in thousands of real US dollars)	12,204	46,041	0.247	875,179
Military personnel[a]	Troops under the command of the national government (in thousands)	148	392	1	4,750
Population[a]	Country's total population (in thousands)	37,466	127,582	135	1,403,500
GDP/capita[b]	Real (national accounts) GDP divided by population	13,780	18,343	247	182,291
Tax share[a, b]	Total government spending (1) per capita divided by total military spending (1)	0.04	0.48	0.000002	25.09
Polity2[c]	Combined polity score describing regime authority on a 21-point scale (−10 to +10)	1.64	7.36	-10	10
Conflict intensity[d]	Sum of internal and external armed-conflict intensities	0.70	1.74	0	14

Source: a: Singer et al. (1972). b: Feenstra et al. (2015). c: Marshall et al. (2020). d: Marshall (2020).

V. Data

This study advances the empirical application of the BD-BG framework by leveraging a large, longitudinal panel data set. This extensive data set enables a comprehensive analysis of temporal and cross-country dynamics in national defense spending, distinguishing our approach from the much earlier study by Dudley and Montmarquette (1981) that relied on limited cross-sectional data. Our data set is an unbalanced, longitudinal panel of 150 countries spanning from 1950 to 2016, which amounts to at most 7,508 observations available for regression analysis. The average number of annual observations per country in our baseline regression models is 50, with

a minimum of 16 and a maximum of 67. The data set's coverage is largely determined by data availability for the baseline variables in our theoretical model: national defense spending, tax-price share, national population, and income per capita. Since our model uses a logarithmic transformation, observations with nonpositive or missing values for the main variables of interest are dropped from the regression sample.

Since the deterrence or national-security benefits of defense spending are difficult to quantify, we follow the common practice in the literature and use total real military expenditures as a proxy for the overall level of the alleged public good provided by the government. Recognizing that total real defense expenditure might not perfectly measure the latent national-security variable, we also test an alternative dependent-variable measure: total military personnel, which should rise with population growth if national defense behaves as a rival good. Given the high collinearity between the military-expenditure and military-personnel variables, as shown by the pairwise correlations in table 2, we expect consistent results across both measures. Both measures are sourced from the National Material Capabilities (NMC) data set, originally created by Singer et al. (1972) and later expanded by Singer (1987). Each of these dependent variables is described in more detail below.

Table 2. Pairwise-correlations matrix

	Military spending	**Military personnel**	**Popula-tion**	**Tax share**	**GDP/ capita**	**Polity2**	**Conflict intensity**
Military spending	1						
Military personnel	0.7631*	1					
Popula-tion	0.564*	0.7703*	1				
Tax share	-0.020	-0.0273*	-0.020	1			
GDP/ capita	0.105*	-0.0009	-0.057*	-0.019	1		
Polity2	0.036*	0.2464*	0.002	0.014	0.203*	1	
Conflict intensity	0.146*	-0.0021	0.266*	-0.024*	-0.170*	-0.132*	1

Notes: * denotes statistical significance at the 0.05 level.

The NMC data set defines military expenditure as the part of a state's total (gross) annual military budget that contributes to military

capacity. This includes all appropriations under the national government's authority available to the military in times of war. However, NMC military expenditures exclude nonmilitary appropriations, as some nations have civil ministries under military control (for example, national police forces) and including those appropriations would overestimate those nations' military capability. Conversely, NMC adjusts military expenditure figures upward if outlays in other budget parts enhance military capacity. Expenditures on pensions, superannuation pay, relief, and subsidies to widows and orphans, which do not contribute to military power, are excluded where possible. The NMC figures reflect gross rather than net expenditures to avoid issues related to yearly variations in stockpile buildup, depreciation, and liquidation. Surplus military appropriations and credits transferred from previous years are counted as military expenditures only in those years when the funds are actually spent.

In most cases, expenditure data were originally collected in national currency units and then converted, using the Correlates of War currency-conversion data set, into US dollars using either current market or government exchange rates or, wherever prudent, black market rates. To moderate short-term fluctuations, the NMC project sometimes revises the resulting series with a smoothing process that uses a seven-year moving average—for example, for the wholesale suspension of the gold standard in the 1930s. Occasional interpolations are performed by NMC to fill small intervals in a series, but only when currency conditions seem to have been stable. We take the total military expenditure figures from NMC and adjust them for inflation using the Penn World Tables' index of the price level of government consumption.

