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Military Outlays and Economic Growth: A Nonlinear Disaggregated Analysis for a Developed Economy

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Abstract: There is a dearth of comprehensive studies examining the compositional and asymmetric effects of defence spending on simultaneous economic growth. This study uses the Nonlinear Autoregressive Distributed Lag (NARDL) approach to analyse how disaggregated defence spending affects economic growth in Greece in the short and long term. The results hold significant theoretical and practical policy implications. First, military spending boosts economic growth in the short term but hampers it in the long run. Second, the long-term effects of positive and negative defence spending shocks are distinct, with positive shocks more detrimental to economic growth than the benefits of negative shocks. Finally, our study reveals that personnel expenditures have the most significant and enduring effects on economic growth compared to other military spending categories. Based on these results, Greece should adopt a new defence doctrine that relies on extensive personnel reserves, prioritises state intelligence and production technology, and promotes domestic military equipment over expensive foreign options.

Keywords: political economy; economic growth; defence spending; defence budget components; NARDL

JEL Classification: C22; H56; O11

1 Introduction

This study uniquely examines how the compositional and asymmetric effects of military funds affect economic growth, addressing regional security challenges,

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sustainable growth rates, and the academic debate on defence expenditure and economic growth. This research provides a unique perspective on the relationship between military funds and economic growth, making it stand out in the field.

In light of the recent Russian aggression against Ukraine, there has been a growing need for European and NATO member countries to consider increasing their military spending. However, governments have been faced with the challenge of balancing this with other resource demands such as social welfare programs, education, infrastructure, healthcare, and higher living standards. Effectively reconciling these other resource demands while preserving national defence and security, promoting economic growth, and maintaining political stability is a formidable task.

Greece's membership in NATO and constant threats to its national security have resulted in a higher allocation of military expenses compared to other NATO states. These expenditures have comprised a significant portion of the government's budget. Economic goals, security needs, and Türkiye's aggressive behaviour in the Aegean and Eastern Mediterranean have triggered Greece's substantial military spending. These factors combine to make Greece an intriguing case study for examining the impact of military funds on economic growth.

In addition, Greece, as a member of the European Union (EU) and the Economic and Monetary Union (EMU), has had to consider economic limitations when determining its military expenditures. Despite the global financial crisis of late 2008, which led many NATO and EU member states to reduce defence spending, Greece has continued to allocate more than 2 % of its GDP to the military. Given Greece's unique circumstances, this study's findings could provide valuable insights towards strategic decisions on defence spending and resource allocation.

Development economics studies the relationship between military spending and economic growth. Two frameworks, Keynesian and neoclassical, have enabled the examination and explanation of this relationship. The Keynesian framework views military spending as a means to boost national income growth. In the neoclassical framework, defence spending is viewed as a public good for national security. However, allocating resources to the military can have negative effects, such as reducing investment and creating opportunity costs (D'Agostino, Dunne, and Pieroni 2010; Faini, Annez, and Taylor 1984; Pieroni 2009).

A consensus on the impact of defence expenditure on economic growth has remained elusive despite extensive empirical research following Benoit's works in 1973 and 1978, even in the most recent studies. A first strand of recent empirical studies by Dimitraki and Win (2021), Mohanty, Panda, and Bhuyan (2020), Aijaz Syed (2021), Laniran and Ajala (2021), and Emmanouilidis and Karpetis (2021) revealed that defence expenditure has a positive impact on economic growth.

In contrast, a second strand of recent empirical studies by Azam (2020), d'Agostino et al. (2020), Desli and Gkoulgkoutsika (2021), Emmanouilidis and Karpetis (2022), Saba (2022), and Becker and Dunne (2023) revealed a negative impact of defence spending on economic growth. A third strand of studies, by Dunne and Smith (2020), Su et al. (2020), Kollias and Tzeremes (2022), and Dimitraki and Emmanouilidis (2023), did not provide a definite conclusion concerning the relationship between military expenditure and economic growth.

Various factors could account for the inconsistencies in empirical results, such as differences in theoretical frameworks, model specifications, estimation approaches, forms of data, country samples, and analysis periods (see, for a relative explanation, the studies of Dunne and Uye 2010; Luqman and Antonakakis 2021).

Undeniably, existing empirical studies have not thoroughly studied the short- and long-term effects of defence spending on economic growth (see Khalid and Habimana 2021). In the short term, military spending can stimulate domestic demand, but it may not lead to long-term increases in capital and production capacity. Additionally, military spending can crowd out public and private investment, particularly in heavily indebted countries. Furthermore, military spending can disrupt resource allocation by influencing prices independently of market forces (Knight, Loayza, and Villanueva 1996; Su et al. 2020).

In this context, most empirical studies have overlooked the analysis of the short- and long-term effects of defence expenditure, resulting in a lack of definitive evidence in the field. However, more recent studies have employed modern econometric methods such as Autoregressive Distributed Lag (ARDL), Nonlinear Autoregressive Distributed Lag (NARDL), and the wavelet approach to address this issue (see Azam 2020; Emmanouilidis 2024; Khalid and Habimana 2021; Saba 2022).

For certain, there has been a lack of explicit studies regarding how positive and negative changes in military spending affect economic growth. Government strategies in response to economic cycles and geopolitical challenges have varied based on ideological beliefs. Left-wing governments tend to allocate less to military equipment compared to right-wing governments, which aim to satisfy their respective voter bases. Therefore, applying the symmetric approach fails to explain how positive and negative changes in defence spending affect economic growth.

An asymmetric approach offers a more comprehensive understanding of the relationship between military spending and economic growth as the dynamics of economic cycles and geopolitical challenges can be captured. Further, an asymmetric approach can provide valuable insights into the dynamics of the situation by encompassing periods of both economic growth and recession. Therefore, concerning model specification, the asymmetric technique is considered more effective than the symmetric approach (see Topal, Unver, and Türedi 2022).

Significantly, most studies examining the relationship between defence expenditure and economic growth have utilised linear econometric methods and assumed that spending has a symmetrical impact on economic growth. Notably, a small number of recent studies considered the asymmetric relationship between defence spending and economic growth (see Ahad and Dar 2017; Aijaz Syed 2021; Luqman and Antonakakis 2021; Emmanouilidis 2024; and Ullah et al. 2021).

Admittedly, the empirical literature has not yet examined the potential variations in the impact of different components of military expenditure on economic growth. Given the diverse nature of military outlays, the absence of decomposition analysis in current studies has limited understanding of the relationship between military spending and economic growth. These expenditures typically include personnel wages, equipment, infrastructure, training, and operating costs, each of which potentially exerts distinct impacts on economic growth.

More significantly, disaggregation presents an intriguing avenue for exploring new research inquiries and generating innovative ideas regarding national and collective economic, security, and strategic resource allocation decisions (Becker and Dunne 2023). In fact, only a small number of studies (see Becker and Dunne 2023; Emmanouilidis 2024; Mohanty, Panda, and Bhuyan 2020; Olejnik 2023) have attempted to separate the effects of defence spending on economic growth. However, these empirical findings have displayed inconsistencies stemming from variations in theoretical paradigms, model specifications, estimation techniques, data sources and forms, country samples, and analysis periods.

Considering the contradictory findings and unexplored aspects of previous studies, three essential research questions emerged:

I. How does military spending affect short- and long-term economic growth?
II. How do positive and negative military spending shocks influence economic growth?
III. How does each component of military spending affect short- and long-term economic growth?

This study aims to deepen our understanding of the relationship between military expenditure and economic growth by analysing critical factors that have not been simultaneously explored in previous empirical research. This research adds value to existing literature in multiple ways.

First, this research stands out as one of the first empirical endeavours to examine the impact of disaggregated military data on economic growth. We anticipated that the inclusion of a decomposition analysis in our study would enhance comprehension of the links between military spending and economic growth, considering the diverse nature of military outlays. We expected these findings to provide consistent policy recommendations. Second, the study relied on valid and comparable data on Greece's defence spending, obtained through a thorough analysis of multiple NATO printed and digital publications on "Information on Defence Expenditures" over the past four decades. Third, the political landscape in Greece has been unstable, with frequent shifts in economic, social, and external policies. A symmetric approach alone cannot fully explain how changes in defence spending affect economic growth. Therefore, this study employed the NARDL method (Shin, Yu, and Greenwood-Nimmo 2014) to examine how positive and negative changes in military spending influence economic growth in both the short and long run, thereby providing policymakers with more intricate knowledge. Fourth, this study differentiates itself from most existing research in Greece by utilizing the most recent and comprehensive data, which ensures robust and concrete insights into the implications of the prolonged economic crisis within the country's economic framework. Finally, the relationship between military expenditure and economic growth in Greece, where spending has exceeded 2 % of GDP for four decades, has implications for other EU and NATO members. With rising geopolitical challenges and potential increases in military budgets, including aid to Ukraine, optimising defence fund allocation is crucial for supporting economic growth. This study's findings could provide valuable insights for strategic decision-making in defence spending and resource allocation.

The paper's structure is as follows: Section 2 provides a comprehensive summary of the budget allocated to the defence sector in Greece. Section 3 outlines a thorough examination of the related theoretical and empirical studies. Sections 4 and 5 describe the applied model specification and the dataset used in the study. Section 6 provides a comprehensive overview of the estimation methods used. Section 7 analyses the empirical findings, and Section 8 offers conclusions, including the proposing of policy recommendations.

2 Recent Trends in the Greek Economy and Military Spending

Greece's economic course offers valuable policy insights. Having joined NATO in 1952, the EU in 1981, and the Eurozone in 2001, Greece underwent significant policy shifts that impacted its economic trajectory. From 1980 to 2022, Greece experienced four stages: stagnation (1980–1994), growth (1995–2007), a financial crisis (2008–2016) with a GDP drop of approximately 29 %, and a weak recovery (2017–2022), with an average annual GDP growth of 1.54 %.

Greece's defence efforts have been substantial, with the country recording one of the highest military expenditures among NATO and EU members (Figure 1). Over

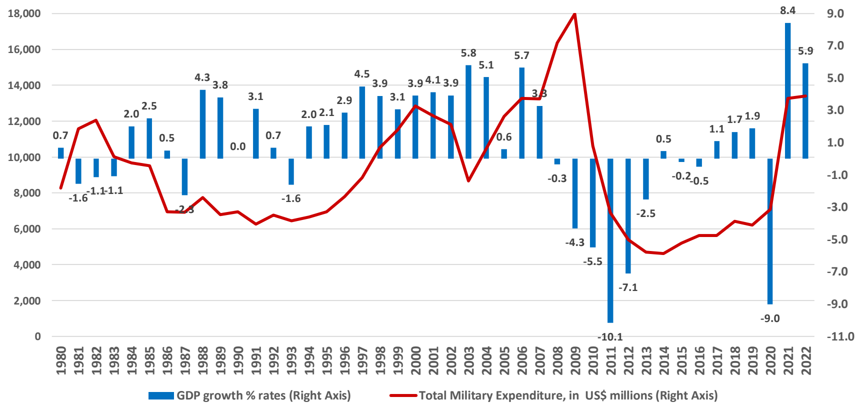

Figure 1: Greek trends in economic growth rates and military spending. Source: World Bank (2023) and SIPRI (2023) databases.

the last four decades, it has consistently allocated approximately 3.43 % of its GDP to defence. Notably, there was a significant increase in military spending in 2021 and 2022, primarily directed towards the acquisition of military equipment, which marked a shift where equipment spending surpassed personnel costs (see Figure 2). The Greek-Turkish crisis in 2020 was a significant turning point in defence expenditure trends.

On the other hand, NATO members' spending notably increased during Donald Trump's presidency of the United States from 2017 to 2021, and even more so following Russia's complete invasion of Ukraine in early 2022. NATO projected that 18

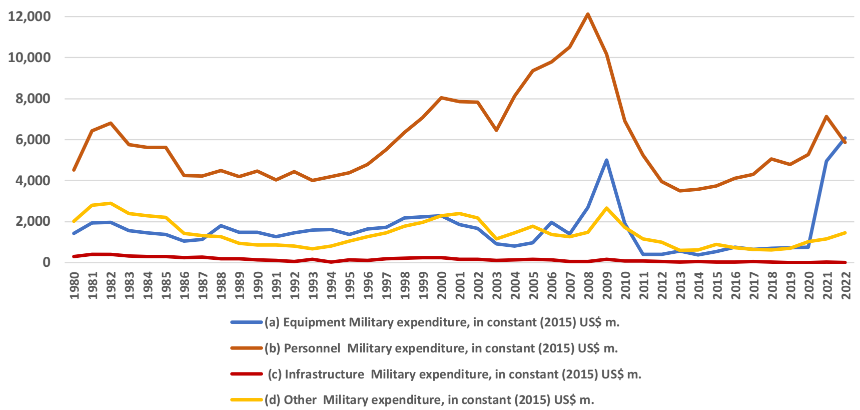

Figure 2: Greek defence spending by primary category. Source: Authors calculations based on SIPRI (2023) and NATO databases.

of its 32 member countries would meet the 2 % GDP defence spending target by 2024, representing a significant rise from just five countries achieving this target by 2016.

NATO divides defence expenditures into four main categories:

a) Equipment expenditure, encompassing significant equipment spending and research and development (R&D) directed towards major equipment.
b) Personnel expenditure, which includes military and civilian costs, as well as pensions.
c) Infrastructure expenditure, including NATO's shared infrastructure and construction projects undertaken by individual member nations for military purposes.
d) Other spending, encompassing operations and maintenance, additional R&D expenses, and any expenditure not explicitly allocated in the previous categories.

