The Effects of Expenditures in Different Military Sectors on Economic Growth

A quantitative analysis of NATO countries between 1990 and 2019

Bachelor Thesis in Political Science

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Abstract

There is a large literature on the relationship between military spending and economic growth, but there is no general consensus of what the effects might be. The findings are often inconclusive due to the ambiguous effects of supply mechanisms where both positive and negative externalities may arise. However, no previous studies have disaggregated military expenditures into different sectors which may contribute to the ambiguity of the literature. This study therefore investigates the relationship between expenditures in different military sectors and economic growth in NATO countries, in order to fill the research gap of existing literature. Using the theoretical framework of the augmented Solow model, this study argues that military spending in different sectors may have various effects on how effective workers are to produce output. Using country specific and time specific fixed effects models with robust standard errors, this study examines the growth effects of military spending in different military sectors in an unbalanced panel data set of 29 countries between 1990 and 2019. The results suggest that expenditures in the military personnel sector may lead to increased economic growth one year after the initial expenditure, while expenditures in the equipment sector and "other" sector have no effect on economic growth. The results may provide important policy implications for politicians when budget allocation decisions are made.

Keywords: military expenditures, economic growth, augmented Solow model, NATO

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Introduction

What can be expected when governments decide to increase defense budgets? In December 2020, the Swedish parliament reached the conclusion to increase the annual defense budget by 85 % from 2015 to 2025, the largest increase of military budgets in Sweden in 70 years (Government Offices of Sweden, 2021). Peter Hultqvist, the Swedish minister for defence, suggests increased volatility of the political landscape in Europe, much due to Russia's activities, is the reason behind the decision (Ibid). However, the decision could also have impacts on other aspects of society. For example, what will happen with a country's economy with increased military spending?

Economic issues are one of the top concerns for American voters (Hiller, 2018). The economy is not only a pre-electoral public concern in USA. Pre-election campaigns in most western societies circle around how the government spend resources, in order to gain electoral votes. Lowering taxes, more spending on health care and education, and military budgets are often high on the political agenda. However, the effects of increased military spending on economic growth are often overlooked as the two issues seem unrelated to the general public which may not be the case.

The impact of increased military spending on economic development have been debated by researchers for decades. Some researchers, such as Hiller (2018), suggest that increased military spending leads to slower economic growth and that it is detrimental for wealthier countries. They point to the negative externalities an increase in military spending may have on investment possibilities, the availability of factors for production and the trade-off between military spending and other government funded policy areas, such as health care and education. On the other hand, some researchers, such as Heo (1998), argues that countries like Sweden, Switzerland and Ireland could benefit from more military spending. They point to the benefits of increased military spending on research and development of technology as well as increased security on markets, which could lead to more investment incentives.

The empirical evidence from previous studies is ambiguous. However, all previous studies on military spending's effect on economic growth have treated military expenditures as one budget. It can be argued that the mechanisms that drive economic effects from military spending derive from various sectors within the military. Hence, military spending in different sectors may have separate effects on the economy. An increase in total military expenditures does not necessarily mean that more personnel is being used. Neither is it certain that research and development increases with more military spending. In other words, previous studies have not disaggregated total military spending, which may contribute to the ambiguity of existing evidence. An important question arises: Do expenditures in various military sectors have different effects on economic growth? Using a quantitative approach, this thesis tries to examine the possible effects of military spending in different military sectors and the impact on economic growth, in order to fill the research gap in existing literature.

Previous literature suggests military expenditures affect the economy through three main channels: demand, supply and security. The demand channel points to the negative effects military spending may have on investment possibilities and thus economic growth (Heo, 1998). The supply channel refers to the negative externalities of a possible trade-off between increased military spending and decreased budgets for non-military sectors as well as the availability of factors for production. Also, the supply channel suggests possible positive externalities through technological spill overs (Yakovlev 2007). The security channel refers to increased investment incentives that market security may generate (Dunne, Smith & Willenbockel, 2005).

The ambiguity of the effects through the supply channel suggest further research is necessary. The mechanisms that drive economic growth through the supply channel will therefore be implemented in the theoretical framework of the augmented Solow model. The key assumption of the augmented Solow model used in the defense economics literature is that military spendings affect technology and human capital, mechanisms that relates to the supply channel, which in turn determines economic growth. This paper further expands on previous literature, suggesting that expenditures in different military sectors may have various effects on technology and human capital, as separate military sectors affect different mechanisms in the supply channel.

The theoretical derivation of the augmented Solow model will serve as the basis for the empirical analysis. The research design will discuss how the empirical analysis is set up in order to examine the effects of military spending in different sectors on economic growth. NATO countries will serve as the sample for this analysis due to the availability of data on expenditures in different military sectors. NATO disaggregate military expenditures into three sectors which will be analyzed separately: The equipment sector, personnel sector and "other" sector. Furthermore, potential problems with data and the methodological approach will be discussed as some econometric issues complicates the premises of unbiased estimates.

The results from the empirical analysis suggest significant positive estimates of expenditures in the military personnel sector one year after the initial expenditure, but no significant estimates for expenditures in the equipment sector or the “other” sector are found when control variables are added to the models. The results therefore suggest that increased expenditures in the military personnel sector may increase economic growth one year after the initial expenditure.

