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In Defence of Social Security Against National Security:

A Lotka-Volterra Model of Military Expenditures and Civilian Expenditures

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Abstract

This paper introduces a novel application of the Lotka-Volterra model to analyze the dynamic interplay between military and civilian government spending in the United States from 1960 to 2019. Drawing on the classical 'guns versus butter' framework, we conceptualize military spending as a predator and civilian spending as prey, both constrained by GDP as a shared resource. By constructing a system of nonlinear differential equations, we model inter-sectoral competition, long-term memory effects, and time-varying growth and carrying capacities. The model reveals strong asymmetries in budgetary interaction: military expenditures exert a disproportionately negative impact on civilian spending, while being more sensitive to shared constraints, suggesting a prey-like vulnerability. Using a genetic algorithm for parameter estimation, we demonstrate that shifts in growth rates and sectoral capacities correspond closely with historical inflection points, such as the Cold War and the War on Terror. Our findings offer compelling evidence of Lotka-Volterra-like oscillatory behavior in public budget allocation, underscoring the strategic dominance of military priorities over social investments. This dynamic modeling approach provides new insights into the systemic trade-offs embedded in fiscal policy and raises critical questions about the sustainability of militarized economic strategies.

Keywords: Lotka-Volterra, guns-and-butter, military spending, social spending, modelling

JEL Classifications: C630; H51; H52; H56

Introduction

A strand of defense economics literature addresses the guns-and-butter argument, which suggests a budgetary trade-off between military spending and civilian government expenditures such as health and education. Since Russett's (1969) seminal work, a growing body of empirical research has examined this argument using various econometric models across different countries and time periods. Unsurprisingly, the findings remain inconclusive, with some studies confirming a trade-off, others finding no significant relationship, and some even suggesting that military and social spending can coexist or be positively correlated.

This study aims to contribute to this debate by introducing a novel approach to analyzing the guns-and-butter argument in a dynamic context. Specifically, we examine the dynamics of military spending and social expenditures (i.e. health and education) within a predator-prey framework, inspired by the Lotka-Volterra model. The Lotka-Volterra model is a foundational framework in mathematical biology, originally developed by Alfred J. Lotka (1920) and Vito Volterra (1926) to model the evolving interactions between two interdependent species, such as predator-prey relationships or competing populations. This system of differential equations captures the oscillatory nature of population dynamics, where the presence of one species influences the growth rate of the other, often resulting in complex and cyclical behavior.

Beyond its biological applications, the Lotka-Volterra framework has been widely extended to economics, going back to Goodwin (1967), who modeled the cyclical relationship between employment and wage share. Later, Paul Samuelson (1971) expanded the model to accommodate multiple interacting agents and deriving its equilibrium properties. His generalization provided valuable insights into competition dynamics in markets, economic growth, and resource allocation across competing sectors. In more recent studies, the framework has been applied to consumer-resource interactions (Ramos-Jiliberto, 2005), population growth (Krutilla & Reuveny, 2006; Puliafito et al., 2008), and the dynamics between employment and wage share (Dosi et al., 2024), among others. In this context, we conceptualize military spending as competing with civilian spending for share of the GDP to investigate the guns-and-butter trade-off. In doing so we can analyze how the share of military spending, measured as a percentage of GDP, impacts civilian spending, also measured as a percentage of GDP. Additionally, by comparing the values of competition-related parameters that we estimate by

fitting our model to historical data, we can understand which sector tends to dominate the other, and how that relationship has shifted across different time periods. This perspective allows us to model the interactions between these competing expenditures dynamically, rather than assuming a static or linear trade-off. By employing a Lotka-Volterra-based modeling approach, this paper offers a fresh perspective on the debate, providing comprehensive evidence on the interplay between military and social spending in a dynamic and interdependent framework for the case of the United States for the period of 1960-2019.

This perspective draws directly from the tradition of evolutionary economics, which emphasizes out-of-equilibrium dynamics, structural transformation, and institutional evolution over time (Nelson and Winter 1982; Chen and Galbraith 2012). Like technological paradigms and firm strategies in evolutionary models, state budgetary priorities can be viewed as evolving rules and routines shaped by geopolitical shocks, macroeconomic crises, and ideological shifts. In this sense, the fiscal state is not a rational optimizer allocating resources efficiently, but an adaptive system characterized by inertia, feedback loops, and conflict between competing priorities, military security and social provisioning. The results indicate that military and civilian budgetary allocations follow Lotka-Volterra-like dynamics, with military spending placing greater strain on civilian spending, similar to how a dominant species inhibits the growth of a competitor. While military spending is more sensitive to direct inefficiencies when both sectors are active, the overall dynamics are shaped more strongly by the competitive advantage of military budgets through resource-based constraints. Finally, cyclic shifts in military spending growth rates, such as the Cold War buildup and the War on Terror resurgence, reflect an alternating dominance pattern akin to Lotka-Volterra predator-prey oscillations.

The remainder of the paper is structured as follows: the next section briefly reviews the "guns and butter" argument. Section 3 introduces the data and methodology, while Section 4 presents the results. The final section offers concluding remarks and summarizes the findings.