Greece's allocation of financial resources for personnel has differed significantly from the NATO average. Personnel costs, which cover both the military and civilian sectors, have been the primary focus in Greece. From 1980 to 2022, Greece dedicated 65.8 % of its defence budget to human expenses, whereas NATO countries collectively allocated 55.3 % to the same category.

In terms of military equipment, Greece allocated the same percentage (17 %) as the NATO average during this period, but there were variations. Regarding infrastructure expenditure, Greece consistently allocated 1.6 % of its defence budget, while NATO countries allocated almost double that amount, at 3.6 %. Finally, while NATO member states, on average, contribute approximately 24.1 % of their budgets to operations and maintenance expenses, including additional R&D costs, Greece only allocated 15.6 % within that timeframe (see Table 1).

Table 1: The distribution of military spending in Greece and NATO countries.

	1980–2022	1980–1989	1990–1999	2000–2008	2009–2022
Greece-equipment	17.0 %	17.2 %	21.3 %	12.8 %	16.5 %
Nato-equipment	17.0 %	17.4 %	16.2 %	16.2 %	17.6 %
Greece-personnel	65.8 %	58.3 %	62.8 %	72.0 %	69.4 %
Nato-personnel	55.3 %	52.6 %	57.7 %	55.0 %	55.5 %
Greece-infrastructure	1.6 %	3.2 %	1.8 %	1.1 %	0.6 %
Nato-infrastructure	3.6 %	4.5 %	3.8 %	3.7 %	3.1 %
Greece-other	15.6 %	21.3 %	14.2 %	14.1 %	13.5 %
Nato-other	24.1 %	25.6 %	22.3 %	25.1 %	23.8 %

3 Theoretical and Empirical Literature on Defence Spending and Economic Growth

Diachronically, national governments allocate a substantial portion of public funds to defence expenses. Following Benoit's studies in 1973 and 1978, recent research endeavours have explored the economic consequences of this significant scale of budget expenditure.

3.1 Theoretical Literature on Defence Spending and Economic Growth

The literature review reveals an engaging academic debate between two contrasting paradigms: Keynesian and neoclassical. This discourse, focusing on the influence of defence spending on economic growth, is intellectually intriguing and of scholarly relevance.

In the Keynesian framework, increasing military spending has been shown to drive demand for goods and services, thereby positively impacting employment and economic growth (Pieroni 2009). Similarly, Faini, Annez, and Taylor (1984) proposed that heightened military spending can enhance capacity utilisation, profitability, and investment when demand is lower than expected. However, directing a substantial portion of government spending towards imports may lessen the impact of these dynamic effects, thereby complicating the analysis of the relationship between GDP growth and military spending (Manamperi 2016).

While security measures imply a positive correlation between military expenditure and economic progress, this association is mainly relevant in underdeveloped economies grappling with poverty, where stability is a critical barrier to growth. However, this framework between military expenditure and economic growth must also consider supply-side factors, such as technological spillover effects. In turn, Smith (1980) introduced production factors to address the limitations of focusing solely on demand.

Neoclassical economic theory postulates that military spending can have negative effects on economic output. Neoclassical approach includes the concept of the crowding-out effect, which suggests that prioritising military spending over public investments such as healthcare and education can hinder long-term economic growth. Additionally, funding military expenditure through borrowing or increased taxation may reduce private investments, which highlights the impact of public sector decisions on private investment (Lipow and Antinori 1995).

Finally, during a debt crisis, military spending and arms imports can impact investment and economic growth. Military borrowing has been shown to reduce consumption, thereby impeding economic growth (Dimitraki and Kartsaklas 2018). Neoliberals view national defence as a public utility resulting in opportunity costs, with which inflation, global financial disparities, and excessive public debt have been associated. Military spending may boost long-term economic growth if the benefits outweigh the costs (Waszkiewicz 2016).

3.2 Empirical Literature on Defence Spending and Economic Growth

Studies on the relationship between military spending and economic growth have yielded inconclusive results. We focused on recent studies that used advanced econometric methods and extensive datasets.

A first group of recent empirical studies presented evidence of the positive impact of defence spending on economic growth. For example, Ahad and Dar (2017) studied Russia from 1992 to 2014, and Dimitraki and Win (2021) analysed Jordan's economy from 1970 to 2015, with both confirming a positive relationship between defence spending and economic growth in the short and long term. Mohanty, Panda, and Bhuyan (2020) examined India's economy from 1970 to 2016, revealing a similar positive relationship. Emmanouilidis and Karpetis (2021) focused on Türkiye from 1987 to 2019, finding that defence spending positively affected economic growth over both short and long time periods. Finally, Aijaz Syed (2021) examined India and China from 1990 to 2018, revealing that defence spending stimulated economic growth in both the short and long term.

A second group of studies, such as those by Laniran and Ajala (2021) on Nigeria from 1981 to 2017 and Ullah et al. (2021) on Pakistan from 1985 to 2018, have suggested that defence spending has a negative impact on short-term economic growth but a positive impact on long-term economic growth.

A third group of more recent empirical studies consistently indicated that defence spending negatively impacts economic growth, particularly in the long term. For instance, studies by Ahmed et al. (2020a), Ahmed, Zafar, and Mansoor (2020b) on Myanmar from 1975 to 2014, Khalid and Habimana (2021) on Türkiye from 1961 to 2014, Lanrui et al. (2022) on Pakistan from 1972 to 2018, and Emmanouilidis's (2024) on the US from 1949 to 2021 showed that defence spending initially boosts economic growth but hinders long-term growth.

A fourth group of studies revealed a detrimental impact of defence spending on economic growth in both the short and long term. Examples of studies in this group include Ahad and Dar (2017) examining the UK and the US; Ahmed et al. (2020a), Ahmed, Zafar, and Mansoor (2020b), Luqman and Antonakakis (2021), and Rehman et al. (2023) focused on Pakistan; Maher and Zhao (2022) on Egypt; Hung-Pin and Tsung-Li (2022) on Taiwan; and Saba (2022) on South Africa.

A fifth group of empirical studies, including Azam (2020), d'Agostino (2020), Desli and Gkoulgkoutsika (2021), Emmanouilidis and Karpetis (2022), Becker and Dunne (2023), and Dada et al. (2023), used various panel estimations in different groups of countries and revealed that military spending hampers economic growth mostly in the long run.

Finally, another group of studies revealed an ambiguous effect of miliary spending on economic growth. For instance, Dimitraki and Emmanouilidis (2023) found a positive correlation between military expenditure and economic growth in Spain from 1954 to 2021, but during the democratic regime years (1975–2021), this relationship became negative. Similarly, Su et al. (2020) studied China from 1952 to 2014 and found both positive and negative effects of defence spending on economic growth, indicating an ambiguous effect. Finally, Dunne and Smith's (2020) panel study covering 46 countries did not show a strong relationship between military expenditure and growth.

Table A1 in the Appendix presents a comprehensive overview of recent empirical research exploring the link between defence spending and economic growth.

It is critical to delve deeper into empirical studies that have applied disaggregated data to examine the effects of defence expenditures on economic growth and investment. For instance, Malizard (2013) examined the impact of military spending on private investment in France from 1980 to 2010. The study revealed that non-equipment military spending tends to crowd out investment, whereas military equipment spending stimulates investment. Mohanty, Panda, and Bhuyan (2020) studied the connection between economic development and defence spending in India from 1970 to 2016. They discovered that investing in capital defence boosts economic growth, whereas spending on revenue defence does not yield the same effect. Similarly, Becker and Dunne (2023) conducted panel estimations across NATO and EU countries, revealing a negative correlation between military spending and economic growth, primarily driven by personnel expenditures and, to a lesser extent, operating costs.

Furthermore, Olejnik (2023) explored the impact of defence spending on economic growth in nine Central and Eastern European countries from 1999 to 2021. The findings indicated that personnel expenditures provide the greatest multipliers compared to other subcategories, such as military spending on equipment and infrastructure. More recently, Emmanouilidis (2024) examined the influence of US defence budget components from 1949 to 2021, revealing that costs associated with military personnel exert the most negative impact on economic growth, while expenses for operations and maintenance have a similar, albeit less significant, effect.

Previous empirical studies on the relationship between defence spending and economic growth in Greece have yielded contradictory findings. Initially, a small number of studies indicated a positive relationship between military expenditure and economic growth (Balfoussias and Stavrinos 1996; Chletsos and Kollias 1995; Kollias 1994, 1995). However, subsequent studies, including those by Antonakis (1997, 1999), Dunne and Nikolaidou (2001), and Paparas, Richter, and Paparas (2016), suggested a detrimental impact of military spending on economic growth. Additionally, Mylonidis (2008), Dunne and Nikolaidou (2012), and Malizard (2016) used panel data from EU-15 economies, including Greece, and confirmed the negative effect of military outlays on economic growth.

Finally, a third group presented empirical investigations identifying a neutral or insignificant impact of military expenditure on Greece's economic growth. This set comprises empirical studies that involved mainly time series analyses in the context of Greece (see Dritsakis 2004; Dunne and Nikolaidou 2005; Dunne, Nikolaidou, and Vougas 2001; Georgantopoulos 2012; Kollias and Makrydakis 2000; Manamperi 2016; Nikolaidou 2016). Table A2 in the Appendix outlines the empirical studies on Greek defence spending and economic growth.

The literature review highlights the numerous studies examining the relationship between military expenditure and economic growth. However, the deductions remain inconclusive, particularly in the case of Greece. The discrepancies are caused by variations in conceptual frameworks, model parameters, estimation methods, data types, the countries studied, and analysis periods. Notably, there is a lack of comprehensive studies that have simultaneously investigated the compositional and asymmetric effects of defence spending on economic growth.

This study aimed to address these gaps by utilising the latest disaggregated military spending data to provide significant and comprehensive insights for policy development. To achieve this, we evaluated a series of null hypotheses.

1. H_{01}: There is no difference in the impact of military spending on short- and long-term economic growth.
2. H_{02}: Positive and negative defence spending shocks do not differentiate in effect on economic growth.
3. H_{03}: There are no unique impacts of different components of military expenditure on economic growth.

4 Model Specification

Military spending is a complex and essential area of economic study, as it accounts for a significant portion of global resources. Economic, political, tactical, social, cultural, and ethical factors all form part of the analysis of military expenditure (Dunne and Nikolaidou 2012).

Two theoretical frameworks, Keynesian and neoclassical, allow for examination of the relationship between military spending and GDP growth. In the Keynesian framework, the state prioritises society's welfare and views military expenditure as a boost to national income through the multiplier effect. According to the neoclassical framework, military spending is a public good that prioritises national interests by weighing trade-offs and security benefits.

The Keynesian and neoclassical frameworks have guided economists in developing various models to explore the relationship between military spending and economic growth. One of the earliest, the Feder–Ram model (Feder 1983), includes military expenditure as an independent variable in a single regression equation. The Feder–Ram model's appeal lies in independently analysing the impacts of military and non-military expenditures on economic growth. However, Dunne, Smith, and Willenbockel (2005) argued that the Feder–Ram model is prone to misinterpretation and has significant limitations concerning econometric analysis, indicating the need for further research and improvement. The augmented Solow model, initially proposed by Solow in 1956, has gained interest since its introduction to defence economics by Knight, Loayza, and Villanueva in 1996. The main advantage of the augmented Solow model is the provision of a coherent analytical framework with verifiable coefficient restrictions. However, the Solow model falls short of explaining an observed increased standard of living (D'Agostino, Dunne, and Pieroni 2010).

Recently, the Barro growth model (1990) has gained increased interest in the defence economics literature (see Compton and Paterson 2016; d'Agostino, Dunne, and Pieroni 2017, 2019, 2020; Dimitraki and Emmanouilidis 2023; Dimitraki and Menla Ali 2015; Dimitraki and Win 2021; Emmanouilidis and Karpetis 2022; Manamperi 2016; Mylonidis 2008; Pieroni 2009; Utrero-González, Hromcová, and Callado-Muñoz 2019). The Barro (1990) style models, although not explicitly derived from theoretical equations, have been considered to provide more reliable estimates in defence growth literature compared to other models. The Barro growth model posits that tax-financed government expenditure can influence total output via the production function. This model suggests a nonlinear relationship between budgetary spending and economic growth, as it considers the changing relationship between government spending, productivity, and taxes (Dunne, Smith, and Willenbockel 2005; Yakovlev 2007).

The intricate design of the original Barro model (Aizenman and Glick 2006) has led economists to consider potential exogenous variables when examining the correlation between defence outlays and economic growth. We used a modified Barro framework, based on studies by Mylonidis (2008), Pieroni (2009), and Manamperi (2016), to analyse the impact of defence expenditure on Greece's economic growth.

Furthermore, we included control variables such as domestic investment, population growth, and literacy rates in the relative model specification, to reduce omitted variable bias (Caporale and Pittis 1997; Lütkephol 1982).

Therefore, this study employed the following regression growth model for the case of Greece between 1980 and 2022.

$$\text{GDPpc}_t = a_1 + \text{INVE}_t + \text{EDUC}_t + \text{POPU}_t + \sum_{j=1}^{5} \varepsilon_j \text{MILIT}_{jt} + \text{u}_{1t} \quad (1)$$

The dependent variable GDPpc_t represents the natural logarithm of GDP per capita (measured in constant 2015 US dollars) at time $t = 1, 2, \ldots T$, and was employed to capture the economic growth. GDP includes all of a country's outputs, including defence and education services that the majority of national governments provide (Callen 2022). Our study normalised and linearised GDP per capita using its logarithmic form.