The benefits of disaggregating military expenditures into different sectors and the separate effects on economic growth will provide politicians with important implications on how their decision to either increase or decrease military budgets will affect the economy. Government institutions have budget constraints and have to decide where funds best serve the public. Furthermore, politicians can use this study to increase their knowledge of how military expenditures in different sectors affect the economy and justify military budget decisions.

Literature Review

The purpose of this study is to examine the effects of military spending in different military sectors on economic growth, which may contribute to important implications for policy makers. The effects of total defense spending on economic growth differ across countries. Heo (1998) suggests that an increase in military spending would impede economic growth for 63% of countries, as they show negative elasticities. In other words, economic growth tends to decrease with more military expenditures and increase with less military expenditures for 63% of countries. Furthermore, Heo (1998) suggests a positive elasticity for 30% countries, which implies that 30% of countries would benefit from more military spending. The remaining 7% show inelastic indications, meaning that a change in military spending would not affect economic growth.

Previous literature suggest three main channels in which defense spending may influence economic growth; demand, supply and security. First, the demand channel refers to the level of defense burden and the budget induced trade-off between defense spending and investment.

Investments are important for countries' productivity, which is a key factor of economic growth (Heo, 1998). Demand mechanisms suggests that an increase in military expenditures reduces investment possibilities and lead us to expect a negative effect on economic growth. For example, military spending is a government expenditure, and an increment has to be financed. The government can do so by increasing private income taxes, printing new money, or through budget deficits. If the government increase taxes, individuals have less money to save and corporations less money to invest. If the government borrows money to cover budget deficits, interest rates will increase which leads to increased competition for money and thus private and public investments will reduce. Printing new money is a classic inflationary condition, which leads to a reduction in willingness to invest and save, as there is less real value of money available (Ibid). These three situations all affect investment possibilities negatively and an increase in military expenditures may therefore hamper economic growth. That means that politicians have to weigh the benefits of increased military spending against the drawbacks of reduced investment possibilities. Studies have also shown that, in a time of crisis, people tend to vote for parties with the competence of handling economic issues which may influence how governments chose to finance increased military budgets, depending on party association (Bélanger & Nadeau, 2014).

Second, the supply channel refers to the trade-off between an increase in military budget and a decrease in budgets for nonmilitary sectors. According to Heo (1998), increasing military budgets are often in expense for development programs. Development programs tend to benefit economic growth and therefore a decrease in development programs tend to reduce economic growth. Furthermore, Dunne et al. (2005) elaborate on this by describing supply effects in terms of the availability of technology and factors for production, such as labor, human capital and natural resources, which together determines the potential output. For example, an increase in military spending caused by more military personnel may lead to less skilled workers available for production in non-military sectors which may hamper economic growth (Yakovlev, 2007). Dunne et al. (2005) further argues that military resources are not available for citizens, although some research and development (further referred to as R&D) may have commercial spin-offs. For example, radar systems and the internet are products of military R&D which have been made available for the private sector and have had huge impacts on productivity (Moretti, Steinwender & Van Reenen, 2019). Also, Moretti et al., (2019) presents a systematic cross-country analysis of all OECD countries which suggest that a 10 % increase in military R&D results in a 4% increase in private R&D. In other words, an increase in military R&D

expenditures may increase private R&D which in turn may improve productivity through better technology, and thus benefit economic growth. The effects of military expenditures on economic growth through the supply channel are ambiguous where both negative and positive externalities can emerge.

Third, the security channel refers to securing property from domestic and foreign threats, which is essential for market operationalization and investment incentives (Dunne et al., 2005). Aizenman and Glick (2003) finds that military expenditures used to counter external threats should increase economic growth while military expenditures used for rent seeking i.e., manipulating public policies for personal gain, or corruption purposes should decrease economic growth. Lin and Lee (2011) further analyze the effects of military spending and external military threats on economic growth and concludes that a country's optimal defense burden depends on its risk preferences.

In summary, previous literature suggest that an increase in total military expenditures may have negative effects on economic growth through the demand channel. An increase in military expenditures, ceteris paribus, has to be financed and the methods for financing increased military expenditures tend to have a negative effect on investment willingness. Thus, demand mechanisms suggest negative effects on economic growth from increased military expenditures. The literature on the effects of military expenditures on economic growth through the supply channel is ambiguous. If increased military budgets are financed by reducing budgets of non-military sectors, development programs may be negatively affected and may therefore result in slower economic growth. Also, skilled workers available for the private production sector may decrease with more military personnel which may have negative effects on productivity. On the other hand, military R&D may have commercial spin offs which may lead to positive technological externalities which could increase productivity. These are all mechanisms that derive from expenditures of different military sectors which may contribute to the ambiguity of earlier studies. Furthermore, the literature on the security channel suggests that an increase in military expenditures used to establish security and to counter external threats may have positive effects on economic growth.