2. Social Security vs National Security

The 'guns and butter' argument refers to the idea that increased military spending comes at the expense of social expenditures such as health and education. This raises a fundamental question: why do governments overlook this crowding-out effect, and what are the drivers

behind disproportionate military budgets? Different schools of economic thought offer diverse explanations for the determinants and impacts of military spending on the economy (Elveren, 2025). The neoclassical approach (i.e. mainstream economics) focuses on economic growth and considers military spending within an optimization problem, where national security is treated as a pure public good in a rational choice setting. In this framework, the state is assumed to be a rational actor, seeking to maximize national interest by comparing the marginal benefits and costs of military spending. The benefit, or ultimate goal, is national security, but this may come at the expense of social security if military expenditures lead to declines in health and education spending. However, this approach is often criticized for its ahistorical perspective, as it fails to consider the role of international institutions and assumes rationality among states and other actors, which is a problematic assumption. Overall, the neoclassical approach provides limited insight into the broader determinants of military spending.

This raises the question: If states are not entirely 'rational actors', what is the 'rationale' behind the disproportionate allocation of military budgets? The Keynesian perspective offers an alternative explanation from a demand-side standpoint, viewing military spending as a component of general government expenditure. A particularly relevant concept is Military Keynesianism, which suggests that governments use military spending as a counter-cyclical economic tool, increasing expenditures during recessions to stimulate demand. While military spending can boost aggregate demand and contribute to short-term economic growth, it may also diminish the economy's productive capacity in the long run by diverting resources away from health, education, and other productive sectors, while also reinforcing gender inequality (Elveren & Moghadam 2022; Elveren et al. 2022; Elveren 2024a). A key limitation of Military Keynesianism is its failure to account for the potential long-term negative effects of military spending. Additionally, this perspective treats military spending similarly to civilian government spending, without explaining why military expenditures are prioritized over social expenditures such as health and education.

This leads to another question: Why is military spending often preferred over social spending? The liberal school, adopting an institutional perspective, answers this question through the Military-Industrial Complex (MIC). According to this theory, the primary determinant of military spending is the internal role of the military and military interests (Melman, 1965;

Galbraith 1969; Elveren, 2019). The MIC represents a coalition of vested interests within the state and arms industry, promoting the agenda of this symbiotic alliance under the guise of national security. This raises the question: Is it possible to achieve an optimal level of military spending? According to liberal economists, the answer is yes, but only if this powerful interest group can be effectively controlled.

However, Marxist scholars reject this liberal perspective as naïve, arguing that MIC theory fails to recognize the fundamental role of military spending in capitalist economies. The Marxist school, particularly the underconsumptionist view (Baran & Sweezy, 1966; Kidron, 1970), provides a more comprehensive theoretical framework. This perspective suggests that military expenditure absorbs economic surplus, preventing crises, whereas other government expenditures, such as health and education, would conflict with capitalist interests. Furthermore, military spending serves as a mechanism for maintaining the hierarchical structure between core and peripheral economies, as well as within core countries themselves. Despite its broader scope, the Marxist approach remains incomplete, as it does not fully address all dimensions of military spending.

Beyond these perspectives, the Post-Keynesian school offers a valuable contribution by emphasizing the role of income distribution between workers and capitalists. This approach is particularly relevant because military spending significantly affects income inequality, largely through the crowding out of social expenditures, which disproportionately benefit the working class and lower-income groups. Post-Keynesian analysis considers both direct and indirect effects, acknowledging how military spending influences economic growth through income distribution, given the differing marginal propensities to consume among capitalists and workers (Elveren et al. 2023; Elveren et al. forthcoming-b).

One critical question remains: Can disproportionate military spending be explained solely by economic and strategic motives? Feminist scholars argue no, contending that militarism and patriarchy are mutually reinforcing. They highlight the gendered consequences of military spending, which disproportionately harms women and marginalized groups. Adopting an interdisciplinary lens, feminist perspectives emphasize that the roots of war and conflict lie in patriarchal institutions dominated by men, drawing connections between conflict at the micro, meso, and macro levels (Cockburn 2014; True 2015). Feminist economists further show, both in

structural theoretical models and empirical studies, that militarization exacerbates gender inequality and undermines long-term economic growth (Elveren 2024b; Elveren et al., forthcoming-a).

One key insight from this discussion is that, regardless of economic perspective—whether neoclassical, Marxist, post-Keynesian, or feminist—the fundamental economic principle of trade-offs is highly relevant to military spending. Disproportionate military budgets, justified under the guise of "national security," are likely to hinder health and education expenditures, which are essential for ensuring "social security." Building on the discussion of the trade-off between military spending and social expenditures, the relationship between military expenditures, welfare regimes, and income inequality reveals critical dynamics. Social democratic welfare regimes, which emphasize redistribution and strong public services, generally allocate fewer resources to military spending, prioritizing social welfare over defense. In contrast, liberal and productivist welfare regimes, which are more market-oriented and emphasize economic efficiency, often maintain higher military budgets at the expense of welfare provisions (Töngür and Elveren 2015). This pattern reflects broader state priorities, where greater military spending comes at the cost of investments in education, healthcare, and social protection. The guns-and-butter trade-off is thus particularly pronounced in regimes that prioritize security and defense over welfare, reinforcing social stratification.