INVE_t defines gross fixed capital formation as a proportion of GDP. Traditional economic theory has highlighted the importance of investment in driving economic growth by increasing physical capital. However, the endogenous growth theory, developed by Romer (1994) and Barro (1990), has challenged this idea by considering factors such as infrastructure, human resources, and technological advancements in capital formation. Empirical evidence from various studies has supported understanding of the significant impact of capital formation on economic growth (see Azam 2020; d'Agostino et al. 2020; Dada et al. 2023; Manamperi 2016; Mylonidis 2008; Pieroni 2009).

POPU_t specifically refers to population growth, reflecting a country's demographic patterns. Many studies in the field have used POPU_t as an explanatory variable (see Dimitraki and Win 2021; Dimitraki and Emmanouilidis 2023; Lanrui et al. 2022; Mylonidis 2008; Manamperi 2016; Pieroni 2009). The consensus is that population growth has a significant impact on economic growth and can potentially increase per-capita output growth rates (Peterson 2017).

EDUC_t measures the percentage of individuals aged 25 and older who have completed tertiary education, thereby assessing the education level of the population, and has been applied as an explanatory variable in similar studies (see Laniran and Ajala 2021; Luqman and Antonakakis 2021; Manamperi 2016; Mylonidis 2008; Pieroni 2009). Higher education levels have been shown to increase a country's ability for technological advancements and improve existing knowledge, which are essential for economic growth (Benhabib and Spiegel 1994).

MILIT_{jt}, where j ranges from 1 to 5, represents different measures of military expenditure. Specifically, $j = 1$ denotes the logarithm of the total military spending in constant 2015 US dollars. Similarly, $j = 2$ represents the logarithm of military spending allocated to equipment in constant 2015 US dollars. When $j = 3$, it signifies the military expenditure logarithm dedicated to personnel in constant 2015 US dollars. When $j = 4$, it indicates the logarithm of military spending associated with personnel in constant 2015 US dollars. Finally, $j = 5$ represents the logarithm of military expenditures relative to operating costs in constant 2015 US dollars.

5 Data Information

To obtain robust findings, this study used an original dataset covering Greece from 1980 to 2022. The dataset included annual observations on key variables such as the logarithm of GDP per capita (in constant 2015 US dollars), domestic investment as a percentage of GDP, population growth, and tertiary education levels retrieved from the World Bank and UNESCO. Furthermore, we retrieved defence spending data (in constant 2015 US dollars) from the Stockholm International Peace Research Institute (SIPRI) database.

To determine Greece's primary category of defence spending, we meticulously reviewed and analysed NATO "Information on Defence Expenditures" publications. NATO initially documented only the category of equipment, using average figures from 1970 to 1974, 1975–1979, and 1980–1984. In 1985, NATO began collecting annual data on equipment, personnel, infrastructure, maintenance, and operations spending. The 1980–1984 dataset was an annual average for 1980. To balance the dataset for all variables in this analysis, we used interpolation to estimate missing data points for 1981, 1982, 1983, and 1984 (see Becker and Dunne 2023).

To ensure a comprehensive and robust empirical analysis, we created four additional variables representing critical defence expenditure areas, such as a) equipment, b) personnel, c) infrastructure, and d) operating costs. We calculated these variables, measured in logarithmic millions and expressed in US dollars for 2015, by multiplying NATO's distribution of defence expenditures across categories by SIPRI's defence expenditure data. Table 2 summarises the variables used in this study, while Table 3 shows descriptive statistics for each significant variable.

6 Methodology

This study employed a multidimensional econometric methodology. In the first phase, we assessed the variables' integration properties by examining the presence of unit roots in time series data. We used advanced unit root tests, such as the DF-GLS (Elliott, Rothenberg, and Stock 1996) and NP (Ng and Perron 2001), but these tests do

Table 2: Description of the variables and data sources.

Variable	Label of variable	Unit of measurement	Source	Website
GDP per capita	$GDPpc_t$	Log of the GDP per capita (constant 2015 US$)	World Bank	https://data.worldbank.org/indicator/NY.GDP.PCAP.KD
Total military expenditure	$MILIT_t$	Log of the total military expenditure in constant 2015 US$	SIPRI military expenditure database	https://milex.sipri.org/sipri
Military expenditure in equipment	$MILIT\text{-}EQUIP_t$	Log of defence expenditure in equipment	NATO database	https://www.nato.int/cps/en/natohq/topics_49198.htm
Military expenditure in personnel	$MILIT\text{-}PERSON_t$	Log of defence expenditure in personnel	NATO database	https://www.nato.int/cps/en/natohq/topics_49198.htm
Military expenditure in infrastructure	$MILIT\text{-}INFRAS_t$	Log of defence expenditure in infrastructure	NATO database	https://www.nato.int/cps/en/natohq/topics_49198.htm
Military expenditure in other expenses	$MILIT\text{-}OTHER_t$	Log of defence expenditure in other expenses	NATO database	https://www.nato.int/cps/en/natohq/topics_49198.htm
Gross fixed capital formation	$INVE_t$	Gross fixed capital formation (% of GDP)	World Bank	https://data.worldbank.org/indicator/NE.GDI.FTOT.ZS
Educational attainment	$EDUC_t$	Percentage (%) of total educational attainment, at least completed short-cycle tertiary, population 25+,	UNESCO database	http://data.uis.unesco.org/Index.aspx
Population	$POPU_t$	Population growth (annual %)	World Bank	https://data.worldbank.org/indicator/SP.POP.GROW

not account for breakpoints in the time series. To address this gap, we also employed the Zivot and Andrews (2002) test to identify a single unknown breakpoint within the series. We performed unit root tests with both a constant and a trend.

Table 3: Statistics Summary of the main variables in Greece, 1980–2022.

	$GDPpc_t$	**$INVE_t$**	**$EDUC_t$**	**$POPU_t$**	**$MILIT_t$**	**$MILIT\text{-}EQU_t$**	**$MILIT\text{-}PER_t$**	**$MILIT\text{-}INFR_t$**	**$MILIT\text{-}OTH_t$**
Mean	9.79	20.24	19.21	0.24	9.06	7.20	8.63	4.60	7.16
Median	9.80	22.85	19.10	0.33	9.02	7.28	8.57	4.88	7.15
Maximum	10.09	30.66	35.10	1.20	9.80	8.71	9.40	6.00	7.97
Minimum	9.58	10.69	7.60	−0.73	8.44	5.93	8.16	1.94	6.39
Std. Dev.	0.15	5.81	9.42	0.48	0.35	0.63	0.32	0.98	0.46
Skewness	0.43	−0.53	0.14	−0.45	0.14	0.06	0.59	−0.77	0.02
Kurtosis	2.13	1.93	1.57	2.64	2.02	3.18	2.38	3.00	1.91
Jarque–Bera	2.67	4.07	3.79	1.66	1.87	0.09	3.21	4.26	2.11
Probability	0.26	0.13	0.15	0.44	0.39	0.96	0.20	0.12	0.35
Sum	420.82	870.23	826.02	10.13	389.55	309.57	371.21	197.95	307.90
Sum Sq. Dev.	0.95	1,417.52	3,726.30	9.87	5.12	16.69	4.42	40.39	9.03
Observations	43	43	43	43	43	43	43	43	43

In the second phase, we studied the NARDL model's short- and long-term asymmetries. We used Wald statistics to test for asymmetry in the Greek GDP per capita and defence spending. Due to data constraints, we did not examine other explanatory variables. Wald tests determine linear or nonlinear dependence between variables. The rejection of the linear dependence null hypothesis indicates nonlinear dependence if the p-value is below 0.05. Broock et al. (1996) found nonlinear interactions in the series when the DBS test rejected the null hypothesis.

In the third phase of this study, we used the NARDL methodology (Shin, Yu, and Greenwood-Nimmo 2014) to examine military expenditure and economic growth. The NARDL method has many advantages compared to traditional methods. First, it captures asymmetric variable interactions, unlike the linear ARDL approach (Pesaran, Shin, and Smith 2001). Second, the NARDL model handles variables with different integration orders. Third, it estimates both the long- and short-term effects of explanatory variable. Finally, the NARDL model is more effective than others because it can handle diverse series cointegration patterns (Kumar et al. 2021; Salem et al. 2022).

The linear form of Equation (1) has been explicitly defined. However, dividing the defence spending variable into positive and negative segments was necessary to derive the asymmetries. Therefore, we expressed Equation (1) as:

$$\mathrm{GDPpc}_t = \alpha_1 + \beta_1 \mathrm{INVE}_t + \gamma_1 \mathrm{EDUC}_t + \delta_1 \mathrm{POPU}_t + \sum_{j=1}^{5} \varepsilon_j \mathrm{MILIT}_{jt}^{+} + \sum_{j=1}^{5} \zeta_j \mathrm{MILIT}_{jt}^{-} + \mathrm{u}_{1t} \quad (2)$$

where MILIT_{jt}^{+} indicates the partial sums of the positive shocks of military expenditures, MILIT_{jt}^{-} represents the partial sums of the adverse shocks of military spending.

Shin, Yu, and Greenwood-Nimmo (2014) described a threshold approach that incorporates asymmetry into the variables of military outlays and their components:

$$\begin{aligned} \mathrm{MILIT}_t^{+} &= \sum_{j=1}^{t} \Delta \mathrm{MILIT}_j^{+} = \sum_{j=1}^{t} \max\left(\Delta \mathrm{MILIT}_j^{+}, 0\right) \\ \mathrm{MILIT}_t^{-} &= \sum_{j=1}^{t} \Delta \mathrm{MILIT}_j^{-} = \sum_{j=1}^{t} \max\left(\Delta \mathrm{MILIT}_j^{-}, 0\right) \end{aligned} \quad \text{(3a) and (3b)}$$

Following Pesaran, Shin, and Smith (2001) and Shin, Yu, and Greenwood-Nimmo (2014), we could reiterate Equation (2) by considering Equations (3a) and (3b) as follows:

$$\begin{aligned}\Delta \mathrm{GDPpc}_t = {} & \alpha_0 + \sum_{i=1}^{n} \alpha i_{\mathrm{GDPpc}} \Delta \mathrm{GDPpc}_{t-\mathrm{i}} + \sum_{i=0}^{n} \alpha i_{\mathrm{INVE}} \Delta \mathrm{INVE}_{t-i} + \sum_{i=0}^{n} \alpha i_{\mathrm{EDUC}} \Delta \mathrm{EDUC}_{t-\mathrm{i}} \\ & + \sum_{i=0}^{n} \alpha i_{\mathrm{POPU}} \Delta \mathrm{POPU}_{t-i} + \sum_{i=0}^{n} \alpha i^{+}_{\mathrm{MILIT}} \Delta \mathrm{MILIT}^{+}_{jt-i} + \sum_{i=0}^{n} \alpha i^{-}_{\mathrm{MILIT}} \Delta \mathrm{MILIT}^{-}_{jt-i} \\ & + \alpha_1 \mathrm{GDPpc}_{t-1} + \beta_1 \mathrm{INVE}_{t-1} + \gamma_1 \mathrm{EDUC}_{t-1} + \delta_1 \mathrm{POPU}_{t-1} + \varepsilon^{+}_1 \mathrm{MILIT}^{+}_{jt-1} \\ & + \zeta^{-}_1 \mathrm{MILIT}^{-}_{jt-1} + u_{2t}\end{aligned} \tag{4}$$

The indications (+) and (–) separately denote the positive and negative partial sum disintegrations.

Cointegration can be assessed using two distinct statistical measures in the nonlinear paradigm. According to Banerjee, Dolado, and Mestre (1998), the initial test employed is a *t*-test (referred to as t_{BDM}), which assesses the null hypothesis of no cointegration (H_0: $\alpha 1 = 0$) in comparison to the alternative hypothesis of cointegration (H_α: $\alpha 1 < 0$).

The *F*-test was utilised to evaluate the enduring connection between the variables by examining the statistical importance of the lagged values of the variables. According to Pesaran, Shin, and Smith (2001), the null hypothesis refers to the absence of a long-term cointegration relationship, indicating the lack of cointegration among the variables in Equation (4) $\mathrm{H}_0 : \alpha_1 = \beta_1 = \gamma_1 = \delta_1 = \varepsilon^{+}_1 = \zeta^{-}_1 = 0$, in contrast to the alternative hypothesis $\mathrm{H}_\alpha : \alpha_1 \neq \beta_1 \neq \gamma_1 \neq \delta_1 \neq \varepsilon^{+}_1 \neq \zeta^{-}_1 \neq 0$. If the calculated value of the *F*-statistic was higher than the upper critical value, there was enough evidence to reject the null hypothesis that the two sets of data are not connected. Conversely, if the calculated value did not exceed the critical value, we would uphold the null hypothesis. If the expected *F*-value fell within the interval defined by the minimum and maximum values, the outcome was indeterminate.