Regarding our second measure of the dependent variable, the NMC data set defines military personnel as troops under the command of the national government intended for use against foreign adversaries. These include active, regular military units of the land, naval, and air components but exclude reserve and colonial troops. When national police forces are fully integrated into the military chain of command and serve both foreign combat and internal security functions (for example, the old National Guard of Nicaragua and the national police forces of many African states), they are included in the NMC military personnel figures. Each country's military-personnel measure excludes foreign military forces, forces of semiautonomous states and protectorates, and insurgent troops. Irregular forces such as civil defense units, frontier guards, gendarmerie, carabinieri, and other

quasi-military units are usually excluded, even when they constitute the only military force a nation has (for example, in Costa Rica and Switzerland). Since these are not regular national armed forces under a military chain of command, their inclusion would distort the count of personnel available for national defense. Consequently, the NMC military-personnel figures reflect the project's best judgment on which forces are intended for combat with foreign parties.

The key independent variables used in our baseline model include total national population (N) taken from the NMC project, real GDP per capita (Y) taken from the Penn World Tables, and the tax share (t) calculated by the authors using military expenditure data from NMC and government spending's share of GDP from the Penn World Tables. The commonly used tax-share measure in the literature is the median tax burden divided by total government spending on municipal or locally provided public goods such as education or police. However, for nationally provided public goods such as defense, financed by central-government revenues and borrowing, we must use a different approach. Using military spending per capita divided by total military spending as a proxy for the mean tax share would simply invert the population variable, creating perfect multicollinearity and making it unusable.

After theoretical and empirical exploration, we settled on total government spending per capita divided by total military spending as our preferred tax-share measure. Government spending per capita serves as a proxy for the median tax burden. The rationale is that the median voter is more likely to be aware of the overall tax burden than the rather specific military tax burden. Since military spending is typically financed out of general revenues and generally collinear with it, this measure reflects the visible burden to taxpayers. Additionally, population's indirect impact on the tax share (via economies of scale) is also captured in this measure: Just as per capita government burden falls with population growth, ceteris paribus, so does the mean tax price as a share of total military spending.

We also explored and tested an extensive list of potential time-variant control variables, ranging from institutional and political country characteristics (government corruption, military involvement in politics, alliances, treaties, etc.) to economic and demographic factors (trade, unemployment, etc.). However, most of the variables were either statistically nonsignificant or highly collinear with the model's baseline regressors. Including additional control variables often reduced the number of usable observations and degrees of

freedom or increased multicollinearity concerns. Drawing on previous studies, theory, and empirical tests, we narrowed down the final set of optimal control variables to yield a parsimonious yet highly explanatory model. The two control variables that accomplish this are the democracy index from the Polity V Project by Marshall and Gurr (2020) and the intensity of armed internal or external conflict from Marshall (2020). These variables enter our empirical model without logs because of the presence of zero or negative values. They are described in more detail below.

The revised combined polity score (Polity2), from the Polity V Project, used in this study measures regime authority on a 21-point scale, ranging from −10 (hereditary monarchy) to +10 (consolidated democracy). This score comprises six component measures that record key qualities of executive recruitment, constraints on executive authority, and political competition. It captures changes in the institutionalized qualities of governing authority, allowing us to control for the diverse political arrangements across countries that are not directly specified in our theoretical model.

The armed-conflict integer variable, ranging from 0 to 14 in our sample, is the sum of internal (intrastate) and external (interstate) armed-conflict intensities from the Major Episodes of Political Violence data set. A country may simultaneously face various internal and external security threats, directly affecting defense spending. The Major Episodes of Political Violence project defines major episodes of political violence as systematic, sustained lethal violence by organized groups resulting in at least five hundred directly related deaths. There are seven Major Episodes of Political Violence categories of armed conflict: international violence, international war, international independence war, civil violence, civil war, ethnic violence, and ethnic war. Each episode has a societal-systemic impact magnitude, measured on an 11-point scale (0–10). The impact score is recorded for each year a country is directly affected by warfare. When multiple episodes occur in a single country in a single year, the episode scores are summed for that category. Countries intervening in episodes occurring solely in another country are generally not considered directly affected by the violence.