Political regimes further shape these dynamics. Democratic states, particularly those with strong welfare institutions, tend to strike a balance between military and social spending, whereas authoritarian regimes frequently allocate disproportionate resources to military expenditures to maintain internal control and suppress dissent (Töngür et al. 2015). This reallocation of resources exacerbates income inequality by diverting funds away from redistributive policies that benefit lower-income populations. High military spending often correlates with weaker welfare provisions and reduced income redistribution, contributing to a widening gap between social classes. Empirical evidence suggests that in societies with extensive military expenditures economic inequality increases (Ali 2007). Thus, the guns-and-butter trade-off is not only a question of budgetary priorities but also a mechanism that shapes broader patterns of economic inequality and social stratification.

Since Russett's (1969) seminal work, numerous empirical studies have investigated this trade-off using cross-country, single-country, and time-series analyses. Findings are inconclusive, with some studies confirming a trade-off, others finding no significant relationship, and some even suggesting positive correlations, indicating that higher military spending does not hinder social spending but instead increases it. Several cross-country studies have examined whether military spending reduces social expenditures across different economic and political contexts. Dabelko and McCormick (1977), for 1950-1972, analyzed 76 countries and found evidence of a negative relationship between military expenditures and education and health spending. Deger (1985), for 50 less developed countries (LDCs) covering 1965-1973, also found that higher military spending led to declines in education spending. However, Hess and Mulan (1988), for 77 developing countries in 1982 and 1983, found that countries with higher military burdens tended to allocate a greater share of GDP to education expenditures.

More recent panel studies also provide inconclusive findings. Reeves and Stuckler (2013) analyzed 31 OECD countries for 1980-2010 and found little evidence that military spending crowded out health expenditures. In contrast, Ikegami and Wang (2023) examined 116 countries for 2000-2017, Grigorakis and Galyfianakis (2023) studied 129 countries for 2000-2018, and Lang and Vo (2024) investigated 43 countries for 1990-2021—all confirming a negative impact of military spending on health expenditures. Zhang et al. (2017), for G7 and BRICS countries, found no trade-off in the G7 but a trade-off in BRICS countries. However, other cross-country studies challenge the crowding-out argument. Coutts et al. (2018), for MENA countries for 1995-2011, found no impact of military spending on health expenditures. Biscione and Caruso (2021), for 26 transition economies covering 1990-2015, found no significant trade-off. Lin et al. (2013), for 29 OECD countries from 1988 to 2005, argued that advanced welfare states may accommodate both military and social spending, leading to a positive association. In a follow-up study, focusing on 29 NATO countries for 2000-2021, Grigorakis and Galyfianakis (2024) showed that military spending increased out-of-pocket health expenditures. Gbadegesin (2024), for G7 countries covering 1971-2022, found a positive correlation between military and social spending.

Some time series studies have covered a large set of countries. Verner (1983), for 18 Latin American countries from 1948 to 1979, used time-series analysis to show that a trade-off

existed only in El Salvador, while ten countries exhibited a positive relationship and seven showed no significant association. Harris et al. (1988), for 12 Asian countries from 1967 to 1982, reported that only four countries exhibited negative trade-offs. However, Apostolakis (1992), for 19 Latin American nations from 1953 to 1987, found an overall trade-off between military and social spending.

Research on the United States has produced varying conclusions regarding the presence of a trade-off. Russett (1969), for the period 1939-1967, found that military spending crowded out health and education expenditures. Lee (1972) also confirmed this trade-off for the United States. Peroff (1977), for 1929-1971, and later Peroff and Podolak-Warren (1979), for 1929-1974, found that military spending undermined health and education expenditures. Mintz and Huang (1991), for 1953-1987, found no short-term effects but identified significant long-term indirect trade-offs. Hollenhorst and Ault (1971) critiqued Russett's methodology, arguing that his findings were affected by failing to differentiate between wartime and peacetime spending. Domke et al. (1983), for the period 1954-1976, examined the U.S. alongside the UK, France, and Germany and found no evidence of a trade-off. Later studies challenged these earlier conclusions. Mintz (1989), replicating Russett's (1982) study but disaggregating total military spending into subcomponents, found no trade-off.

Findings from other country-specific analyses further highlight inconclusiveness of findings. For Turkey, Yildirim and Sezgin (2002), for 1924-1992, found trade-off between military and health spending but a positive relationship with education. Gunluk-Senesen and Ozsoy (2002), for 1925-1998, confirmed a negative association between military and social spending. Ozsoy (2008) later confirmed these findings. Eryigit et al. (2012), for 1950-2005, found a trade-off between military and education and health expenditures. Zhao et al. (2015), for China between 1952 and 2012, identified a clear trade-off between defense and public expenditures. Frederiksen and Looney (1994), for Pakistan covering 1973-1986, found little evidence of trade-offs. Ali (2011), for Egypt covering 1987-2005, found that military expenditures crowded out health spending but crowded in education spending. For Greece, Kollias and Paleologou (2011), for 1972-2004, found that higher military spending was associated with increased education and social expenditures. Johnson and Wells (1986), for the Soviet Union covering 1951-1980, found that military spending negatively affected housing and

consumer goods production but left education and healthcare largely intact. For Taiwan, Davis and Chan (1990), for 1961-1985, found no significant impact of military spending on education spending.