There is an extensive literature on military spending as one expenditure and its effect on output. However, no study has disaggregated military spending and analyzed the effects of input levels to different military sectors on economic growth. As there are no explicit consensus in the defense economics literature of total military spending and the effects on economic growth, it is necessary to further expand the literature by analyzing the effects of expenditures in different military sectors on economic growth. The uncertainty is most likely due to the ambiguous effects of the supply mechanisms discussed above, thus it makes sense to analyze the impact of each sector through the supply channel. For example, an increase in military personnel expenditures may lead to less skilled workers available for production purposes which in turn may hamper economic growth. On the other hand, military R&D expenditures may lead to technological advancements which increases productivity. In other words, supply mechanisms may be affected differently depending on which military sector funds are allocated to. Disaggregating military expenditures in different sectors will thus provide a more distinct depiction of the impacts of military expenditures on economic growth.

Depending on what sector money is allocated to, the effects on economic growth may differ. Understanding the impacts of military spending in different sectors will provide valuable information for political policy makers responsible for budget allocation decisions. Government institutions have budget constraints and politicians have to decide where money best serves the public. Therefore, by analyzing the effects of expenditures in various military sectors on economic growth, politicians can use this study to increase their knowledge of how military spending in different military sectors affect the economy or to justify decisions regarding which military sector funds are allocated to. Thus, as earlier studies have only examined output levels as an effect of total military spending, as well as the ambiguity from previous literature of the effects through the supply channel, this thesis rather examine how input levels in different military sectors affect economic growth through the supply channel, in order to fill the research gap in existing literature.[1]

Theory

The most pressing issue of previous literature is the ambiguity of the effects through the supply channel. The augmented Solow model, introduced by Mankiw, Romer & Weil (1992), provides suggestions for how mechanisms in the supply channel may affect economic growth and will therefore serve as the theoretical framework in this study. There are other models used in the defense economics literature such as the Barro model. However, the Barro model is better

[1] Parts of the literature review are copied from PM3 in the previous course SK1313

suited for analyzing the effects through the demand channel and security channel (Yakovlev, 2007 and Dunne et al., 2005).

The key assumption of the augmented Solow model is that factor productivity is affected by defense spending share through a "level effect on the efficiency parameter that controls labor augmenting technical progress" (Dunne et al. 2005). In other words, military spending may affect a technical parameter A through mechanisms suggested by the supply channel, which decide how effective workers are. How effective workers are determines productivity and therefore economic growth. For example, military spending on R&D may lead to better technology which will make workers more efficient and thus increase productivity. Also, if experienced workers leave the private production sector and join the military, new workers who are less efficient will enter the production sector and thus decrease productivity. In order to fully understand how military expenditures in different sectors may affect economic growth, it is important to understand the basics of the neoclassical model for economic growth which the augmented Solow model derives from.

Models for Economic Growth

The augmented Solow model is an extension of the neoclassical model for economic growth. The main assumptions of the neoclassical model are that economic growth is determined by capital K, labor L and technical progress A (Heo, 1998). The neoclassical model often describes the economy with a standard Cobb-Douglas production function, which represents the relationship between capital and labor to produce output. Furthermore, the neoclassical model assumes there are decreasing marginal returns to capital and a fixed level of technology where rate of savings, population growth and technological progress are exogenous variables (Yakovlev, 2007). Furthermore, capital depreciates over time and as there are decreasing marginal returns to capital, the production in a given country will strive towards a steady state level where capital depreciation equals capital investments. In other words, the model suggests that all investments in physical capital should be used to repair or replace depreciated capital. The steady state situation also implies that the marginal product of capital equals the marginal product of labor i.e., the optimal number of workers are used for the physical capital available (Canarella & Pollard, 2011). Economic growth due to temporarily increased capital investments are only temporary and will return to the former steady state level if investment rates are not held constant. Thus, the neoclassical model suggest that only technological progress can influence long term economic growth as the marginal product of capital increases with better technology (Heo, 1998).

Mankiw et al. (1992) further developed the neoclassical model, included human capital in the model and introduced the augmented Solow model to the literature. The inclusion of human capital helps explain why marginal product of capital is higher in rich countries. Higher levels of human capital results in higher marginal product of physical capital as workers are more efficient in optimizing how to use physical capital and therefore increases output per worker. The bottom line is that better educated and trained workers will be more efficient in operating machines as well as combining labor and physical capital to produce output (Canarella & Pollard, 2011). For a more detailed theoretical derivation of the augmented Solow model, please see appendix A.

The augmented Solow model have been used as a foundation for analyses of the defense economic literature where Knight et al. (1996) and Yakovlev (2007) used variants of the augmented Solow model for estimating the effects of military expenditures on economic growth. As discussed earlier, the key assumption of the augmented Solow model used by Knight et al. (1996) is that factor productivity is affected by military spending share of GDP through a "level effect of efficiency parameter that controls labor augmenting technical progress" (Dunne et al., 2005). In other words, military expenditures assume to be affecting a technical parameter A through the supply channel which is a determinant of output. One can think of labor augmenting technical progress as residual growth of GDP that capital and labor cannot explain. For example, technological and human capital advancements determine how effective a worker is and therefore output levels. To simplify the model, technical progress A represents all knowledge and technology of how to combine physical capital and labor to produce output.