To confirm the persistent relationship between variables, one must verify the presence of cointegration. Incorporation of the error correction term (ECT_{t-1}) into the NARDL model built upon Equation (1). This study introduced the integration of an error correction component into the fundamental causality analysis, as outlined in Equation (4).

$$\begin{aligned}\Delta \mathrm{GDPpc}_t = {} & \theta_1 + \varphi_1 \mathrm{ECT}_{t-1} + \sum_{i=1}^{k} h_i \Delta \mathrm{GDPpc}_{t-i} + \sum_{i=0}^{n} k_i \Delta \mathrm{INVE}_{t-i} + \sum_{i=0}^{n} l_i \Delta \mathrm{EDUC}_{t-i} \\ & + \sum_{i=0}^{n} m_i \Delta \mathrm{POPU}_{t-i} + \sum_{i=0}^{n} \mathrm{n}^{+}_i \Delta \mathrm{MILIT}^{+}_{jt-i} + \sum_{i=0}^{n} o^{-}_i \Delta \mathrm{MILIT}^{-}_{jt-i} + u_{3t}\end{aligned} \tag{5}$$

The ECT represents the error-correcting term in the long-term cointegrating equation, and the difference operator Δ signifies the change in variables. The *ks* values in each sum were determined using the Akaike information criterion. Equations (3a) and (3b) of the fundamental error correction model revealed that the residual term o ($i = 1$) and the constant term (θ_1) adhered to a normal distribution.

To accurately specify the NARDL model, it was necessary to analyse the presence of short- and long-run nonlinear relationships between key variables such as military expenditure and GDP per capita. Due to data limitations, asymmetries in other explanatory variables could not be considered. A Wald-type test was therefore employed to assess asymmetry in military spending in both the short and long term.

$$H_0: \sum_{i=0}^{n} ai^{+}_{\mathrm{MILIT}}\mathrm{MILIT}^{+}_{t-\mathrm{i}} = \sum_{i=0}^{n} ai^{-}_{\mathrm{MILIT}}\mathrm{MILIT}^{-}_{t-i} \tag{6}$$

In the examination of long-term asymmetry, the null conjecture was examined using the following:

$$H_0: -\varepsilon^{+}_{1}/a_1 = -\zeta^{-}_{1}/a_1 \tag{7}$$

The rejection of the null hypothesis in all examples indicates the presence of asymmetric effects in both the short and long term, suggesting that Equation (4) may have accurately characterised the estimated model. However, the absence of evidence to reject the two null hypotheses in all instances implies that the impact of total military spending and its subcategories is symmetrical, indicating that Equation (4) conforms to the conventional linear model.

The long-term impact of the explanatory variables on the dependent variable was automatically calculated in EVIEWS 13 by multiplying the long-run estimated coefficient of each independent variable with $-(1/\alpha 1)$ in Equation (4) (see Bårdsen 1989).[1]

In the final phase of this study, we computed the symmetric and asymmetric cumulative dynamic multipliers. These multipliers illustrated the dependent variable's reactions to both a positive and negative unit change in the regressors. This analysis made it possible to trace the trajectory from one state of equilibrium to another after a unit alteration in both positive and negative directions.

7 Findings

7.1 Time-series Unit Root Tests

Table 4 presents the results of the two sophisticated unit root tests and suggests that the variables exhibited stationarity either in their initial form (MILIT_t, $\mathrm{MILIT\text{-}EQU}_t$, and $\mathrm{MILIT\text{-}PER}_t$) or after conducting first-order differentiation (GDPpc_t, INVE_t, POPU_t, EDUC_t, $\mathrm{MILIT\text{-}INFR}_t$, and $\mathrm{MILIT\text{-}OTH}_t$). The Zivot and Andrews (2002) structural break unit root test results in Table 4 show that all variables were stationary

1 The long-run parameters are automatically computed using EVIEWS 13.

after accounting for the structural break at the first difference. Greece's economic crisis triggered the structural breaks from 2008 to 2016. Thus, the NARDL bounds testing approach was applicable in this study, as none of the series were stationary at or above the first difference level. Specifically, structural breakdowns may indicate nonlinear correlations between the dependent and explanatory variables (Shahzad et al. 2017).

7.2 Tests for Short- and Long-run Asymmetry

Table 5 shows the short- and long-term asymmetry between Greek GDP per capita and defence spending, including subcategories. Most models confirmed short- and long-term asymmetric correlations, thereby rejecting the null hypothesis of symmetry. Thus, negative and positive defence spending, including subcategories, were shown to have different effects on Greek GDP per capita. Interestingly, we observed consistent long-term asymmetries in personnel and equipment expenditure but no short-term asymmetry, suggesting that these impacts may take time to manifest.

7.3 Time-series Cointegration Test

Table 6 shows the estimates from the cointegration analysis. Most models showed statistical significance in both the *t*-statistics test (Banerjee, Dolado, and Mestre 1998) and the *F*-statistics test (Pesaran, Shin, and Smith 2001). In model specification (2), only the *t*-statistics test was significant, whereas in model specification (4), only the *F*-statistics test was significant. Therefore, we rejected the null hypothesis of no cointegration, confirming a long-term association between the variables in all model specifications.

7.4 Evaluation of the Short- and Long-run Coefficients

After establishing long-term cointegration, we analysed the short- and long-term impacts of variables such as military spending, domestic investment, educational attainment, and population growth on per-capita income. Table 7 describes the short-term dynamic variables linked to the long-term relationships derived from Equations (3a) and (3b) of the Error Correction Model (ECM).

In the short term, military expenditure positively impacts GDP, with a significant beneficial relationship evident, especially between periods $t-1$ and $t-2$. A 1 % increase in military spending resulted in a cumulative 0.482 % increase in GDP.

Table 4: Unit root test results.

Variables	DF-GLS		Ng-Perron		Zivot-Andrews		
	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend	
At Levels	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**Breakpoint**	**Statistic**
$GDPpc_t$	−1.060 (1)	−1.870 (1)	−3.064 (1)	−7.342 (1)	−4.289	2010	−2.980
$INVE_t$	−0.544 (1)	−2.021(1)	−1.088 (0)	−8.382 (0)	−4.844**	2010	−4.036
$EDUC_t$	0.946 (0)	−1.813 (0)	1.475 (0)	−4.270 (0)	−2.976	1998	−3.432
$POPU_t$	0.282 (4)	−2.483 (4)	1.184 (4)	−25.736 (1)***	−4.145	2011	−3.756
$MILIT_t$	−2.639 (1)***	−2.659 (1)	−13.700 (1)**	−13.422 (1)	−4.321	2010	−3.252
$MILIT\text{-}EQU_t$	−3.045 (1)***	−3.106 (1)*	−23.762 (1)***	−25.152 (1)***	−3.998	2011	−3.917
$MILIT\text{-}PER_t$	−2.299 (2)*	−2.418 (2)	−12.402 (2)**	−13.732 (1)	−5.845***	2010	−5.042**
$MILIT\text{-}INFR_t$	0.347 (2)	−2.199 (1)	−3.263 (2)	−7.237 (1)	−5.193**	2009	−5.004*
$MILIT\text{-}OTH_t$	−1.712 (0)*	−2.509 (0)	−4.976 (0)	−11.843 (1)	−3.449	2010	−3.109
At first difference							
$GDPpc_t$	−3.748 (0)***	−3.788 (0)**	−16.167 (0)***	−23.560 (2)***	−5.336**	2008	−6.193***
$INVE_t$	−4.841 (0)***	−5.467 (0)***	−18.748 (0)***	−19.838 (0)**	−6.622***	2008	−7.372***
$EDUC_t$	−5.270 (0)***	−5.797 (0)***	−19.781 (0)***	−20.346 (0)**	−6.297***	1992	−6.214***
$POPU_t$	−4.149 (4)***	−4.446 (3)***	−17.157 (3)***	−29.486 (1)***	−4.756*	2015	−5.182**
$MILIT_t$	−3.572 (1)***	−4.275 (0)***	−14.562 (0)***	−18.470 (3)**	−5.481***	2010	−7.962***
$MILIT\text{-}EQU_t$	−5.287 (1)***	−5.287 (1)***	−19.803 (0)***	−41.545 (1)***	−5.747***	2015	−7.414***
$MILIT\text{-}PER_t$	−3.138 (0)***	−3.975 (0)***	−12.743 (0)**	−15.769 (0)*	−5.970***	2009	−6.783***
$MILIT\text{-}INFR_t$	−6.733 (1)***	−9.221 (1)***	−30.646 (0)***	−17.822 (0)**	−8.051***	1995	−7.938***
$MILIT\text{-}OTH_t$	−4.240 (0)***	−5.085 (0)***	−17.281 (0)***	−19.090 (0)**	−6.010***	2002	−6.718***

Table 4: (continued)

	Critical values for the DF-GLS test		Critical values for the NP (MZa) test		Critical values for the Zivot-Andrews test	
	Constant	**Constant & trend**	**Constant**	**Constant & trend**	**Constant**	**Constant & trend**
1 %	−2.622	−3.770	−13.800	−23.800	−5.340	−5.570
5 %	−1.949	−3.190	−8.100	−17.300	−4.930	−5.080
10 %	−1.612	−2.890	−5.700	−14.200	−4.580	−4.820

Notes: The DF-GLS and Ng-P tests' optimal lag structures are determined using the Akaike information criterion (AIC) and are indicated in parentheses. At the 1 %, 5 %, and 10 % levels, respectively, ***, **, and * indicate rejection of the null hypothesis of a unit root.

Table 5: Results of the Wald tests for short- and long-run asymmetry.

		Short-run asymmetry (Wald test)				
		$MILIT_t$	$MILIT\text{-}EQU_t$	$MILIT\text{-}PER_t$	$MILIT\text{-}INFR_t$	$MILIT\text{-}OTH_t$
Estimated model 1:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT_t)$	5.4059 (0.0356)**				
Estimated model 2:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}EQU_t)$		0.5722 (0.4653)			
Estimated model 3:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}PER_t)$			0.2133 (0.6497)		
Estimated model 4:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}INFR_t)$				14.1762 (0.0044)***	
Estimated model 5:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}OTH_t)$					13.3045 (0.0065)***
		Long-run asymmetry (Wald test)				
		$MILIT_t$	$MILIT\text{-}EQU_t$	$MILIT\text{-}PER_t$	$MILIT\text{-}INFR_t$	$MILIT\text{-}OTH_t$
Estimated model 1:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT_t)$	5.9049 (0.0291)**				
Estimated model 2:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}EQU_t)$		3.6152 (0.0734)*			
Estimated model 3:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}PER_t)$			10.1300 (0.0058)***		
Estimated model 4:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}INFR_t)$				15.4004 (0.0035)***	
Estimated model 5:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT\text{-}OTH_t)$					15.5506 (0.0043)***

p-values in (.). *, **, *** indicate significance at 10 %, 5 % and 1 %, respectively.

Conversely, a 1 % decrease in military spending immediately raised GDP by 0.070 %, while a 1 % reduction in period t–1 decreased GDP by 0.077 %. Overall, negative changes in military expenditure have a minimal impact on income in the medium term.

Table 6: Results of the cointegration test.

		Test statistic	Value
Estimated model 1:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, MILIT_t)$	*F*-statistic:	7.1918
		t-statistic:	−5.1629
Estimated model 2:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, \text{MILIT-EQU}_t)$	*F*-statistic:	3.0519
		t-statistic:	−4.0325
Estimated model 3:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, \text{MILIT-PER}_t)$	*F*-statistic:	9.3599
		t-statistic:	−4.3113
Estimated model 4:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, \text{MILIT-INFR}_t)$	*F*-statistic:	5.5145
		t-statistic:	−1.8540
Estimated model 5:	$GDPpc_t = f(INVE_t, EDUC_t, POPU_t, \text{MILIT-OTH}_t)$	*F*-statistic:	9.3771
		t-statistic:	−5.9987

Bounds critical values

Sample size	10 %		5 %		1 %	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
***F*-statistic**						
35	2.5080	3.7630	3.0370	4.4430	4.2570	6.0400
40	2.4830	3.7080	2.9620	4.3380	4.0450	5.8980
Asymptotic	2.2600	3.3500	2.6200	3.7900	3.4100	4.6800
***t*-statistic**						
Asymptotic	−2.5700	−3.8600	−2.8600	−4.1900	−3.4300	−4.7900

Notes: Banerjee, Dolado, and Mestre (1998) test for t-statistics; Pesaran, Shin, and Smith (2001) test for F-statistics. *I(0) and I(1) are respectively the stationary and non-stationary bounds.

There are two approaches to linking the short-term positive economic impact of defence spending in Greece with existing literature. First, our findings aligned with the Keynesian multiplier effect theory, which suggests that increased military spending boosts demand for goods and services, thereby reducing resource unemployment and triggering economic growth (Pieroni 2009).

Second, our results were consistent with recent empirical studies, including those by Ahmed et al. (2020a), Ahmed, Zafar, and Mansoor (2020b) for Myanmar, Khalid and Habimana (2021) for Türkiye, Emmanouilidis and Karpetis (2021) for Türkiye, Lanrui et al. (2022) for Pakistan, Dimitraki and Win (2021) for Jordan, Mohanty, Panda, and Bhuyan (2020) for India, Aijaz Syed (2021) for India and China, Dimitraki and Emmanouilidis (2023) for Spain, and Emmanouilidis (2024) for the US.

Regarding the impact of investment on economic development, there was a positive relationship between economic development and the cumulative lagged coefficients of short-term domestic investment fluctuations. However, the combined

Table 7: Results of the short-run estimated coefficients.