Overall, the empirical literature on the 'guns and butter' argument presents a highly mixed and context-dependent picture. While some studies support the crowding-out hypothesis, others suggest no relationship or even positive correlations between military and social spending. The key determinants of these variations include economic development levels, government structures, welfare policies, and geopolitical considerations. For instance, it is more likely that military spending crowds out social spending such as education and health and therefore exacerbating income inequality in the cases of weak welfare regimes (Töngür and Elveren 2015) and less democratic countries (Fordham and Walker 2005; Töngür et al. 2015).

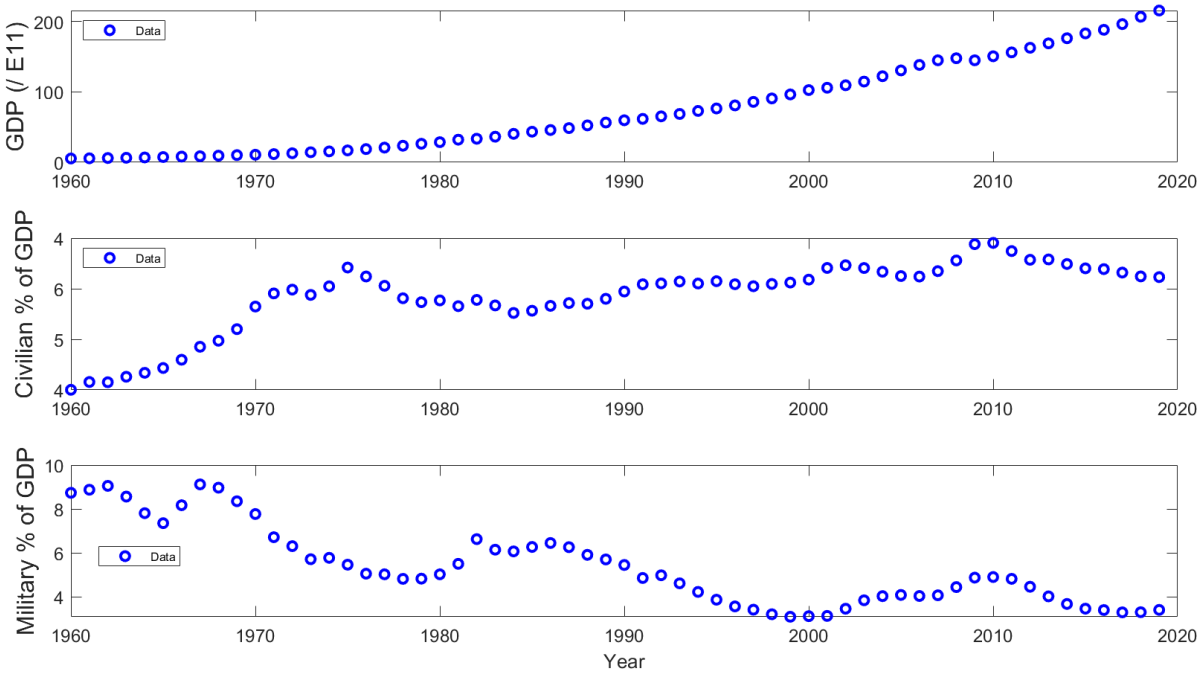
Against this background, the goal of this paper is to further contribute to the literature by examining the nature of the dynamics between military and social spending through a novel modeling approach. We conceptualize military spending as the predator and civilian spending as the prey, with GDP serving as a shared resource constraint for both sectors.

3. Data and Method

3.1 Data

We use annual GDP, civilian expenditures (health expenditures + education expenditures) and military expenditures data of the US for 1960-2019. GDP data is taken from the World Bank World Development Indicators (World Bank 2025). Health expenditures data is taken from Centers for Medicare & Medicaid Services, Office of the Actuary, National Health Statistics Group; U.S. Department of Commerce, Bureau of Economic Analysis; and U.S. Bureau of the Census, while education data is obtained from Federal Reserve Bank of St. Louis (Federal Reserve Economic Data 2025). Military spending is taken from the Stockholm International Peace Research Institute. For the parameter-estimation process, GDP was divided by 1.0×10^{11}, and civilian and military spending were expressed as fractions of total GDP to form the two primary response variables: *C/G* and *M/G* (see Figure 1).

Figure 1: GDP, Military Spending, and Civilian Spending in the US, 1960-2019



3.2 Method

We model the dynamics of civilian spending (C), and military spending (M) as they compete for a shared resource (GDP) using a system of nonlinear ordinary differential equations. The model is based on a Lotka-Volterra-style competition framework, adapted to represent dynamics in economic systems. In this formulation, civilian spending (C) and military spending (M) are treated as competing populations drawing from a shared and limited resource: Gross Domestic Product (G). Unlike traditional ecological models, we also model GDP directly as a growing quantity, making it both a limiting resource and a dynamic variable that drives the behavior of C and M. The model incorporates interdependent growth and competition between the civilian and military sectors. The system is given by:

$$\frac{dG}{dt} = r_G(t)G \tag{1}$$

$$\frac{dC}{dt} = r_C(t)C\left(1 - \frac{C+\alpha_{CM}M}{\lambda_C(t)\bar{G}_{C_\chi}}\right) - m_1 CM \tag{2}$$

$$\frac{dM}{dt} = r_M(t)M\left(1 - \frac{M+\alpha_{MC}C}{\lambda_M(t)\bar{G}_{M_y}}\right) - m_2CM \quad (3)$$

where $\bar{G}_{C_x}$ and $\bar{G}_{M_y}$ denote moving averages of GDP over the past *x* and *y* years, respectively, which serve as lagged resource availability terms (i.e., carrying capacities) for the civilian and military sectors. The $\lambda_C(t)$ and $\lambda_M(t)$ parameters represent time-dependent percentages that alter the carrying capacities over time. This structure captures how economic resources are allocated with memory, reflecting fiscal inertia and delayed responses to macroeconomic changes. The intrinsic growth rates $r_C(t)$ and $r_M(t)$, as well as drivers of carrying capacities $\lambda_C(t)$ and $\lambda_M(t)$, are modeled as piecewise constant functions to capture historical shifts in economic policy and spending priorities. Their relative values therefore provide a measure of institutional support, strategic emphasis, or policy momentum during each historical period.