Introducing expenditures in different military sectors

This paper expands on previous theoretical framework by arguing that military spending in different military sectors may have various effects on technical parameter A, and thus economic growth. The study will follow NATO's disaggregation and examine three sectors of military expenditures[2]: equipment, personnel, and "other". NATO's disaggregation is chosen because of the availability of the data. While it would be preferred to examine the direct effects of the mechanisms in the supply channel on technical parameter A, such as examining the direct expenditures of military R&D or military training, gathering the data would simply be too time consuming for this study.

First, equipment refers to expenditures on military equipment and R&D devoted for equipment. Nancy L. Spruill (2007) define military equipment as "Weapon systems that can be used directly by the armed forces to carry out battlefield missions" (p. 4). Thus, technology such as the internet, drones and satellite systems are results of equipment research. Dunne et al. (2005) argues that military spending share is not likely to change technology. However, Moretti et al., (2019) argues that a 10% increase in government funded R&D, and in particular military R&D, generate a 4% increase in privately funded R&D. Furthermore, Gumus & Celikay (2015) show positive and significant results of the impact of R&D on economic growth. As technology such as the internet have had huge impacts on productivity, it is reasonable to assume that military expenditures related to equipment may have a positive effect on technical parameter A, and thus increase economic growth. However, the positive externalities may not be visible until years after the investment as it takes time for R&D to generate a final product. Also, military technology and resources may not be available for the general public. Thus, new technology will not have an effect on productivity until it is used in production.

Second, military personnel refer to expenditures on salaries and retirement costs of all personnel working in the military sector (Peter G. Peterson Foundation, 2021). Expenditures related to military personnel are included in the analysis as it may affect the number of skilled workers available for production as well as it may affect the knowledge of using physical capital to produce output. As described in the literature review, the supply mechanisms for military expenditure and its effect on economic growth suggest that the trade-off may impede economic growth if the number of skilled workers used in production decreases (Yakovlev, 2007). For example, if experienced workers join the army, less skilled workers may work in production as the new workers may not have the same experience. This mean that not all physical capital is being used in its optimal capacity and therefore total output is not

[2] NATO categories also include infrastructure, but this sector falls outside of this study.

maximized. Output per worker may therefore decrease in the short term before new workers learn how to operate more efficiently. However, when new workers learn how to operate machines more efficiently in the same extent as old workers, output per worker should increase again and return to its former levels. This scenario would suggest a delayed increase in technical parameter A which would temporarily benefit economic growth. Therefore, one could expect an initial temporal decrease in output per worker as new workers enter production, as well as a delayed temporal increase in output per worker when new workers are more efficient.

Third, “other” expenditures refer to expenditures not related to any of the above sectors or infrastructure and includes operation and maintenance costs as well as R&D expenditures not related to equipment. For example, different military operations, mobilization of forces as well as the cost of education and special skills training are included in the “other” sector (Office of the Under Secretary of Defense, 2020). One can use the same arguments as for the equipment sector for the effects of expenditures on R&D, where studies have shown that an increase in military R&D have an additional positive effect on private R&D, and that R&D expenditures have a positive effect on economic growth (Moretti et al., 2019 and Gumus & Celikay, 2015). Furthermore, operation and maintenance include the cost of special skills training and education which are important factors of human capital. As both human capital and technology may have positive effects on technical parameter A and thus economic growth, other military expenditures are included in the analysis.

The different military sectors of equipment, personnel and “other” are all assumed to affect technical parameter A. The theoretical equation for technical parameter A would look as follows.

$$A(t) = A_0 e^{gt} meq(t)^{\theta} mpl(t)^{\phi} mot(t)^{\sigma}$$

Where A_0 is the initial value of technical parameter A, meq is military spending as a share of GDP in the equipment sector, θ is the elasticity of long-run military equipment expenditure share, mpl is military spending as share of GDP in the personnel sector, ϕ is the elasticity of long-run military personnel expenditure share, mot is military spending as a share of GDP in the “other” sector, σ is the elasticity of long-run military expenditure share in the “other” sector, and g is the exogenous rate of Harrod-neutral technical progress[3]. e is the natural number and is used for logarithmic transformations. For the full theoretical derivation of the augmented Solow model, please see appendix A.

Research Design

Data Description

The sample used in this analysis will be NATO countries between 1990 and 2019. The final dataset contains 30 countries with different number of annual observations from official public reports, depending on each country's NATO membership between 1990 and 2019 (NATO, 1994, 1999, 2005, 2010, 2014, 2020). These countries were selected on the basis of NATO documents and the availability of military expenditures in different sectors, in order to identify the separate effects on economic growth. While there are some issues of selection bias as only NATO countries are examined as well as cross-sectional dependence as NATO members have guidelines to follow of how much, as a share of GDP, should be spent on the military, this is a first step of analyzing military expenditures in different sectors and the effects on economic growth. Potential problems will be further discussed under subsections "problems with data" and "methodological problems". The total number of observations in this panel data are 651 and includes data for GDP per worker, expenditures in different military sectors, investment rates, workers growth rates and education. The empirical specification model will be further discussed in the method section. Countries featured in this sample are shown in table 1, as well as the mean expenditure for each military sector in percentage of GDP.