VI. Estimates

We begin the estimation of the congestion (or rivalry) parameter (γ) for national defense spending by fitting the most parsimonious

theoretical model, which includes country fixed effects and just three independent variables: tax share, population, and real income per capita. Since all of these variables enter the regression model in natural logs, their coefficients can be interpreted as elasticities. The coefficient estimates for population (ρ) and tax-price share (δ) are used to calculate the rivalry parameter as $\gamma = \rho/(1+\delta)$.

Table 3. Determinants of national defense spending

Model **Estimator**	**(1)** **OLS-FE**	**(2)** **OLS-FE**	**(3)** **OLS-FE**	**(4)** **Median-FE**
Population	0.283** (0.130)	0.302** (0.128)	0.432*** (0.128)	0.472*** (0.035)
Tax share	-0.441*** (0.055)	-0.419*** (0.055)	-0.404*** (0.055)	-0.375*** (0.011)
GDP/capita	0.362*** (0.081)	0.392*** (0.081)	0.418*** (0.081)	0.332*** (0.021)
Conflict intensity		0.063*** (0.017)	0.057*** (0.018)	0.072*** (0.006)
Polity2			-0.020*** (0.006)	-0.016*** (0.002)
Rivalry parameter (γ)	0.52	0.51	0.72	0.76
F-test (p-value)	0.008	0.007	0.107	0.0000
N	7,508	7,508	7,467	7,467
Overall R2	0.81	0.81	0.81	0.78
Mean variance inflation factor	2.97	2.61	2.48	2.48

Notes: The dependent variable is military expenditure. All variables except for conflict intensity and Polity2 are in natural logs. The rivalry parameter $\gamma=\rho/(1+\delta)$, where ρ and δ are the coefficients for population and tax share, respectively. The F-test is conducted for the null hypothesis H_0: $\rho - \delta = 1$. The median regression reports the pseudo R-squared. All models include country or within fixed effects (FEs) and use cluster-robust standard errors (shown in parentheses). Statistical significance at the 0.01 level is denoted by ***, 0.05 level by **, and 0.1 level by *.

The estimates, shown as model 1 in table 3, reveal that all three explanatory variables in the baseline model are statistically significant at the commonly accepted levels and have the expected signs. Namely, higher population and real income per capita increase the demand for national defense, while higher tax share decreases it, ceteris paribus. The model's average variance inflation factor is 2.97,

which is well below the commonly accepted critical value of 10. The R-squared is 0.81—respectable for such a parsimonious model. Most importantly, the rivalry parameter is 0.52 and is significantly different from 1, according to the F-test. This model's estimate puts national defense right in the middle of Samuelson's rivalry spectrum from 0 to 1, implying that it is neither perfectly rival (like a pure private good) nor perfectly nonrival (like a pure public good).

The estimates for model 2, which includes conflict intensity as an extra regressor, are also shown in table 3 and tell a similar story: All variables are statistically significant at the commonly accepted levels and have the expected signs. The values of the variance inflation factor, R-squared, and F-statistic are very similar to those in model 1. The rivalry parameter is 0.51 and is also significantly different from 1, according to the F-test.

In model 3, we add a measure of institutional democracy (Polity2) as our final control variable; we show the results in table 3. All variables appear statistically significant at the commonly accepted levels and have the expected signs. The variance inflation factor and R-squared statistic in model 3 are similar to those in the previous models, but the rivalry parameter rises to 0.72 and the F-test cannot distinguish it from 1 at the 90 percent confidence interval. Similarly to Goldsmith (2003) and Yakovlev (2007, 2008), we also find that lower conflict intensities and more democratic institutions appear to reduce national defense spending, ceteris paribus.

Because there is a significant number of outliers[9] (almost 20 percent of our sample), we reestimate model 3 using quintile (median) regression, presenting the results as model 4 in table 3. As before, all variables are statistically significant at the commonly accepted levels and have the expected signs. The variance inflation factor and R-squared statistic remain comparable, but the rivalry parameter rises to 0.76, moving closer to the purely private (rival good) range. This might be our most robust model for inferring what military spending levels would be if the government provided national defense as a pure (nonrival) public good. To estimate these levels, we compare the model's predicted military spending based on the median values of the independent variables to the predicted values obtained assuming the population's coefficient is zero, as would be the case for a totally nonrival good. Using this method, we find that countries, on average, would spend about 30 percent less on

[9] We use Hadi's (1992) approach to detect outliers.

national defense if it were provided as a totally nonrival good. Measured another way, the population elasticity coefficient of 0.47 from model 4 implies 47 percent overprovision at the margin when compared to a nonrival public good, which would have an elasticity of 0.