Model 1: $\Delta GDPpc_t$ is the dependent variable				Model 2: $\Delta GDPpc_t$ is the dependent variable				Model 3: $\Delta GDPpc_t$ is the dependent variable			
Selected model: ARDL(4,1,4,4,3)				Selected model: ARDL(4,2,4,4,1)				Selected model: ARDL(4,1,4,4,4)			
Variable	Coefficient	T-ratio	Prob-value	Variable	Coefficient	T-ratio	Prob-value	Variable	Coefficient	T-ratio	Prob-value
$\Delta GDPpc_{t-1}$	0.009	0.061	(0.951)	$\Delta GDPpc_{t-1}$	0.335	2.311	(0.030)	$\Delta GDPpc_{t-1}$	−0.180	−1.854	(0.077)
$\Delta GDPpc_{t-2}$	−0.177	−1.116	(0.278)	$\Delta GDPpc_{t-2}$	−0.312	−1.927	(0.066)	$\Delta GDPpc_{t-2}$	−0.276	−2.432	(0.024)
$\Delta GDPpc_{t-3}$	0.376	2.557	(0.019)	$\Delta GDPpc_{t-3}$	0.422	2.400	(0.024)	$\Delta GDPpc_{t-3}$	0.505	3.992	(0.000)
$\Delta INVE_t$	0.016	7.166	(0.000)	$\Delta INVE_t$	0.007	2.904	(0.008)	$\Delta INVE_t$	0.013	6.862	(0.000)
$\Delta INVE_{t-1}$				$\Delta INVE_{t-1}$	0.006	2.390	(0.025)	$\Delta INVE_{t-1}$			
$\Delta INVE_{t-2}$				$\Delta INVE_{t-2}$				$\Delta INVE_{t-2}$			
$\Delta INVE_{t-3}$				$\Delta INVE_{t-3}$				$\Delta INVE_{t-3}$			
$\Delta EDUC_t$	0.009	2.076	(0.051)	$\Delta EDUC_t$	0.001	0.288	(0.775)	$\Delta EDUC_t$	0.012	2.984	(0.007)
$\Delta EDUC_{t-1}$	−0.042	−7.136	(0.000)	$\Delta EDUC_{t-1}$	−0.029	−4.113	(0.000)	$\Delta EDUC_{t-1}$	−0.036	−7.415	(0.000)
$\Delta EDUC_{t-2}$	−0.038	−7.060	(0.000)	$\Delta EDUC_{t-2}$	−0.026	−4.151	(0.000)	$\Delta EDUC_{t-2}$	−0.032	−7.396	(0.000)
$\Delta EDUC_{t-3}$	−0.033	−6.045	(0.000)	$\Delta EDUC_{t-3}$	−0.022	−4.138	(0.000)	$\Delta EDUC_{t-3}$	−0.030	−7.446	(0.000)
$\Delta POPU_t$	0.078	2.343	(0.030)	$\Delta POPU_t$	0.105	2.462	(0.021)	$\Delta POPU_t$	0.079	2.650	(0.014)
$\Delta POPU_{t-1}$	−0.171	−5.166	(0.000)	$\Delta POPU_{t-1}$	−0.143	−3.583	(0.001)	$\Delta POPU_{t-1}$	−0.172	−5.854	(0.000)
$\Delta POPU_{t-2}$	−0.074	−2.548	(0.019)	$\Delta POPU_{t-2}$	−0.043	−1.188	(0.247)	$\Delta POPU_{t-2}$	−0.072	−2.841	(0.009)
$\Delta POPU_{t-3}$	−0.139	−5.249	(0.000)	$\Delta POPU_{t-3}$	−0.099	−3.154	(0.004)	$\Delta POPU_{t-3}$	−0.130	−5.561	(0.000)
$\Delta MILIT_t^{+}$	−0.018	−0.344	(0.734)	$\Delta MILIT\text{-}EQU_t$	0.024	2.808	(0.009)	$\Delta MILIT\text{-}PER_t$	0.006	0.229	(0.821)
$\Delta MILIT_t^{-}$	−0.070	−2.169	(0.043)					$\Delta MILIT\text{-}PER_{t-1}$	0.183	7.439	(0.000)
$\Delta MILIT_{t-1}^{+}$	0.320	5.440	(0.000)					$\Delta MILIT\text{-}PER_{t-2}$	0.066	2.409	(0.025)
$\Delta MILIT_{t-1}^{-}$	0.077	2.561	(0.019)					$\Delta MILIT\text{-}PER_{t-3}$	−0.034	−1.513	(0.145)
$\Delta MILIT_{t-2}^{+}$	0.162	2.288	(0.033)								
$\Delta MILIT_{t-2}^{-}$	0.005	0.147	(0.884)								
ECTerm	−0.678	−7.653	(0.000)	ECTerm	−0.551	−4.837	(0.000)	ECTerm	−0.496	−8.585	(0.000)
Intercept	5.618	7.680	(0.000)	Intercept	4.991	4.853	(0.000)	Intercept	4.026	8.637	(0.000)
R-squared = 0.908				R-squared = 0.810				R-squared = 0.916			
Adjusted R-squared = 0.817				Adjusted R-squared = 0.687				Adjusted R-squared = 0.848			
S.E. of regression = 0.017				S.E. of regression = 0.022				S.E. of regression = 0.016			
F-stat. = 9.913***				F-stat. = 6.566***				*F*-stat. = 13.5016***			
DW-statistic = 2.133				DW-statistic = 2.086				DW-statistic = 2.205			
Akaike info. criterion = −4.980				Akaike info. criterion = −4.459				Akaike info. criterion = −5.171			
Schwarz Bayesian criterion = −4.127				Schwarz Bayesian criterion = −3.777				Schwarz Bayesian criterion = −4.403			

Table 7: (continued)

Model 4: $\Delta GDPpc_t$ is the dependent variable				Model 5: $\Delta GDPpc_t$ is the dependent variable			
Selected model: ARDL(4,3,4,4,4)				Selected model: ARDL(4,4,4,4,4)			
Variable	**Coefficient**	**T-ratio**	**Prob-value**	**Variable**	**Coefficient**	**T-ratio**	**Prob-value**
$\Delta GDPpc_{t-1}$	−0.510	−3.723	(0.000)	$\Delta GDPpc_{t-1}$	0.321	3.432	(0.004)
$\Delta GDPpc_{t-2}$	0.115	0.743	(0.469)	$\Delta GDPpc_{t-2}$	0.120	1.287	(0.220)
$\Delta GDPpc_{t-3}$	−0.279	−1.488	(0.159)	$\Delta GDPpc_{t-3}$	0.578	5.121	(0.000)
$\Delta INVE_t$	0.025	9.777	(0.000)	$\Delta INVE_t$	0.006	3.026	(0.009)
$\Delta INVE_{t-1}$	−0.020	−4.706	(0.000)	$\Delta INVE_{t-1}$	0.003	1.612	(0.130)
$\Delta INVE_{t-2}$	−0.010	−3.633	(0.002)	$\Delta INVE_{t-2}$	0.003	1.602	(0.133)
$\Delta INVE_{t-3}$				$\Delta INVE_{t-3}$	0.005	3.024	(0.009)
$\Delta EDUC_t$	0.001	0.222	(0.827)	$\Delta EDUC_t$	0.026	7.348	(0.000)
$\Delta EDUC_{t-1}$	0.006	1.739	(0.104)	$\Delta EDUC_{t-1}$	−0.061	−8.514	(0.000)
$\Delta EDUC_{t-2}$	−0.010	−2.498	(0.026)	$\Delta EDUC_{t-2}$	−0.044	−7.868	(0.000)
$\Delta EDUC_{t-3}$	−0.026	−4.931	(0.000)	$\Delta EDUC_{t-3}$	−0.033	−7.246	(0.000)
$\Delta POPU_t$	−0.097	−3.199	(0.006)	$\Delta POPU_t$	0.109	3.936	(0.000)
$\Delta POPU_{t-1}$	−0.006	−0.200	(0.844)	$\Delta POPU_{t-1}$	−0.098	−4.385	(0.000)
$\Delta POPU_{t-2}$	−0.053	−1.747	(0.102)	$\Delta POPU_{t-2}$	−0.009	−0.345	(0.735)
$\Delta POPU_{t-3}$	−0.171	−6.255	(0.000)	$\Delta POPU_{t-3}$	−0.074	−3.522	(0.003)
$\Delta MILIT\text{-}INFR_t^{+}$	−0.100	−4.722	(0.000)	$\Delta MILIT\text{-}OTH_t^{+}$	−0.168	−7.164	(0.000)
$\Delta MILIT\text{-}INFR_t^{-}$	−0.013	−0.985	(0.340)	$\Delta MILIT\text{-}OTH_t^{-}$	−0.004	−0.181	(0.856)
$\Delta MILIT\text{-}INFR_{t-1}^{+}$	0.025	1.450	(0.169)	$\Delta MILIT\text{-}OTH_{t-1}^{+}$	0.280	7.016	(0.000)
$\Delta MILIT\text{-}INFR_{t-1}^{-}$	0.263	7.509	(0.000)	$\Delta MILIT\text{-}OTH_{t-1}^{-}$	−0.078	−3.710	(0.000)
$\Delta MILIT\text{-}INFR_{t-2}^{+}$	0.032	2.031	(0.061)	$\Delta MILIT\text{-}OTH_{t-2}^{+}$	0.162	5.882	(0.000)
$\Delta MILIT\text{-}INFR_{t-2}^{-}$	0.150	5.262	(0.000)	$\Delta MILIT\text{-}OTH_{t-2}^{-}$	−0.066	−3.470	(0.004)
$\Delta MILIT\text{-}INFR_{t-3}^{+}$	0.020	1.430	(0.174)	$\Delta MILIT\text{-}OTH_{t-3}^{+}$	0.139	4.862	(0.000)
$\Delta MILIT\text{-}INFR_{t-3}^{-}$	0.031	1.902	(0.078)	$\Delta MILIT\text{-}OTH_{t-3}^{-}$	−0.070	−3.737	(0.002)
ECTerm	−0.290	−7.174	(0.000)	ECTerm	−1.152	−9.562	(0.000)
Intercept	1.811	7.211	(0.000)	Intercept	10.254	9.584	(0.000)
R-squared = 0.947				R-squared = 0.969			
Adjusted R-squared = 0.861				Adjusted R-squared = 0.913			
S.E. of regression = 0.015				S.E. of regression = 0.011			
F-stat. = 11.0178***				*F*-stat. = 17.241***			
DW-statistic = 2.586				DW-statistic = 2.410			
Akaike info. criterion = −4.5277				Akaike info. criterion = −5.766			
Schwarz Bayesian criterion = −4.242				Schwarz Bayesian criterion = −4.688			

coefficients for lagged variables related to changes in educational attainment and population growth suggest that increasing population and educational levels need time to influence economic growth positively.

The lagged error correction term (ECT) coefficient was negative and statistically significant at the 1 % level. In the initial model specification, the ECT coefficient of 0.678 indicated an annual resolution of approximately 67.8 % of the variation.

At a disaggregated level, the empirical findings showed that expenditure on military equipment and R&D dedicated to significant equipment were statistically significant at the 1 % level in the short term. Specifically, a 1 % increase in this segment of military spending was shown to boost output by merely 0.024 %. This trend was primarily driven by increased spending on R&D within these sectors, as well as the transfer of expertise to other areas of the economy. However, if a significant portion of government spending is allocated to imports, these dynamic effects within an economy diminish, as observed in the Greek context.

The short-term results revealed that defence spending on personnel had a positive, symmetrical, and statistically significant effect on GDP in years $t-1$ and $t-2$. In the short to medium term, a 0.249 % increase in cumulative GDP resulted from a 1 % increase in military personnel costs. Compared to other categories of military spending, our findings suggest that personnel expenditure had the most prominent impact on economic growth in Greece in the short run.

Concerning the short-term positive economic impact of defence spending on personnel in Greece, there were two links with existing literature. First, the findings indicated that continual excessive hiring, along with the defence industry's more generous compensation compared to the private sector in Greece, boosted overall demand, thereby positively impacting employment rates and economic growth. Additionally, when individuals from low-income backgrounds were more evenly distributed in the military, their standard of living improved. This evidence supports the idea that military personnel expenditure helps stabilise the economy (see Becker 2021).

Second, our finding aligned with the study by Emmanouilidis (2024), who found that military personnel expenditure exerts the greatest influence on short-term economic activity in the US economy. However, our results differed from the evidence presented by Becker and Dunne (2023), who observed that military spending on personnel negatively affects the growth rate of EU and NATO nations in the short run. This suggests that military personnel expenses may be causing crowding-out effects on investment and/or other types of social spending.

The empirical findings suggest that, at a disaggregated level, positive changes in infrastructure expenditure correlate with negative growth rates. In the short term, a 1 % increase in infrastructure spending decreased cumulative GDP by 0.069 %. Conversely, a 1 % decrease in military infrastructure led to a cumulative 0.444 %

decline in economic performance. Interestingly, adverse changes in military infrastructure appear to impact economic output significantly more than positive changes. Overall, the impact of military infrastructure appears to be beneficial in the short term, particularly in Greece.

The results indicate that a 1 % increase in operational and maintenance expenditure, R&D costs, and other expenses led to a 0.412 % increase in income in the short run. Conversely, a 1 % decrease in this category of military spending resulted in a 0.214 % increase in income. The findings indicate that variations in operational and maintenance costs had comparable economic consequences for personnel expenditure, despite differences in resource allocation in Greece during the period under analysis.