There are two pairs of competition parameters in the model: α_{CM}, α_{MC} and m_1, m_2. The α_{CM} and α_{MC} values are inter-sectoral competition through shared resource limitation (GDP), determining how much the presence of one sector reduces the effective carrying capacity of the other. That is, they shape how each sector perceives the available economic space, modifying growth indirectly through the GDP-driven carrying capacity constraint. These terms capture structural effects like political prioritization, institutional earmarks, or rigid baseline funding that limits reallocation flexibility. In contrast, m_1 and m_2 are constant interaction terms that quantify direct negative feedback from simultaneous investment in both sectors. These represent losses that occur even when GDP is not limiting, and can represent things like policy friction, administrative inefficiencies, or budgetary conflict. Thus, while the α values reveal how strongly one sector limits the other through structural competition for economic resources, the m values offer insight into the additional costs and inefficiencies that arise from their simultaneous operation.

Parameter Estimation

Table 1: Model parameters

Parameter	Type	Description
m_1	Scalar	Direct competition loss imposed on *C* by *M*, independent of resource availability
m_2	Scalar	Direct competition loss imposed on *M* by *C*, independent of resource availability
α_{CM}	Scalar	Resource limitation imposed on C by M
α_{MC}	Scalar	Resource limitation imposed on *M* by *C*
$\bar{G}_{C_x}$	Estimated (Integer)	Average GDP over the past *x* years, used in the *C* equation
$\bar{G}_{M_y}$	Estimated (Integer)	Average GDP over the past y years, used in the M equation
$r_G(t)$	Piecewise Scalar (4 values)	Intrinsic growth rate of GDP
$\lambda_C(t)$	Piecewise Scalar (6 values)	Time-dependent carrying capacity
$\lambda_M(t)$	Piecewise Scalar (7 values)	Time-dependent carrying capacity
$r_C(t)$	Piecewise Scalar (6 values)	Time-dependent civilian sector growth rate
$r_M(t)$	Piecewise Scalar (7 values)	Time-dependent military sector growth rate

Table 1 shows all parameters used in our model. The temporal scope of the dataset includes major historical inflection points in defense and domestic policy, including periods of war, recession, and economic expansion. To allow the model to capture the shifting dynamics of civilian-military resource allocation over time, we model the growth rate parameters $r_C(t)$ and $r_M(t)$, as well as carrying-capacity terms $\lambda_C(t)$ and $\lambda_M(t)$, are modeled as piecewise constant functions. We also consider $r_G(t)$ as time-varying to accurately model GDP data. Table 2 contains the time intervals we considered in our model. Allowing these parameters to vary enhances the model's flexibility and aligns it with observed changes in the structure and allocation of national expenditures. Additionally, the estimated values provide valuable insight into how the two sectors interacted in each time period.

Table 2: Time intervals for piecewise constant parameters

GDP Intervals	Years	Rationale
Interval 1	$t < 2008$	Stable economic expansion with moderate long-run growth.
Interval 2	$2008 \leq t < 2009$	Great Recession creates sharp contraction in GDP growth.
Interval 3	$2009 \leq t < 2010$	Immediate post-crisis rebound with near-zero growth.
Interval 4	$t \geq 2010$	Sustained recovery and moderate post-recession growth.
Civilian Intervals	**Years**	**Rationale**
Interval 1	$t < 1965$	Post-WWII expansion and New Deal legacy result in steady domestic investment.
Interval 2	$1965 \leq t < 1977$	Great Society programs and rising inflation paired with Vietnam-era civilian strain.
Interval 3	$1977 \leq t < 1988$	Stagflation and deregulation contribute to a shift toward neoliberal economics.
Interval 4	$1988 \leq t < 1996$	End of Cold War. Peace dividend reduces military emphasis and boosts domestic flexibility.
Interval 5	$1996 \leq t < 2009$	Long period of domestic growth and bipartisan welfare reform.
Interval 6	$t \geq 2009$	Post-recession stimulus and healthcare expansion (e.g., ARRA, ACA).
Military Intervals	**Years**	**Rationale**
Interval 1	$t < 1965$	Cold War buildup but prior to full Vietnam engagement.
Interval 2	$1965 \leq t < 1968$	Sharp Vietnam escalation under LBJ. Peak draft and defense spending.
Interval 3	$1968 \leq t < 1980$	Vietnam drawdown and military retrenchment.
Interval 4	$1980 \leq t < 1991$	Reagan-era buildup. Peak Cold War military expansion.
Interval 5	$1991 \leq t < 2001$	Post-Gulf War military contraction and peace dividend.
Interval 6	$2001 \leq t < 2010$	War on Terror and Afghanistan/Iraq conflicts.
Interval 7	$t \geq 2010$	Drawdowns and pivot to modernization. Emerging multipolar threats.