As can be seen across all four models in table 3, adding meaningful control variables or using different estimation techniques does not materially change our findings. All four models exhibit respectable explanatory power and a tight fit between actual and predicted values of the dependent variable (less than 1 percent difference). The estimates consistently show that national defense spending exhibits relatively rival, private-good-like characteristics. Notably, the estimated coefficients for the logged variables in our models can be interpreted as elasticities, all of which are less than 1 in absolute value, as can be seen in table 3. This indicates somewhat inelastic demand for national defense spending. Specifically, the population elasticity estimates range from 0.28 to 0.47 across the four models, while the tax-price elasticity estimates range from −0.38 to −0.44. This is consistent with the findings in the BD-BG studies of a low tax-price elasticity of demand for publicly provided goods—typically between −0.2 and −0.4 (Oates, 2004). The income elasticity estimates range from 0.33 to 0.41, indicating that national defense spending or its deterrence effect is a normal good (that is, the demand for national defense rises with real per capita income). This positive income elasticity estimate is consistent with the argument of Hendrickson et al. (2018) that higher national income could increase the external threats of plunder, resulting in higher domestic military spending to deter it.

Table 4. Determinants of military personnel

Model Estimator	(5) OLS-FE	(6) OL-FE	(7) OLS-FE	(8) Median-FE
Population	0.515*** (0.087)	0.527*** (0.085)	0.676*** (0.083)	0.691*** (0.025)
Tax share	-0.193*** (0.030)	-0.179*** (0.028)	-0.159*** (0.025)	-0.116*** (0.008)
GDP/capita	-0.251*** (0.071)	-0.234*** (0.072)	-0.198*** (0.069)	-0.289*** (0.015)
Conflict intensity		0.037*** (0.014)	0.035** (0.014)	0.021*** (0.004)
Polity2			-0.023*** (0.004)	-0.019*** (0.001)
Rivalry parameter (γ)	0.64	0.64	0.80	0.78
F-test (p-value)	0.0001	0.0001	0.027	0.0001
N	7,355	7,355	7,314	7,314
Overall R2	0.54	0.6	0.61	0.78
Mean variance inflation factor	3.03	2.66	2.51	2.51

Notes: The dependent variable is military personnel. All variables except for conflict intensity and Polity2 are in natural logs. The rivalry parameter $\gamma=\rho/(1+\delta)$, where ρ and δ are the coefficients for population and tax share, respectively. The F-test is conducted for the null hypothesis H_0: $\rho - \delta = 1$. The median regression reports the pseudo R-squared. All models include country or within fixed effects (FEs) and use cluster-robust standard errors (shown in parentheses). Statistical significance at the 0.01 level is denoted by ***, 0.05 level by **, and 0.1 level by *.

A key strength of our study is in the robustness checks using an alternative dependent-variable measure—total military personnel—to ensure the reliability of our findings. We consider military-personnel figures to be a useful proxy for the resources dedicated to the provision of national defense (military spending and personnel exhibit positive and statistically significant correlation in our sample). Consequently, we reestimate the four models in table 3 using total military personnel. The new regression results, shown as models 5–8 in table 4, demonstrate exemplary consistency with models 1–4 in table 3, except for the income-per-capita variable.[10] As before, all

[10] Contrary to table 3's results, the estimates in table 4 suggest that higher income per capita decreases the demand for military personnel, ceteris paribus. This finding is consistent with Yakovlev's (2008) study documenting that higher-income countries use more military capital in place of military personnel.

variables in table 4 are statistically significant at the commonly accepted levels and have the expected signs. The variance-inflation-factor values also remain comparable, but the R-squared values are notably lower in the first three regressions in table 4 compared to the corresponding models in table 3. This is understandable given that military personnel is not a perfect proxy for national security, the latent variable that military spending is supposed to capture.

Most importantly, the rivalry parameter is higher across all models in table 4 than in table 3, ranging from 0.64 to 0.81. The F-test confirms that these congestion parameter values are significantly different from 1. The higher rivalry estimates in the models with military personnel as the dependent variable suggest a stronger link between military personnel staffing and population growth than between defense spending and population growth, holding everything else constant.