Annual data for real GDP growth, Labor Force, Employment ratio, and investments are retrieved from the World Bank database (World Bank, 2021a, 2021b, 2021c, 2021d), whereas annual military expenditures in the different military sectors are calculated from numerical GDP values using NATO documents, which show the percentages of total military expenditures allocated to each sector. Total military expenditures as a share of GDP are

[3] Harrod neutral technical progress is the increase in labor efficiency, so that labor force in efficiency units increase faster than number of workers available (Oxford reference) and is estimated to be 0.02 (Mankiw et al., (1992)

retrieved from SIPRI's database (SIPRI, 2021). Annual data for education is retrieved from United Nations Development Programme (UNDP, n.d.).

First, the data for numbers of workers are calculated from labor force, age 15 and older, and employment rate, age 15 and older. Furthermore, number of workers are then used to calculate real GDP per worker in constant 2010 USD pricing as well as calculating the growth rate of workers used to identify (g + n + d), an approximation of workers growth rate n, technical progress g, and depreciation d. As described in the theory section, the augmented Solow model suggests that the approximation for (g + n + d) should equal investment rates in the steady state.

Table 1 Countries Featured in Sample and mean expenditures in each sector (% of GDP)

Country	Observations	Equipment	Personnel	Other
Albania	11	.169	.926	.199
Belgium	30	.084	.927	.249
Bulgaria	16	.200	.991	.446
Canada	30	.189	.625	.457
Croatia	11	.150	.1.23	.300
Czechia	21	.201	.693	.408
Denmark	30	.206	.796	.435
Estonia	16	.280	.617	.704
France	20	.465	1.04	.385
Germany	30	.196	.785	.350
Greece	30	.493	2.03	.415
Hungary	21	.152	.584	.442
Italy	30	.211	1.12	.216
Latvia	16	.205	.640	.428
Lithuania	16	.268	.621	.281
Luxembourg	30	.086	.411	.083
Montenegro	7	.104	1.13	.197
Netherlands	30	.239	.809	.402
North Macedonia	7	.097	.735	.194
Norway	30	.435	.764	.565
Poland	21	.326	1.07	.430
Portugal	30	.175	1.57	.246
Romania	16	.293	1.02	.215
Slovakia	16	.208	.732	.338
Slovenia	16	.099	.859	.260
Spain	30	.243	.973	.322
Turkey	30	.834	1.45	.555
UK	30	.536	.923	.822
USA	30	1.01	1.52	1.42
Total	651	.281	.951	.406

Second, real GDP is based on constant 2010 USD pricing in order to make comparisons possible between countries over time where the growth rate is calculated by subtracting the logarithmic value of GDP per worker in time t-1 from the logarithmic values of GDP per worker in time t. Using growth rate of GDP per worker rather than growth rate of total GDP makes it possible to analyze workers productivity. In other words, analyzing growth rate per worker makes it possible to identify the effects of technical advancements due to military expenditures when control variables are included. For example, if the growth rate of workers increases and investments rates remains at the same level, this would lead to a decrease in output per worker. However, if output per worker also remains at the same level, the effect is much likely caused by advancements in technical parameter A.

Third, the data used for investment rates are represented by gross capital fixed formation and shows the percentage of GDP used for physical capital stock investments. Furthermore, military expenditures in the infrastructure sector are already included in this measurement and there is no reason to believe military physical capital investments affect economic growth any differently than non-military physical capital investments. Hence why expenditures in the military infrastructure sector are not analyzed separately.