Focusing on the long-term estimations (see Table 8), it is evident that increases in military expenditure have significantly impacted the Greek economy. A mere 1 % increase in the overall allocation of financial resources towards the military sector resulted in a long-term GDP reduction of 0.633 %. Additionally, the economic significance of adverse changes in aggregate defence expenditures was statistically significant. The negative shock coefficient computed in the variable "MILIT" indicated a negative correlation with income. Specifically, a 1 % reduction in defence expenditures corresponded to a 0.130 % increase in economic growth rates.

In summary, the results suggest that increases in military spending have a more detrimental impact on economic growth than the resulting benefits of negative shocks. Thus, government officials and policymakers should carefully consider initiatives to increase military spending due to the detrimental effects of military spending on economic growth in the long run. Military spending diverts resources from other uses that could boost labour productivity and capital goods use, lowering long-term productivity and economic growth. Without progress with Türkiy to peacefully resolve Aegean Sea disputes based on international law, Greece's military spending is unlikely to decrease due to security and political concerns. The resolution of conflicts has obvious economic and security benefits, which could motivate progress.

In retrospect, the results show that increased defence spending hampers long-term economic growth. Considering Greece, these results were consistent with studies by Antonakis (1997, 1999), Dunne and Nikolaidou (2001), and Paparas, Richter, and Paparas (2016). More importantly, the conclusions aligned with recent studies, including Ahmed et al. (2020a), Ahmed, Zafar, and Mansoor (2020b) for Myanmar, Ahad and Dar (2017) for the UK and the US, Luqman and Antonakakis (2021) for Pakistan, Khalid and Habimana (2021) for Türkiye, Lanrui et al. (2022) and Rehman et al. (2023) for Pakistan, Maher and Zhao (2022) for Egypt, Hung-Pin and Tsung-Li (2022) for Taiwan, Saba (2022) for South Africa, and Emmanouilidis (2024) for the US.

Table 8: Results of the long-run estimated coefficients.

Model 1: $GDPpc_t$ is the dependent variable				Model 2: $GDPpc_t$ is the dependent variable				Model 3: $GDPpc_t$ is the dependent variable			
Variable	**Coefficient**	**T-ratio**	**Prob-value**	**Variable**	**Coefficient**	**T-ratio**	**Prob-value**	**Variable**	**Coefficient**	**T-ratio**	**Prob-value**
$INVE_t$	0.031	4.941	(0.000)	$INVE_t$	0.002	0.215	(0.831)	$INVE_t$	0.036	3.499	(0.001)
$EDUC_t$	0.080	6.356	(0.000)	$EDUC_t$	0.052	5.535	(0.000)	$EDUC_t$	0.100	4.463	(0.000)
$POPU_t$	0.291	4.596	(0.000)	$POPU_t$	0.311	2.844	(0.007)	$POPU_t$	0.360	4.603	(0.000)
$MILIT_t^+$	−0.633	−4.295	(0.000)	$MILIT\text{-}EQU_t^+$	−0.073	−2.252	(0.030)	$MILIT\text{-}PER_t^+$	−0.798	−2.844	(0.007)
$MILIT_t^-$	−0.130	−1.963	(0.057)	$MILIT\text{-}EQU_t^-$	0.055	1.137	(0.263)	$MILIT\text{-}PER_t^-$	−0.103	−0.943	(0.352)

Model 4: $GDPpc_t$ is the dependent variable				Model 5: $GDPpc_t$ is the dependent variable			
Variable	**Coefficient**	**T-ratio**	**Prob-value**	**Variable**	**Coefficient**	**T-ratio**	**Prob-value**
$INVE_t$	0.173	2.048	(0.048)	$INVE_t$	0.007	1.009	(0.320)
$EDUC_t$	−0.075	−1.139	(0.263)	$EDUC_t$	0.080	6.842	(0.000)
$POPU_t$	−0.577	−1.206	(0.236)	$POPU_t$	0.111	1.850	(0.073)
$\Delta MILIT\text{-}INFR_t^+$	−0.754	−1.799	(0.081)	$MILIT\text{-}OTH_t^+$	−0.394	−5.977	(0.000)
$\Delta MILIT\text{-}INFR_t^+$	−1.069	−1.755	(0.088)	$MILIT\text{-}OTH_t^-$	0.067	1.536	(0.134)

Diagnostics tests

	Model 1		Model 2		Model 3		Model 4		Model 5	
	***F*-statistic**	**p-value**	***F*-statistic**	**p-value**	***F*-statistic**	**p-value**	***F*-statistic**	**p-value**	***F*-statistic**	**p-value**
LM test:	0.3086	0.3852	0.1789	0.6527	0.2722	0.4820	2.1277	0.1897	3.3441	0.0924
BPG test:	0.5499	0.7560	1.4062	0.2521	0.4382	0.8763	1.5862	0.2912	0.5686	0.6475
ARCH test:	0.5731	0.4403	0.0265	0.8673	0.0644	0.7945	0.0137	0.9042	0.0586	0.8037
JB test:	1.6700	0.4338	1.9847	0.3706	3.4804	0.1754	1.5238	0.4667	0.3186	0.8527
Ramsey test:	0.0700	0.7955	0.3995	0.5358	0.3227	0.5784	4.8453	0.0589	2.9411	0.1301

Notes: The Akaike information criterion (AIK) was used to pick the ARDL specification. Parentheses denote p-values. Eviews 13 was used to conduct the estimation and cointegration tests.

Meanwhile, the long-run results on defence spending and economic growth contradicted the findings of Ahad and Dar (2017) for Russia, Laniran and Ajala (2021) for Nigeria, and Dimitraki and Win (2021) for Jordan, where long-term defence spending was associated with increased economic growth. Extensive scholarly research has established that defence spending has favourable economic and social consequences, particularly for developing economies, on the premise of robust institutional quality (see Benoit 1978; Dada et al. 2023; Dimitraki and Menla-Ali 2015).

More importantly, the results suggest that military spending has boosted Greek economic growth in the short term but hindered it in the long term. Therefore, it seems, in the short term, increased military spending, known as the Keynesian multiplier effect, can boost overall domestic demand. However, these temporary stimulating effects do not necessarily enhance capital and production capacity. Over time, increased military spending likely weakens the ability to produce goods and services through two channels.

The first channel refers to the adverse influence of military spending on public and private investment, which has been shown to result in a crowding-out effect. This effect is particularly significant for net-debt countries with limited access to external financing, where governments resort to taxation to increase public revenue. The second channel involves the direct influence of military expenditure on the effectiveness of resource allocation, which could potentially improve labour productivity and the effective utilisation of capital goods. Naturally, market forces do not often regulate military expenditure, and relative prices can be disrupted as a result (Carter, Ondercin, and Palmer 2021; Elveren and Hsu 2016; Knight, Loayza, and Villanueva 1996; Su et al. 2020).

Notwithstanding, this study's finding of the diverse impacts of defence spending on economic growth – positive in the short run but negative in the long run – was consistent with recent studies by Ahmed et al. (2020a), Ahmed, Zafar, and Mansoor (2020b) for Myanmar, Khalid and Habimana (2021) for Türkiye, Lanrui et al. (2022) for Pakistan, Dimitraki and Emmanouilidis (2023) for Spain, and Emmanouilidis (2024) for the US.

Furthermore, the findings show that domestic investment boosted economic growth at 1 % significance. Specifically, a 1 % increase in domestic investment led to a 0.031 % increase in per-capita income. The Greek government's efforts to support economic advancement and encourage investment through tax reductions and tailored incentives can potentially achieve favourable long-term growth rates. This result undoubtedly aligns with economic theory.

A series of arguments elucidate the shown marginally positive influence of domestic investment on economic growth. First, increased military spending can boost overall government spending, but may displace domestic investment. Higher taxes for military funding can crowd out private investment by reducing savings and raising domestic interest rates. Second, Greece's low domestic investment levels, averaging 20.24 % of GDP from 1980 to 2022 and dropping to 12.78 % from 2010 to 2019, contributed to limited growth. Finally, Greece has prioritised current expenditure over public investment, and has faced corruption and political instability, thereby affecting the effectiveness of public investment.

The found positive impact of domestic investment on economic growth in Greece aligned with the results of Kollias (1994, 1995), Antonakis (1997, 1999), Dunne and Nikolaidou (2012), Manamperi (2016), and Nikolaidou (2016). More importantly, the results were in line with recent similar studies, such as Azam (2020) for 35 non-members of the Organisation for Economic Co-operation and Development (OECD) countries, Mohanty, Panda, and Bhuyan (2020) for India, Laniran and Ajala (2021) for Nigeria, Desli and Gkoulgkoutsika (2021) for 99 countries, Khalid and Habimana (2021) for Türkiye, Emmanouilidis and Karpetis (2022) for 150 countries worldwide, Lanrui et al. (2022) for Pakistan, Dada et al. (2023) for 31 African nations, and Dimitraki and Emmanouilidis (2023) for Spain.

Regarding the long-term impact of demographic variables, the results indicated that higher education levels and population growth have significantly contributed to economic expansion. Our research showed that a rise in population and higher education attendance led to growth in per-capita income of 0.080 % and 0.291 %, respectively. This evidence confirmed that the more individuals in Greece that are educated, the greater the opportunities to contribute to economic advancement. These findings were consistent with studies by Antonakis (1997, 1999), Manamperi (2016), and Tsitouras et al. (2020) on Greece; Tsitouras et al. (2017) on transitioning European economies; and Dimitraki and Emmanouilidis (2023) on Spain.

However, the population of Greece decreased from 11.1 million in 2010 to 10.43 million in 2022, with a projected decline to 6.4 million by 2099. Therefore, policies that increase fertility and reduce skilled emigration are essential. Sharma (2016) stated that a country's economically active population must grow by 2 % annually to achieve sustainable long-term economic growth; if not, maintaining economic growth becomes challenging. Thus, increasing fertility and reducing the outflow of human capital "brain drain" are crucial for Greek economic growth (Sobotka, Matysiak, and Brzozowska 2019).

The military spending decomposition analysis revealed that all positive changes in military spending categories were statistically significant and linked to economic output. However, only negative changes in military infrastructure were shown to significantly impact economic growth. The long-term coefficients were significantly higher than the short-term estimates, indicating that the variables have a more substantial impact on economic growth in the long term.

Regarding the long-run effect of military equipment spending on economic growth, the results indicated that increased expenditure has a detrimental effect on economic output. For example, a 1 % increase in military equipment expenditure was shown to reduce economic output by 0.073 %. While promoting the domestic military industry can enhance productivity by transferring innovative technologies to the civilian sector (Goel, Payne, and Ram 2008), there may be limitations to this potential boost to economic growth.

In fact, Mowery (2010) argued that the distinct demands of the defence industry can hinder technology transfer to the civilian sector, and, as technology advances, the growing disparity between civilian and military needs may reduce the benefits of spin-offs. Crucially, an economy like that of Greece further limits the dynamic impacts by allocating a significant portion of military spending to imports.

Our study's findings contradicted Becker and Dunne's (2023) results, which suggested that military spending on equipment enhances economic growth in EU and NATO countries. Their study included a sample of many countries with robust domestic military industries, highlighting a different perspective on the relationship between military spending and economic growth compared to the findings discussed in this paper. Interestingly, for the case of the US, Emmanouilidis (2024) discovered that reducing procurement programs can boost total output.

Regarding the long-run effect of military spending on economic growth, the results indicated that positive changes in the military personnel budget negatively impacted long-term economic output. Specifically, our analysis showed that a 1 % increase in this budget correlated with a 0.798 % decrease in GDP over the long term. In contrast, negative adjustments in the military personnel budget were associated with increased economic output, but this relationship was statistically insignificant.

Overall, our study revealed that personnel expenditure has had the most significant and detrimental impact on Greece's economic development compared to other military spending categories. The following two facts appear to support this conclusion: (1) From 1980 to 2022, Greece allocated approximately 66 % of its military budget to military personnel, while the average for other NATO countries was 55 % (World Bank 2023); (2) Greece's armed forces constitute around 3.59 % of the total labour force, compared to 1.43 % for other NATO countries, suggesting higher workforce opportunity costs associated with military spending (World Bank 2023). These facts suggest that the significant allocation of military spending to personnel exacerbates the long-term detrimental impact on the Greek economy. This strategy, often driven by political motives, has led to more of a burden on the economy, with increased social and health provisions for military personnel compared to the general population.

The study's results concerning how personnel spending hurts economies were similar to those of Emmanouilidis (2024) for the US economy, Becker and Dunne (2023) for a group of EU and NATO countries, and Olejnik (2023) for nine Central and

Eastern European countries. These studies found that, compared to other types of military spending, expenditure on personnel has the greatest impact.

Positive changes in military spending on infrastructure have been shown to hinder economic growth, while negative changes benefit economic expansion. A 1 % positive shock can hamper economic growth by 0.754 %, whereas a 1 % negative shock can promote it by 1.069 %. Greece's military budget has traditionally allocated a small share to infrastructure, mainly focusing on non-civilian programs.

In the past, initiatives such as the Mixed Reconstruction Machinery Teams aimed to rebuild Greece's infrastructure after World War II and the Greek Civil War. Despite the 1992 discontinuation of the Mixed Reconstruction Machinery Teams and the 2015 replacement with the Research and Construction Unit, military involvement in Greece's infrastructure is crucial, especially given climate change and natural disasters. This evolving social role may mitigate the detrimental long-term effects of military spending on economic growth.