In sum, our estimates in tables 3 and 4 consistently show that national defense spending is closer to 1 than 0 on the Samuelson Index. This suggests that governments tend to increase both military spending and personnel rather proportionately with population growth, implying that national defense behaves more like a private good than a public good, ceteris paribus. This finding aligns with the public choice view of government policy makers as self-interested, budget-maximizing agents. Our estimates also broadly align with most previous studies that use the BD-BG approach and some that do not (see, for instance, Gonzales and Mehay 1985), which find a high degree of rivalry in the provision of local public goods. However, unlike some previous studies using the BD-BG approach, all of our empirical estimates fall within the theoretical 0–1 range of the Samuelson Index. Furthermore, our findings are also broadly consistent with the stylized observations in studies on national security and conflict, namely Goldsmith (2003) and Hendrickson et al. (2018). Specifically, domestic political economy factors appear to play a major role: economic growth increases defense spending, while competition for resources decreases defense spending in more open, democratic societies.

These empirical findings have important implications for both policy makers and economic theory. Policy makers must acknowledge the rivalry characteristic of national defense spending and work to address the potential for overprovision or overspending identified in this study. Effective strategies could include increasing transparency in defense budgets, aligning spending more closely with measurable

security needs, and mitigating the influence of lobbying and political pressures.

VII. Conclusion

In this paper, we set out to estimate the Samuelson Index for ostensibly the best example of a pure public good—national defense. When fitting the widely used BD-BG theoretical approach to international panel data, we estimated the Samuelson Index to be closer to 1 than 0. This implies that, in practice, national defense provision exhibits more rival, private-good-like characteristics than is typically assumed.

Our estimates challenge the pervasive narrative that national defense is a quintessential pure public good. Furthermore, our estimates are strikingly robust across different model specifications and econometric methods. This gives us considerable confidence that actual national defense provision by governments around the world is not immune to congestion or crowding-out externalities, putting it closer to the realm of rival (private) goods. In fact, we estimate that if population growth had no direct effect on national defense spending, it would be, on average, about 30 to 40 percent lower, globally. This finding, which is consistent with the public choice literature, suggests a tendency for governments to overprovide national defense, particularly with a growing tax base and government budget as a byproduct of population increases. Additionally, our findings show that improvements in democratic institutions and reductions in conflict intensities lower defense spending, ceteris paribus.

From a theoretical perspective, these findings necessitate a reevaluation of how national defense is presented in the economic literature. Although in theory national defense may exhibit nonrival deterrence benefits to both small and large populations, our research suggests that governments in practice tend to increase defense spending with population growth as if they are providing a congested private good. Considering the public sector's tendency to overspend as noted in the public choice literature, our estimates highlight the need to rethink current approaches to national defense. Rather than defaulting to an idealized classification of national defense as a nonrival, public good, academic textbooks and curricula should reflect the public choice critiques and empirical realities surrounding military spending. Incorporating these nuances will help students and policy makers better understand the complexities of public goods and potential inefficiencies encountered in their public provision.

Policy makers should also reevaluate how well their defense budgets meet actual domestic security goals and should implement stricter oversight of bureaucratic inefficiencies, lobbying, and corruption in order to optimize public resource usage. Performance-based cost-benefit budgeting could ensure that military spending is tied to measurable outcomes rather than political incentives. Stricter oversight of defense procurement—through increased transparency, independent audits, and competitive bidding—can reduce inefficiencies associated with lobbying and rent-seeking. Institutional reforms to decouple defense budgets from political cycles may further limit overprovision driven by electoral pressures.

It is important to acknowledge some limitations to the BD-BG approach and offer direction for future research. According to Oates (1988), the useful feature of the BD-BG approach is that it dispenses with a physical measurement of publicly provided goods in favor of total expenditures, facilitating its empirical implementation. However, this feature also comes with a drawback: expenditures hide the larger range of public services provided in larger towns, possibly leading to an overestimation of the rivalry parameter. Reiter and Weichenrieder (1997) also note existing disagreements in the literature regarding the model's functional form and the tendency of BD-BG-based studies to produce rather high rivalry (congestion) estimates for most local public goods. Future scholars may want to test the rivalry of national defense using the input-output method suggested by Reiter and Weichenrieder (1997) as an alternative to the BD-BG approach.

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