Table 2: Descriptive statistics

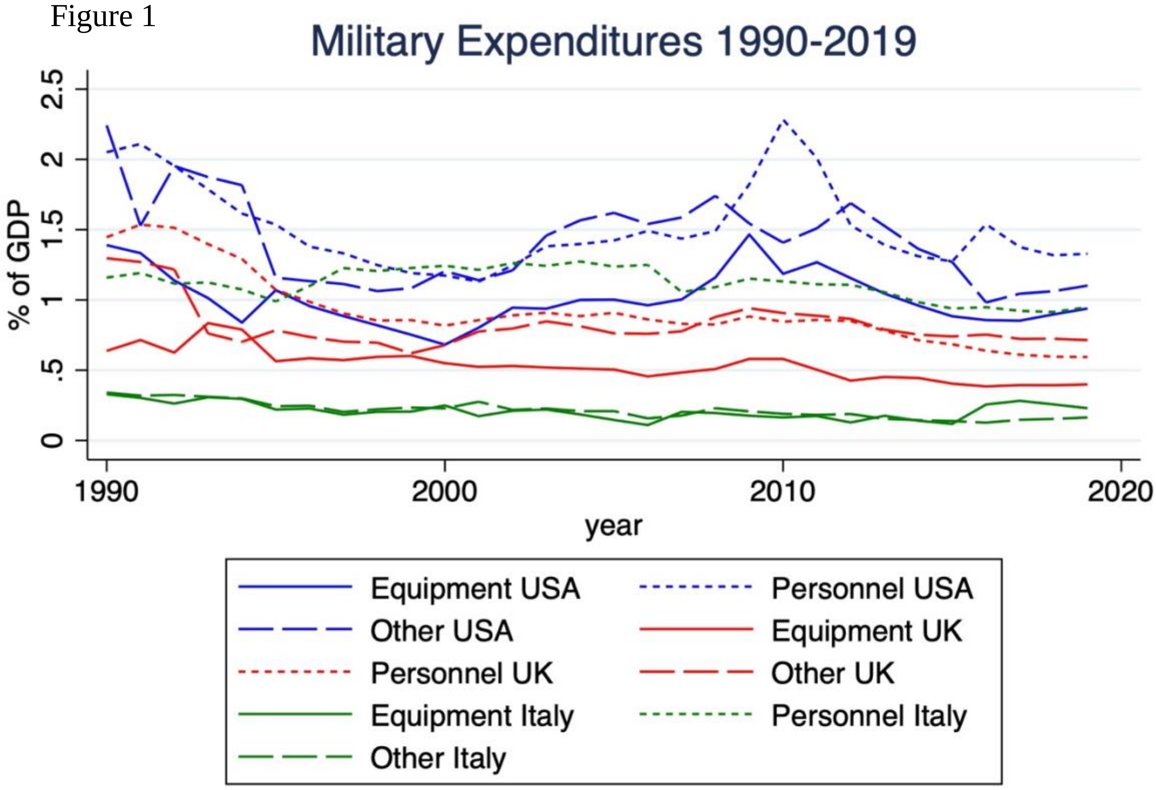
Variable	obs	mean	Countries	Max within	Min within	Max between	Min between	Sd within	Sd between
growth	622	1.5	29	18.1	-19.6	4.2	-0.7	3.6	1.2
Equipment (% of GDP)	651	0.3	29	0.9	-0.1	1.0	0.1	0.1	0.2
Personnel (% of GDP)	651	1.0	29	1.7	0.6	2.0	0.4	0.2	0.3
Other (% of GDP)	651	0.4	29	1.3	0.0	1.4	0.1	0.1	0.3
Investments (% of GDP)	651	22.1	29	33.4	13.5	27.8	17.6	2.8	2.4
Workers growth rate	622	0.9	29	19.5	-15.7	4.4	-1.1	2.6	1.2
Education	651	10.8	29	12.9	6.9	12.9	6.1	0.9	1.6

Fourth, the data used for education are represented average years of schooling and serves as a proxy when controlling for human capital changes.

Fifth, by using SIPRI's data of total military expenditure as a percentage of GDP, the total military expenditures are calculated in 2010 USD pricing for each NATO country between 1990 and 2019. Using NATO documents showing expenditures as percentage of total military expenditure related to different military sectors, the total expenditure for each sector is calculated in 2010 USD pricing. Dividing the total expenditure of each military sector by GDP gives the share of GDP used for the different military sectors.

Descriptive statistics for within and between countries can be seen in table 2 and suggest variation across countries and sectors. The development for expenditures in different sectors over time in USA, UK and Italy can be seen in figure 1 and suggests there is variation within and between countries over time.

Figure 1



(NATO, 1994, 1999, 2005, 2010, 2014, 2020)

Possible Concerns with Data

There are some concerns with collected data which may affect the outcome of this study. First, all variables are analyzed annually. It would be preferred to analyze five-year intervals in order to diminish the effects of business cycles which, on average, lasts for five years. Using five-year intervals would also diminish effects of possible serial correlation (Yakovlev, 2007). However, the period analyzed in this paper lasts from 1990 to 2019 and the number of observations would considerably decrease which makes this approach inappropriate. A possible solution could be to include year fixed effects in the models, in order to control for macroeconomic events that may affect business cycles. This approach would however treat business cycles as uniform across countries which will take care of global trends, but not regional trends.

Second, the data for d and g are approximations and not necessarily the real rates for each country. Mankiw et al (1992), suggest g accounts for 2% of output per worker based on the average of growth in income per capita per year whereas annual depreciation rates are assumed to be equal to 3% for all countries. It is difficult to obtain country specific data for depreciation rates, however there is no reason to expect great differences of depreciations rates across countries (Mankiw et al., 1992). Furthermore, some values for the (g+n+d) approximation is negative. Therefore, when transforming the approximation to logarithmic values, a constant of 0.087257 is added to all values, which is the smallest observation of the (g+n+d) approximation, as logarithmic values cannot be transformed from negative numbers. This technique is common by statisticians and shouldn't significantly affect the estimations.

Third, the data for number of years schooling are included to control for human capital changes. Number of years schooling does not necessarily equal human capital as there are other variables affecting human capital such as health care and individual skills. However, when fixed effects also control for country specific characteristics, using number of years schooling as a proxy serves the purpose of controlling for human capital advancements not related to military expenditures.

Fourth, data on military expenditures could be uncertain as national defenses conceal information not to reveal weaknesses or to gain advantages to external threats (Hutchinson, 2006). Also, the different sectors in NATO documents are broad and include many different possibilities of expenditures within each sector. For example, the equipment sector includes expenditures in purchasing equipment needed for military activities and expenditures related to R&D. Hence, it is not clear how much is used for purchasing equipment such as weaponry, and how much is used for R&D activities. While the data may suffer from some information bias, using the NATO documents is however a first step to expand the defense economics literature and the effects of expenditures in different military sectors on economic growth.