In the fourth military budget category, rising military operating costs may hurt economic growth. According to the results, increasing military operating costs by 1 % reduced economic growth by 0.394 %. This result was in accordance with the findings of Emmanouilidis (2024) for the US economy and Becker and Dunne (2023) for a panel of EU and NATO countries. Within the Greek military budget, the allocation of this type of military expenditure decreased from 25 % in 1980 to 11 % in 2022. However, this type of military spending can hold economic benefits, such as enhancing human capital and benefiting the job market (Gonzalez and Simpson 2021; Heo 2010).

The diagnostic tests confirmed the validity of the NARDL models. However, there may be gaps in the time series data due to shifts in the Greek economy. This study aimed to validate the Cumulative Sum (CUSUM) and Cumulative Sum of Square (CUSUMSQ) tests for short- and long-run elasticities, with the results showing statistical significance at the 5 % level, with constant predicted coefficients (Figure 3a–e).

7.5 Dynamic Multipliers

Classical regression analysis aims to estimate a regressor's causal influence on the dependent variable while holding other variables constant (ceteris paribus). This estimation corresponds to the partial derivative of the dependent variable with respect to the regressor. Within a conventional regression framework, NARDL models integrate dynamic features that influence the current state of the dependent variable through its lagged values and distributed lag regressors. These models are ideal for analysing dynamic causal effects, or multipliers, which examine causal effects over time.

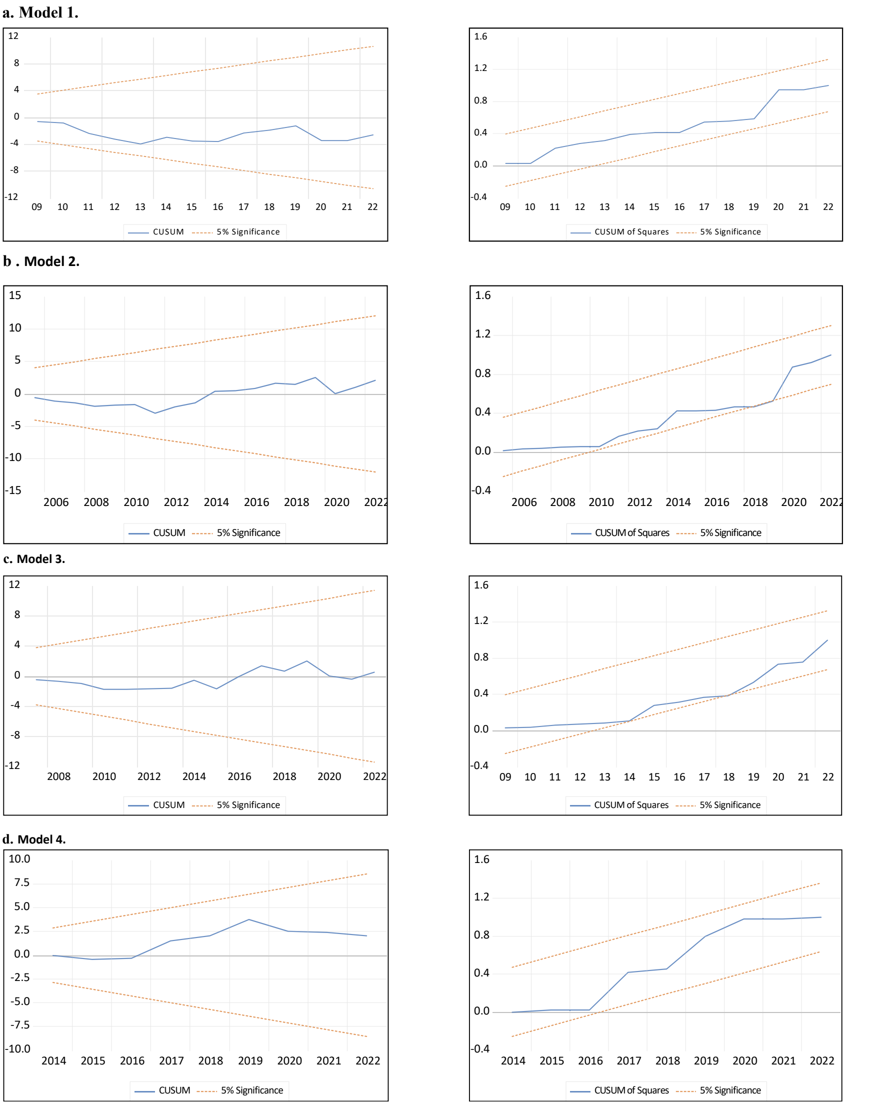

Figure 3a–e: The plot of cumulative sum and sum of squares of recursive residuals.

Figure 4a–h illustrate the response curves of explanatory variables, providing further insight into each variable's contribution to Greece's GDP evolution. Each plot and response curve illustrates the long-term equilibrium values towards which the variables converge. The dashed lines in Figure 4a–h represent the long-term coefficient values from Table 8.

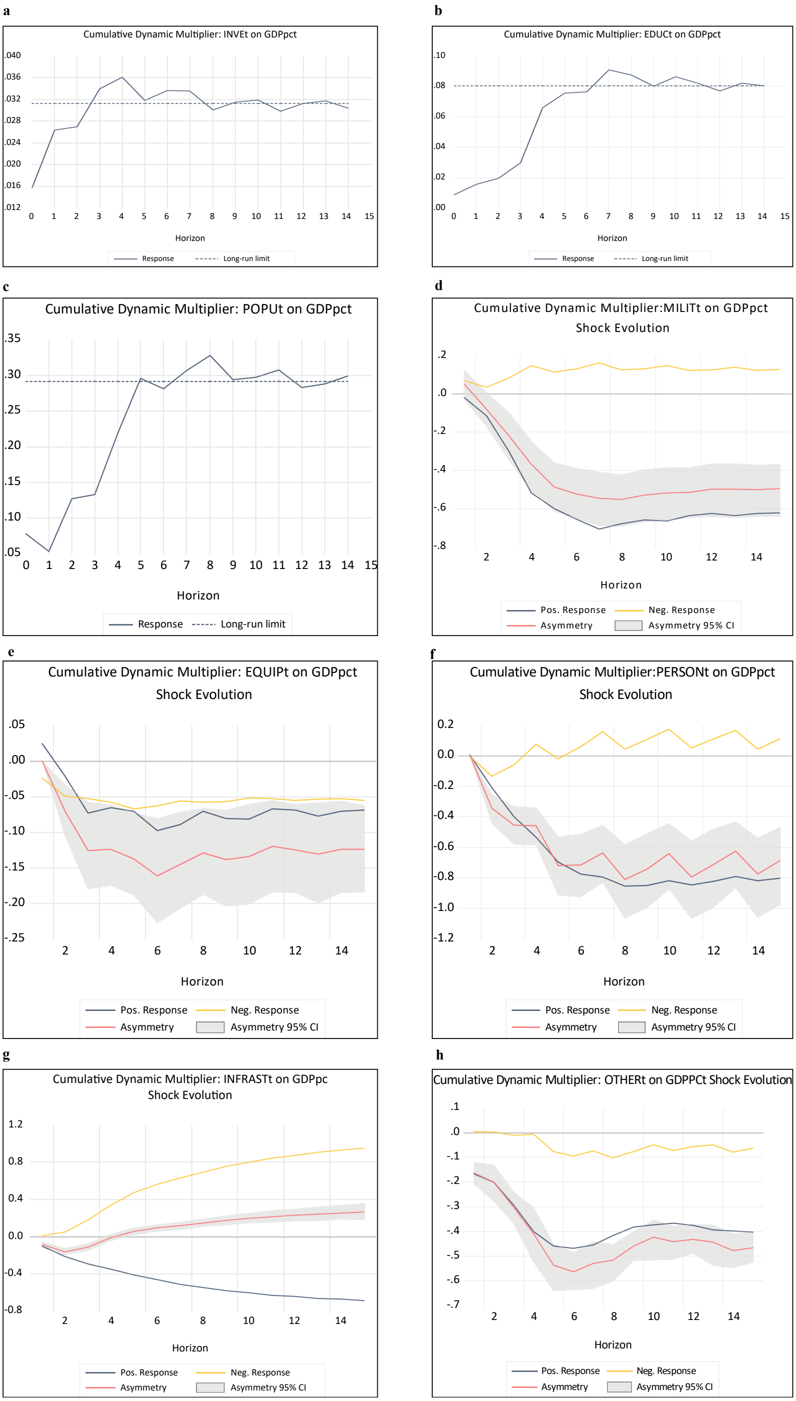

Figure 4a–h: Plot of dynamic multipliers.

Figure 4a shows a 1 % increase in domestic investment results in a steady GDP-per-capita rise of 0.032 % over five years, with a gradual increase in the first three years. Figure 4b reveals that a 1 % positive shock to educational attainment boosted GDP by 0.08 % over seven years, with a notable initial increase in the first six years. Figure 4c indicates that a 1 % positive shock to population growth resulted in a 0.30 % increase in GDP per capita over five years, with significant short- to medium-term gains within the initial four years.

On a disaggregated level, Figure 4e shows that a 1 % increase in military equipment spending reduced GDP per capita by 0.073 % over four years, with a notable positive-to-negative reversal effect in the first three years. Interestingly, a 1 % decrease in equipment spending also reduced GDP per capita by 0.055 % in approximately two years.

Figure 4f shows that a 1 % increase in military personnel spending reduced GDP per capita by 0.798 % over eight years, with a progressively worsening impact from years one to seven. Conversely, a 1 % decrease in personnel spending boosted GDP per capita by 0.130 % over seven years, with a significant negative-to-positive reversal effect within the first four years.

Figure 4g shows that a 1 % increase in military infrastructure spending reduced GDP per capita by 0.754 % over 10 years, with a progressively worsening impact from years one to seven. Conversely, a 1 % decrease in infrastructure spending boosted GDP per capita by 0.800 % over 10 years, with a progressively increasing positive impact during the same period.

Finally, Figure 4h shows that a 1 % increase in military operations and maintenance spending reduced GDP per capita by 0.394 % over four years. Interestingly, a 1 % decrease in equipment spending also reduced GDP per capita by 0.067 % over six years, with a relatively neutral short-term boost in the first five years.

8 Conclusions

This study investigated how the compositional and asymmetric effects of military funds affect economic growth in Greece, addressing regional security challenges, sustainable growth rates, and the academic debate on defence expenditure and economic growth. The study focused on nonlinear methods that considered both short- and long-term impacts, testing them within a growth model framework akin to Barro's (1990) research.

Greece is an exemplary case study, as military spending has consistently exceeded 2 % of the GDP for four decades – a fact that has practical implications for other EU and NATO members. Amidst escalating geopolitical challenges, many countries have been considering increased military budgets. Thus, this study's findings offer important policy insights into optimising defence funding allocation to support sustainable economic growth.

Additionally, the current study has theoretical implications, particularly in three key findings related to its main hypotheses: First, military spending has boosted Greek economic growth in the short term but hindered it in the long run. Second, the long-term effects of positive and negative defence spending shocks are distinct, with positive shocks being more detrimental to economic growth than the benefits of negative shocks. Finally, our study revealed that personnel expenditures have the most significant and enduring effects on economic growth compared to other military spending categories.

Our study yields significant policy implications for the allocation of defence funds and resources to ultimately foster sustainable economic growth. First, governments and policymakers should recognise that excessive military spending hinders sustainable economic growth in developed economies. Thus, it is essential to allocate only the funds necessary for national security.

Second, policies should redirect military funds to critical areas such as education, capital investment, healthcare, and infrastructure. This strategy can boost economic growth, enhance social well-being, reduce poverty, and decrease income and social disparities. However, the potential GDP increase resulting from the reallocation of military funds depends on the prioritisation of productive civilian activities.

Third, positive shocks in military spending have been shown to have a more negative impact on economic growth than the resulting benefits of negative shocks. Thus, governments should be cautious about increasing military spending because the result is the removal of resources from areas that could improve workforce productivity and the use of capital goods, which ultimately hinders long-term productivity and economic growth. Recognising the economic and security advantages of resolving conflicts can encourage the improvement of relations between disputing neighbouring countries.

Fourth, at a disaggregated level, the empirical findings have shown that expenditure on military equipment and R&D dedicated to significant equipment have a relatively weak economic impact on short- (positive) and long-term (negative) economic growth. Greece has spent a significant amount on importing military equipment, which contributes to a large portion of its military spending. Therefore, Greece should focus on producing domestic weaponry and technology instead of relying on costly foreign options.

Fifth, personnel expenditure in the military has a major and lasting impact on Greece's economic growth. While military spending has been found to initially boost domestic demand and growth, it does not lead to long-term increases in capital and production capacity. Political motives drive significant personnel spending, which worsens the negative impact and increases the economic burden. Reducing military personnel could worsen poverty among low-skilled workers and increase youth unemployment. Cutting labour-intensive military programs may affect short-term economic growth and raise concerns about political stability in countries like Greece with substantial military resources.