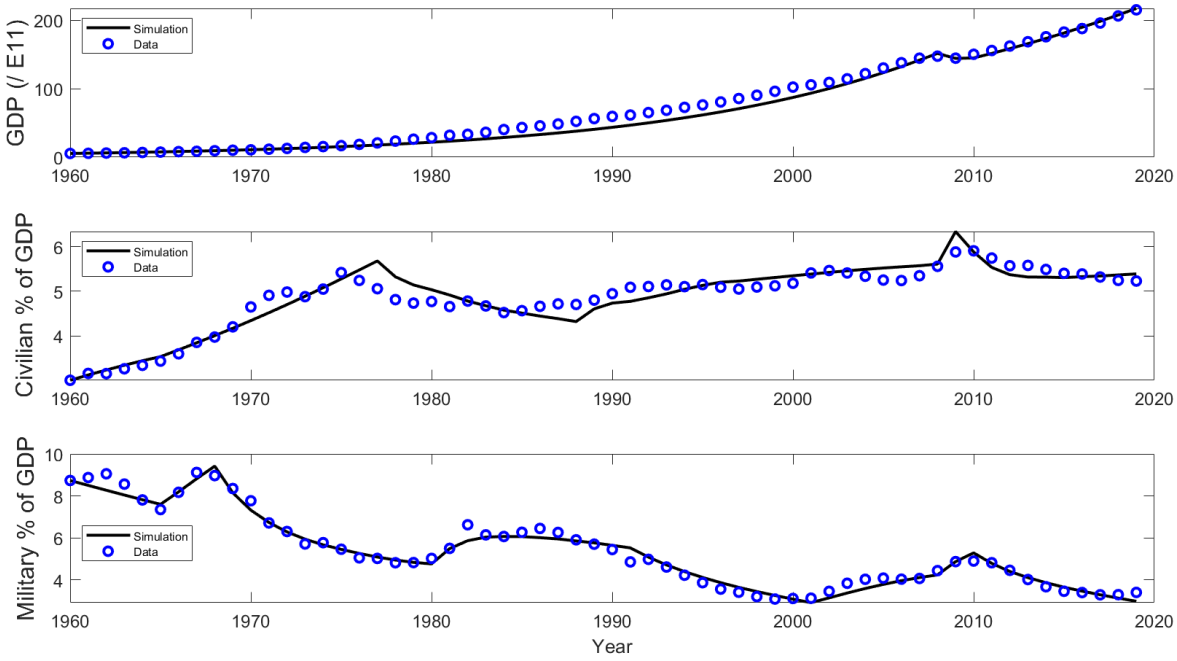
Optimization Procedure

To allow the model to capture the change in GDP during the 2008 recession, we first fit $r_G(t)$ by sight, resulting in the fit shown in Figure 2 and parameter values seen in Table 2. Parameter estimation for the remaining unknown values was performed using a genetic algorithm (GA) implemented in MATLAB's ga( ) function, which is part of the Global Optimization toolbox. The GA was configured with a population size of 1000, a maximum of 700 generations, and an elite count of 100. Optimization was initialized using a manually curated starting population derived from previous exploratory runs. The decision variable vector included 32 parameters: two competition interaction coefficients (m_1 and m_2), two competition coefficients (α_{CM} and α_{MC}), two integer-valued delay parameters ($\bar{G}_{C_x}, \bar{G}_{M_y}$), and 26 total piecewise values across the predefined time intervals for $r_C(t)$, $r_M(t)$, $\lambda_C(t)$, and $\lambda_M(t)$.

Upper and lower bounds were specified for each parameter based on plausible ranges, and integer constraints were enforced on the delay parameters. The optimization sought to minimize the absolute error between model output and available data for civilian and military spending as fractions of GDP using the objective function

$$Objective = \sum_t |C_{model}(t) - C_{data}(t)| + \sum_t |M_{model}(t) - M_{data}(t)| \quad (4)$$

Figure 2: Model fit using estimated parameters



4. Results and Discussion

The genetic algorithm converged on a parameter vector that minimized the error between observed and modeled values with an objective function value of 0.23. The final parameter estimates are shown in Table 3 with the resulting fit in Figure 2. The two GDP delay parameters converged to the maximum value of 30 years, suggesting long-term memory in both civilian and military budget allocation decisions.

The optimized model revealed notable differences in the interaction dynamics between civilian and military spending. The estimated value of the direct interaction term $m_2 = 0.01$ (military loss due to civilian-military interaction) was more than an order of magnitude larger than $m_1 = 4.17x10^{-4}$ (civilian loss from the same interaction). This suggests that military expenditures are more sensitive to shared resource constraints than civilian spending, possibly reflecting a baseline resilience or priority afforded to civilian programs in non-wartime budgets. A similar difference appears in the static competition coefficients with $\alpha_{CM} = 0.23$ (impact of military on civilian) being substantially larger than $\alpha_{MC} = 0.043$ (impact of civilian on military). This indicates that while the military exerts a significant constraining influence on civilian

growth capacity, especially during periods of high military demand, while civilian programs exert relatively little suppressive effect on military expansion. This imbalance may reflect the strategic rigidity of defense budgets compared to the relative flexibility of domestic spending in U.S. fiscal policy. Note that although the military sector shows greater sensitivity to direct interaction ($m_2 > m_1$), the relatively small magnitude of both m_i terms limits their influence on model dynamics. Instead, the dominant competitive pressure in the model is exerted by military spending on civilian growth via the much larger α_i values.