Last, labor force and employment rates are estimates from national government based on labor force surveys and household surveys where date and survey design may affect the data (World Bank, 2021a, 2021d). For example, a participant in the labor force can be employed when answering the survey and later be out of job which then overestimates the annual employment rate. This may lead to information bias where the data retrieved not necessarily represents the actual number of workers in the production sector and thus the estimates may be biased as well. Overcoming this issue is however too time consuming for this study.

Method

This study will conduct a cross country regressions analysis for NATO countries between 1990 and 2019. The independent variables of interests are military expenditures in the different sectors of military equipment, military personnel and "other" military sector not related to equipment, personnel or infrastructure. Also, the specification model includes lagged variables of military equipment expenditures and other military expenditures due to the theoretical derivation of the Cobb-Douglas function[4]. Furthermore, the model specification includes control variables for the value of GDP per worker the preceding year, physical capital investment rates, an approximation for workers growth rate, capital depreciation and technological advancements, as well as average years of schooling. Country specific fixed effects, time specific fixed effects and Robust standard errors[5] are used in order to control for serial correlation and heteroscedasticity issues. An alternative approach using the feasible generalized least square estimator, FGLS, will also be performed as a robustness check.

[4] Using a Cobb-Douglas function to describe military expenditures and the economy is common in the defense economics literature. The derivation can be reviewed in Appendix A.

[5] The default Robust standard errors from Stata are used

The empirical specification model used in this analysis are transformed from the theoretical derivation of a Cobb-Douglas function and can be reviewed in appendix A. Military expenditures in the equipment sector, the personnel sector and the other sector are assumed to affect technical parameter A, which is a determinant of the dependent variable output per worker.

There is a distinction between output level models and economic growth, however, Dunne et al. (2005) argues the distinction is less important in practice thus output levels will be approximately equal to GDP. Furthermore, treating investment rates, s, and workers growth rate, n, as variant across countries and time is common in the defense economic literature (see Knight et al., 1996 and Yakovlev, 2007), although the augmented Solow model suggest these factors are constant in a long-term steady state situation. Harrod neutral technical progress, g, and capital depreciation, d, are considered uniform time invariant constants. Also, the initial level of technology and human capital, A_0, is often considered time invariant but country specific (see Knight et al., 1996 and Yakovlev, 2007) Using the commonly used operationalization methods of previous work, the conceptual equation can be transformed for empirical regression analysis and be specified as follows[6]:

$$\begin{aligned} growth_{it} = \beta_0 + \beta_1 \ln y_{it-1} + \beta_2 \ln s_{it} \\ + \beta_3 \ln(g + n_{it} + d) + \beta_4 \ln meq_{it} \\ + \beta_5 \ln meq_{it-1} + \beta_6 \ln mpl_{it} + \beta_7 mpl_{it-1} + \beta_8\, mot_{it} + \beta_9\, mot_{it-1} \\ + \beta_{10} \ln educ_{it} + FE + \varepsilon \end{aligned}$$

where $growth_{it}$ is the growth rate of real GDP per worker, $\ln y_{it-1}$ is the value of real GDP per worker the preceding year which is a common control variable in economic growth literature, $ln\, s_{it}$ is the share of GDP on physical capital investments, $\ln meq_{it}$ is the share of GDP on expenditures in the military equipment sector, $\ln mpl_{it}$ is the share of GDP on expenditures in the military personnel sector and $\ln\, mot_{it}$ is the share of GDP on military expenditures in the "other" sector. $\ln(g + n_{it} + d)$ is workers growth rate + 0.05 of GDP and

[6] The various military spending sectors will be analyzed separately

is an approximation for workers growth rate n, depreciation rate of capital, d, and Harrod neutral technical advancements, g. Approximating g + d to 0.05 is common in the defense economics literature following Mankiw et al.'s (1992) reasoning of g equals 0.02 and d equals 0.03. Also, the empirical regression specification model includes lagged effects of expenditures in the different military sectors, control variables for average number of years schooling ln $educ_{it}$ and country specific fixed effects FE. ε is an error term, *it* indicate country at year t.

First, all variables, both dependent and independent, take natural logarithmic values due to the derivation of the Cobb-Douglas function and the theorization of marginal production of capital and labor. This approach yields a linear relationship suitable for OLS regression analysis and makes it possible to interpret the beta coefficients as elasticities. Also, interpreting the beta coefficients as elasticities makes it easy to present the results to policy makers. A one percent increase in variable of interest are estimated to result in β_x GDP per worker growth change.

Second, the models will include the real value of GDP per worker in the preceding year. This is a common control variable in the defense economics literature and makes it possible to compare countries with different economic prosperities. In regard to the augmented Solow model, rich economies are more likely to be in its steady state levels or above its steady state level. Thus, physical capital rates should have a lower effect on economic growth in rich countries due to decreasing marginal returns of capital. The real value of GDP per worker in the preceding year should therefore affect economic growth negatively.

Third, as the augmented Solow model suggest economic growth is determined by capital investment rates, number of workers growth rate, depreciation rates of capital and technical advancement rates, the model has to control for these variables, in order to isolate the effects of military expenditures. Including physical capital investments and the approximation of (g+n+d), follows the theoretical framework of the augmented Solow model, where investments should have a positive effect on output per worker as more capital will be available per worker, and (g+n+d) should have a negative effect on output per worker as less capital is available per worker.