Sixth, to address the outlined concerns and reduce inevitable opportunity costs, Greece could adopt a defence doctrine similar to those of Nordic countries, which rely more on personnel reserves. These systems recruit men aged 18 to 60 and allow women to volunteer for military service. Finland's defence system, for example, matches conscripts with tasks that suit their abilities and provides valuable skills for post-service life. To stimulate economic growth, Greece could also strengthen the connection between the military and civilian sectors. In fact, utilising armed forces personnel for public goods and services, particularly in civil protection, can reduce costs and promote sustainable economic growth while simultaneously enhancing military readiness.

Seventh, positive changes in military infrastructure spending have been demonstrated to impede economic growth, whereas negative changes accelerate it. Thus, the military must focus more on public infrastructure to address climate change and natural disasters. This role may mitigate the long-term effects of military spending. To improve military-civilian relations and reduce opportunity costs, military infrastructure, such as hospitals, could be more accessible to civilians, particularly at borders.

Finally, the findings suggest that increasing operations and maintenance expenditure poses a significant long-term economic challenge. Greece could adopt a defence doctrine similar to that of Nordic countries, where substantial reserves are maintained. This would increase military budget allocations by 13 %, towards the NATO average of 25 %. The new spending structure would reduce inelastic costs such as salaries and pensions, redirecting funds to areas that enhance human capital and benefit the job market post-military service. Greece should strengthen military and civilian sector connections so that defence spending promotes economic growth.

In conclusion, the key message of this empirical investigation is that even developed countries must accept future uncertainties and the evolving costs of modern weapons. Technological advancements have changed battle tactics, making information and technology more accessible and affordable. Nations that are complacent in their superiority may find themselves unprepared for defence and security challenges. Therefore, governments should prioritise state intelligence and production technology to effectively balance three critical objectives: national defence and security, economic growth and development, and political longevity.

This study provides a verified framework for examining the relationship between Greece's military spending and economic growth. Future studies should concentrate on applying prolonged time series and integrating additional critical variables that reflect a nation's economic development and prosperity, such as the Human Development Index. Comparing such results with those of neighbouring countries or groups of countries in Europe or other regions could further enhance the empirical literature.

Appendix

Table A1: Recent empirical studies on military spending and economic growth

Study	Sample	Time span	Methodology	Variables	Results
Ahad and Dar (2017).	The USA, the UK and Russia	1992–2014 (quarterly data)	NARDL	GDP, military spending	DEF^+ → (–) growth (long-run) DEF^- → (+) growth (long-run), for the USA and the UK, DEF^+ → (+) growth (long-run) DEF^- → (–) growth (long-run), for Russia
Dunne and Smith (2020).	46 countries	1960–2014	Panel OLS, fixed effects, panel ARDL	GDP, military spending, investment	DEF → (≠) growth
Ahmed, Zafar, and Mansoor (2020b).	Pakistan	1971–2016	ARDL	GDP per capita, energy consumption, military expenditure, ecological footprint	DEF → (≠) growth (short-run) DEF → (–) growth (long-run)
Ahmed et al. (2020a).	Myanmar	1975–2014	ARDL	GDP per capita, military spending, energy consumption, CO2 emissions and exports	DEF → (+) growth (short-run) DEF → (–) growth (long-run)
Azam (2020).	35 non-OECD countries	1988–2019	Panel ARDL	The growth rate of GDP per capita, military expenditure, worker remittances, GDP per capita, gross	DEF → (≠) growth (short-run) DEF → (–) growth (long-run)

(continued)

Study	Sample	Time span	Methodology	Variables	Results
				capital formation, and total life expectancy at birth (years)	
Dimitraki and Win. (2021).	Jordan	1970–2015	ARDL	Annual rate of the GDP per capita, military expenditure, non defense government expenditure, government investment, total population.	DEF → (+) growth (short-run) DEF → (+) growth (long-run)
d'Agostino et al. (2020).	A panel of countries	1984–2014	Panel ARDL	GDP per capita, private investment, employment, International Country Risk Guide (ICRG)	DEF → (−) growth (long-run)
Mohanty, Panda, and Bhuyan (2020).	India	1970–2016	ARDL	Per capita GDP, gross domestic capital formation, the labor force participation rate, per capita defence expenditure, per capita revenue defence expenditure and per capita capital defence expenditure, trade openess	DEF → (+) growth (short-run) DEF → (+) growth (long-run)
Su et al (2020).	China	1952–2014	Time-varying rolling window approach	GDP, defense expenditure	DEF → (−) growth, and DEF → (+) growth, in different periods
Aijaz Syed (2021).	India, China and Pakistan	1990–2018	NARDL	Economic growth, military spending, inflation, and industrial productivity	DEF^{+} → (+) growth (short-run) DEF^{-} → (≠) growth (short-run), for India and China, DEF^{-} → (−) Growth

(continued)

Study	Sample	Time span	Methodology	Variables	Results
					(short-run), for Pakistan, DEF^{+} → (+) growth (long-run) DEF^{-} → (−) growth (long-run), for India and China
Laniran and Ajala (2021).	Nigeria	1981–2017	ARDL	Growth rate of GDP, military spending, government spending, gross fixed capital formation, school enrolment	DEF → (−) growth (short-run) DEF → (+) growth (long-run)
Desli and Gkoulgkoutsika (2021).	70 to 99 countries	1960–2017 to 1995–2017	Dynamic common correlated effects (DCCE)	GDP per capita, military spending, government spending net of military spending, investment, trade openness	DEF → (−) growth
Emmanouilidis and Karpetis (2021).	Turkey	1987–2019	VECM, OLS, DOLS, FMOLS	Real GDP, inflation, military spending, general government final consumption expenditure, the difference between the general government's final consumption expenditure and military spending, money supply	DEF → (+) growth (short-run) DEF → (+) growth (long-run)
Khalid and Habimana (2021).	Turkey	1961–2014	Wavelet analysis with regression	Per capita GDP growth, military spending, private investment, and government spending	DEF → (+) growth (short-run) DEF → (−) growth (long-run)
	Pakistan	1965–2015	QARDL	GDP per capita growth rate,	DEF → (≠) growth (short-

(continued)

Study	Sample	Time span	Methodology	Variables	Results
Luqman and Antonakakis (2021).				military expenditures, urban population, depth of food deficit, schooling, life expectancy and GINI per capita (PPP %)	run) DEF → (−) growth (long-run)
Ullah et al. (2021).	Pakistan and India	1985–2018	NARDL	Economic growth, carbon emission, military expenditures, health expenditures, education expenditures, and energy consumption	DEF^{+} → (−) growth (short-run) DEF^{-} → (+) growth (short-run) DEF^{+} → (+) growth (long-run) DEF^{-} → (+) growth (long-run), for Pakistan DEF+ → (−) growth (short-run) DEF− → (≠) growth (long-run) DEF+ → (≠) growth (long-run) DEF− → (≠) growth (long-run), for India
Kollias and Tzeremes (2022).	116 countries	1995–2019	Panel data analysis	GDP, military spending, investment	DEF → (≠) growth
Emmanouilidis and Karpetis (2022).	150 countries	1960–2019	Dynamic common correlated effects (DCCE)	Per−capita GDP, military spending, investment, population	DEF → (−) growth (long-run)
Hung-Pin and Tsung-Li (2022).	Taiwan	1991–2020	ARDL	GDP, public spending, social welfare expenditure, military expenditure	DEF → (−) growth (long-run)
Lanrui et al. (2022).	Pakistan	1972–2018	NARDL	Real GDP, military expenditure, gross capital formation, population	DEF^{-} → (−) growth (short-run) DEF^{+} → (+) growth (short-run) DEF^{-} → (+) growth (long-

(continued)

Study	Sample	Time span	Methodology	Variables	Results
					run) DEF^{+} →(≠) growth (long-run)
Maher and Zhao (2022).	Egypt	1982–2018	ARDL, FMOLS	GDP growth rate, military expenditure, political instability index	DEF → (–) growth (short-run), DEF → (≠) growth (long-run)
Saba (2022).	South Africa	1960–2018	ARDL-Granger causality test based on VECM	Real GDP and defence spending	DEF → (–) growth (short-run) DEF → (–) growth (long-run)
Becker and Dunne (2023).	34 countries	1970–2019	Panel ARDL, GMM, panel OLS, fixed effects	GDP annual growth, gross fixed capital formation, military burden, population, and four categories of military spending	DEF → (–) growth (short-run) DEF → (–) growth (long-run)
Olejnik (2023).	9 Central and Eastern European countries	1999–2021	Impulse response functions	GDP, three categories of military spending: a) personnel, b) equipment and infrastructure, and d) other expenditures. Personnel	DEF on personnel → growth (short-run)
Dada et al. (2023).	31 African nations	1972–1991	Panel OLS, system GMM, and Driscoll and Kraay non-parametric standard error	Per capita income, military expenditure, institutional quality index, trade openness, gross capital formation, population	DEF → (–) growth (long-run)
Dimitraki and Emmanouilidis (2023).	Spain	1954–2021	DARDL	Real GDP, military and non military expenditure, trade openness, population growth, gross capital formation	DEF →) (+) growth (1954–2021, short-run) DEF →) (+) growth (1954–2021,

(continued)

Study	Sample	Time span	Methodology	Variables	Results
					long-run) DEF → (−) growth (1975–2021, long-run)
Rehman et al. (2023).	Pakistan	1972–2019	NARDL	GDP growth, military expenditure, final consumption expenditure, gross national expenditure, net income, broad money, and total reserves	DEF^+ → (−) growth (short-run) DEF^- → (−) growth (short-run) DEF^+ → (≠) growth (long-run) DEF^- → (+) growth (long-run)
Emmanouilidis (2024).	US	1949–2021	ARDL & NARDL	GDP, government investment, non defence government consumption expenditures, population growth, military spending and four categories of military spending	DEF → (+) growth (short-run) DEF → (−) growth (long-run) DEF^+ → (≠) growth (long-run) DEF^- → (+) growth (long-run)

Table A2: Empirical studies on military spending and economic growth in Greece

Study	Sample	Time Span	Methodology	Variables	Results
Kollias (1994)	Greece	1963–1990	Time series, Engle–Granger analysis	GDP, GDP per capita, military spending, investment, population	DEF → (+) growth (short-run) DEF → (+) growth (long-run)
Kollias (1995)	Greece	1963–1991	Engle–Granger analysis	GDP, GDP per capita, military spending, investment, population	DEF → (+) growth (short-run) DEF → (+)

(continued)

Study	Sample	Time Span	Methodology	Variables	Results
					growth (long-run)
Chletsos and Kollias (1995)	Greece	1974–1990	Time series analysis with OLS	GDP, total investment, military spending, indirect taxes, deficit	DEF → (+) growth
Balfoussias and Stavrinos (1996)	Greece	1960–1992	Ordinary least square, three stage least square	GDP, military spending, investment, population	DEF → (+) growth
Antonakis (1997)	Greece	1960–1990	Ordinary least square	GDP, GDP per capita, military spending, investment, population	DEF → (–) growth
Antonakis (1999)	Greece	1960–1993	Time series, Engle–Granger analysis	GDP growth, GDP per capita, military spending, non-military spending, investment, population	DEF → (–) growth
Kollias and Makrydakis (2000)	Greece	1955–1993	Granger causality with VAR	GDP, military spending,	DEF → (≠) growth
Dunne and Nikolaidou (2001)	Greece	1960–1996	Time series analysis with OLS, 2SLS, 3SLS	GDP growth, GDP per capita, military spending, labour, current account balance	DEF → (–) growth
Dunne, Nikolaidou, and Vougas (2001)	Greece, Turkey	1960–1996	Time series analysis, Granger causality with VAR	GDP, military spending,	DEF → (≠) growth
Dritsakis (2004)	Greece, Turkey	1960–2001	Time series analysis, Granger causality with VAR	GDP, military spending,	DEF → (≠) growth
Dunne and Nikolaidou (2005)	Greece, Spain, Portugal	1960–2002	Time series analysis, Granger causality with VAR	GDP, military spending,	DEF → (≠) growth
Mylonidis (2008)	European Union of 15	1960–2000	Panel OLS with fixed effects	GDP per capita, military spending, investment, population	DEF → (–) growth

(continued)

Study	Sample	Time Span	Methodology	Variables	Results
Dunne and Nikolaidou (2012)	European Union of 15	1961–2007	Panel method with fixed & random effects	GDP per capita, military spending, investment, labour force	DEF → (−) growth
Georgantopoulos (2012)	Albania, Bulgaria, Greece, Romania	1988–2009	Time series analysis, Granger causality with VAR	GDP, military spending,	DEF → (≠) growth
Malizard (2016)	European Union of 15	1960–2011	Panel ARDL	GDP per capita growth, military spending, non-military spending, investment, population, schooling	DEF → (−) growth
Manamperi (2016)	Greece, Turkey	1970–2013	Time series analysis, ARDL	GDP per capita, military spending education, investment, population	DEF → (≠) growth (short-run) DEF→ (≠) growth (long-run)
Nikolaidou (2016)	Greece, Portugal, Spain	1960–2014	Time series analysis with OLS	GDP per capita, military spending, investment, labour force	DEF → (≠) growth
Paparas, Richer, and Paparas (2016)	Greece, Turkey	1957–2013	Time series analysis, Engle–Granger analysis	GDP, military spending,	DEF → (−) growth

Notes: DEF indicates defence spending, growth indicates economic growth, (−) growth indicates a negative effect of defence spending on economic growth, (+) growth indicates a positive effect of defence spending on economic growth, The symbol ≠ indicates an unclear relationship between defence spending and economic growth.

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