Table 3: Final estimated parameter values

Parameter	Value	Description
m_1	4.17e-4	Civilian loss term from C-M interaction
m_2	0.01	Military loss term from C-M interaction
α_{CM}	0.23	Resource limitation of M on C
α_{MC}	0.04	Resource limitation of C on M
$\bar{G}_{C_x}$	30	GDP averaging delay for civilian spending
$\bar{G}_{M_y}$	30	GDP averaging delay for military spending
GDP growth rate intervals $r_G(t)$		
Interval 1	0.0693	$t < 2008$
Interval 2	-0.05	$2008 \leq t < 2009$
Interval 3	0.005	$2009 \leq t < 2010$
Interval 4	0.045	$t \geq 2010$
Civilian growth rate intervals $r_C(t)$		
r_{C0}	0.16	$t < 1965$
r_{C65}	0.12	$1965 \leq t < 1977$
r_{C77}	0.88	$1977 \leq t < 1988$
r_{C88}	0.87	$1988 \leq t < 1996$
r_{C96}	0.09	$1996 \leq t < 2009$

r_{C09}	0.59	$t \geq 2009$
Military growth rate intervals $r_M(t)$		
r_{M0}	0.05	$t < 1965$
r_{M65}	0.19	$1965 \leq t < 1968$
r_{M68}	0.38	$1968 \leq t < 1980$
r_{M80}	0.95	$1980 \leq t < 1991$
r_{M91}	0.15	$1991 \leq t < 2001$
r_{M01}	0.24	$2001 \leq t < 2010$
r_{M10}	0.27	$t \geq 2010$
Civilian carrying capacity as percent of GDP $\lambda_C(t)$		
Interval 1	0.16	$t < 1965$
Interval 2	0.91	$1965 \leq t < 1977$
Interval 3	0.11	$1977 \leq t < 1988$
Interval 4	0.13	$1988 \leq t < 1996$
Interval 5	0.84	$1996 \leq t < 2009$
Interval 6	0.12	$t \geq 2009$
Military carrying capacity as percent of GDP $\lambda_M(t)$		
Interval 1	0.73	$t < 1965$
Interval 2	0.48	$1965 \leq t < 1968$
Interval 3	0.10	$1968 \leq t < 1980$
Interval 4	0.12	$1980 \leq t < 1991$
Interval 5	0.12	$1991 \leq t < 2001$
Interval 6	0.42	$2001 \leq t < 2010$
Interval 7	0.11	$t \geq 2010$

The estimated time-varying growth rates for both civilian ($r_C(t)$) and military ($r_M(t)$), spending reflected key historical transitions. Among civilian intervals, $r_{C77} = 0.88$ and $r_{C88} = 0.87$ were markedly elevated, corresponding to the economic recovery and budget expansions that took place in the early 1990s. In contrast, $r_{C96} = 0.090$ showed a sharp decline in growth rate, likely reflecting late-1990s budget tightening and surplus-driven constraint. This is then followed by a rebound in $r_{C09} = 0.59$ during post-2009 economic stimulus initiatives.

For military growth, $r_{M80} = 0.95$ was the highest value across all estimated parameters and corresponds to the Reagan-era Cold War buildup. The values of $r_{M65} = 0.19$ and $r_{M68} = 0.38$ also reflect the rapid escalation and sustained intensity of the Vietnam War period. A pronounced decline is evident in $r_{M91} = 0.15$, aligning with the post-Gulf War drawdown, while $r_{M01} = 0.24$ and $r_{M10} = 0.27$ show re-intensification during the War on Terror and subsequent years. Overall, these patterns validate the need for piecewise structure in the model, allowing growth dynamics to adapt to evolving geopolitical and economic conditions.

The interplay between growth rates (r_i) and sectoral capacity modifiers (λ_i) revealed several notable imbalances that help explain observed shifts in spending trajectories. In the civilian sector, the period from 1977 to 1988 ($r_{C77} = 0.88$) exhibited exceptionally high intrinsic growth, yet was paired with a moderate carrying capacity ($\lambda_{C77} = 0.11$), suggesting strong expansionary pressure constrained by external factors such as inflation, taxation policy, or political gridlock. Conversely, in the 1988-1996 window, civilian growth slowed ($r_{C88} = 0.87$ to $r_{C96} = 0.090$), but $\lambda_{C88} = 0.13$ and $\lambda_{C96} = 0.84$ reflect a relaxation of structural constraints during a time of deficit reduction and peace dividend spending.

In the military sector, the most striking mismatch occurred during the Reagan-era buildup (1980-1991), where $r_{M80} = 0.95$ was the highest of any interval. This coincided with a relatively low capacity modifier ($\lambda_{M80} = 0.12$), reflecting a possible overshooting of strategic expansion beyond fiscal or political carrying limits. Later, from 2001-2010, both $r_{M01} = 0.24$ and $\lambda_{M01} = 0.42$ rose in tandem, indicating aligned military growth and structural support during the War on Terror. However, post-2010 ($r_{M10} = 0.27$ and $\lambda_{M10} = 0.11$), growth remained elevated despite a sharp drop in capacity, hinting at increased budget strain or shifting defense priorities amid emerging global threats. These divergences between r and λ help disentangle raw sectoral

momentum from institutional or fiscal resistance, enhancing interpretability of long-term spending patterns.

The empirical findings of this paper provide support for conceptualizing military and civilian spending dynamics through a Lotka-Volterra-inspired competition framework. While the model allows each sector to impose pressure on the other, the resulting parameters that resulted from fitting available data imply that military spending behaves analogously to a dominant species exerting systemic pressure on its counterpart, social spending. Parameter results that govern sector-specific perception of GDP availability indicate that increases in military spending disproportionately constrain civilian expenditure, consistent with a dominant species limiting the availability of a shared resource base. Interestingly, the fact that military spending appears to be more sensitive to the direct loss term than civilian spending reveals a potential fragility in defense allocations when domestic investment is high, suggesting that military growth may be more easily disrupted by shared policy focus or administrative conflict. This inversion of the traditional dominance hierarchy reflects a key insight from evolutionary theory, namely, dominant competitors are not always the most resilient, and under certain conditions, their performance can be more negatively impacted by coexistence than that of their presumed subordinates. Surges in military spending during periods like the Cold War and the post-9/11 era reflect broader shifts in dominance and instability, echoing the cyclical dynamics often seen in predator–prey systems. These are not just historical artifacts, but instead represent strategic responses to external shocks, such as rising security threats or global realignments, that lead governments to prioritize military budgets, often at the expense of long-term social investment.

From an evolutionary economics perspective, the results offer important insights into how militarization functions as a path-dependent and structurally embedded institutional logic. Military spending is not merely a reaction to external threats; rather, it emerges as an adaptive strategy within a competitive landscape shaped by geopolitical rivalry, industrial concentration, and alliance pressures. The chaotic nature of military investment, its high fixed costs, rapid obsolescence, and dependence on government funding, reinforces a self-replicating dynamic that favors continuity over efficiency. This predator-prey framework sheds light on the institutional inertia embedded in the system: once military capacity is built up, it creates bureaucratic, economic, and political constituencies that resist resource reallocation toward civilian sectors.

This aligns with evolutionary economics' focus on irreversible investments, institutional routines, and historical contingency. In this context, the suppression of civilian spending is not just a budgetary outcome but a reflection of deeper structural asymmetries between state security priorities and social welfare commitments. These dynamics also highlight the limitations of conventional economic theories, which often fail to capture non-linear dynamics, power asymmetries, and ecological analogies inherent in real-world fiscal systems. By framing military and civilian spending as co-evolving species in competition for a finite economic ecosystem, our analysis underscores the necessity of rethinking fiscal policy through the lens of systemic resilience, long-term adaptability, and socio-ecological balance.

5. Conclusion

This paper has taken a novel approach to the longstanding 'guns and butter' debate by applying a modified Lotka-Volterra model to the interaction between military and civilian spending, conceptualized as two "species" competing for limited resources (GDP) and influencing each other's trajectories. Focusing on the United States from 1960 to 2019, we provide fresh empirical evidence on the trade-off between these two budget categories from an evolutionary economics perspective. While the guns-and-butter argument suggests a budgetary trade-off, decades of empirical research since Russett's (1969) seminal work have yielded mixed and often inconclusive results. This variation is not surprising, given differences in country contexts, political institutions, and welfare regimes. Our study moves beyond standard econometric approaches by modeling military and civilian spending as co-evolving sectors engaged in competition over a shared resource that includes time-lagged responses, time-varying inputs, and dynamic feedback mechanisms.

The results confirm a dynamic consistent with classical competition models (e.g., Lotka-Volterra and Tilman-style systems), where even modest differences in competitive effects can lead to persistent dominance by one sector over the other (Tilman, 1982; Armstrong & McGehee, 1980). In our model, military spending exerts greater pressure on civilian spending, akin to a dominant species suppressing another's growth. At the same time, military spending is more affected by their interaction, indicating a vulnerability during periods of constrained fiscal resources. These interactions are not static: major historical shifts, such as the Cold War buildup and the War on Terror, trigger alternating dominance patterns between the two sectors,

highlighting the cyclical and path-dependent nature of fiscal policy. This framework not only offers a new lens for understanding state expenditure priorities but also underscores the importance of viewing fiscal trade-offs as dynamic processes shaped by institutional, geopolitical, and economic constraints.

We acknowledge several avenues for extending this research. First, it would be valuable to disaggregate civilian spending to examine how the dynamics differ across categories such as health, education, or social protection. Second, applying the model to countries with varying welfare regimes could yield important comparative insights and complement existing research such as Töngür and Elveren (2015), who examined the relationship between military spending, inequality, and welfare regimes. Third, future studies could explore how political regime type, democratization, and institutional militarization influence the predator-prey dynamic, particularly in authoritarian contexts where military spending may be more shielded from democratic accountability. Finally, incorporating ecological and gendered dimensions, such as the environmental impacts of militarization or the crowding-out of care infrastructures, could broaden the scope of evolutionary and heterodox economic analysis. In doing so, we can better understand how national security imperatives are historically and structurally prioritized over social well-being, often at the expense of long-term development and equity.

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