Fourth, in order to control for human capital changes in technical parameter A not caused by military expenditures, average years of schooling is included in the model. While there are more aspects that may affect human capital, such as individual skills and health care, numbers of years schooling should be sufficient for this analysis when country specific fixed effects are accounted for.

Fifth, country fixed effects are included in the model to control for country specific behavior. For example, the initial level of technical parameter A_0 is treated as time invariant but country specific. Time specific fixed effects are also included in the model to control for macroeconomic events, such as the financial crisis of 2008.

Methodological Issues

In this section, four methodological issues common for panel data regressions will be discussed: Multicollinearity, serial correlation, heteroscedasticity and cross-sectional dependency.

First, a potential problem with proposed study is the multicollinearity issue between military spending in different sectors. It is likely that national governments increase all military sectors at the same time, when budget decisions are made and could therefore cause collinearity issues. The correlations between different variables are shown in the correlation matrix in table 2 and suggest tendencies of multicollinearity issues.

Table 2 **Pairwise correlations**

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) growth	1.000						
(2) Equipment sector	0.056	1.000					
(3) Personnel sector	0.029	0.436	1.000				
(4) "Other" sector	0.080	0.692	0.339	1.000			
(5) Investments	0.165	0.007	-0.041	0.044	1.000		
(6) (g+n+d)	-0.339	-0.011	-0.062	0.047	-0.006	1.000	
(7) Education	-0.015	-0.148	-0.542	0.107	-0.170	0.019	1.000

Therefore, a variance inflator factor test, VIF, is conducted between growth, military expenditures in the different sectors, and the control variables. A VIF score of 1 indicate no collinearity, a score of 5 indicate moderate collinearity and scores above 5 indicate high collinearity between variables (Daoud, 2017). The VIF test show possible correlations for all variables with VIF scores of 4.13 for military equipment expenditures, 8.49 for military personnel expenditures, and 10.81 for other military expenditures.

The multicollinearity issue is therefore dealt with by analyzing the effects of military expenditures in different sectors, and its delayed effect, in separate regression models, together with proposed control variables. Performing a second VIF test with only one variable of interest i.e., the different military sectors, the results still show signs of possible correlations, but lower scores on the VIF indicator. The second VIF test generates a score of 3.27 for military equipment expenditures, 8.37 for the military personnel expenditures and 8.54 for other expenditures which implies there still may be some collinearity issues for the military personnel expenditure model and the military other expenditure model.

This may lead to increased standard errors as it is more difficult to differentiate the explanatory variables from each other and thus their individual effect on the dependent variable (Daoud, 2017). In other words, the null hypothesis will not be rejected as easy, thus decreasing the chances of type I errors i.e., rejecting a true null hypothesis, but increasing the chances of type II errors i.e., not rejecting a false null hypothesis. However, the Solow model is a well-established model for economic growth where the control variables are certain to affect output per worker. Thus, the model should be acceptable for a first study of the effects of different military sector expenditures on economic growth, although not all effects will be picked up. The VIF tests can be found in appendix B.

Second, in order to check for autocorrelation and heteroscedasticity, a visual line plot test is conducted for each country. The line plots do not show any clear signs of trends within countries for the growth variable and the time series seems to be stationary. However, using Wursten's (2018) test in Stata for autocorrelation testing, the test identifies serial correlation of the first order on the growth variable. Furthermore, the line plots of the explanatory variables of interest show possible signs of serial correlation for all variables. Wursten's (2018) test in Stata for serial correlation shows that all variables of interests suffer from serial correlation. The serial correlation problem is dealt with using robust standard errors, which controls for both serial correlation and heteroscedasticity, in order to produce as unbiased estimates as possible. Furthermore, the heteroscedasticity problem is dealt with when using the natural logarithm of all variables, as the marginal effect difference decreases with higher values. From an econometric standpoint, the differences are thus smaller and decreases the chances of heteroscedasticity as well as logarithmic values generates a linear relationship suitable for OLS estimation.

Third, in order to control for cross sectional dependency, year fixed effects are included in the model. Year fixed effects control for differences in the growth variable that are not attributed to other explanatory variables. In other words, year fixed effects control for changes in growth each year that are common for all countries. This approach would take care of cross-sectional dependence in the dependent variable in which all countries are affected but does not account for cross-sectional dependence where just a few countries in the sample are affected. However, the issue of cross-sectional dependency may be due to the fact that all countries are part of NATO and follow specific guidelines, which time specific fixed effects will account for.

Using OLS as the estimator with fixed effects and robust standard errors is the general approach used by most researchers. However, earlier defense economic studies have argued that the feasible generalized least square estimator, FGLS, generate less biased estimates for similar models (see Yakovlev, 2007). This study will therefore also perform regressions with the FGLS estimator as a robustness check, in order to ensure the validity of the study. Regression tables for the FGLS estimator can be found in appendix C.

Results and Discussion

This section will present the regression estimates for military expenditures in the equipment sector, personnel sector, and the "other" sector and their effect on GDP per worker. Also, potential explanations will be discussed as well as the robustness of the results.

Expenditures in the Equipment Sector

The regression output for military expenditures in the equipment sector is shown in table 3. First, there seems to be no immediate effect of military expenditures in the equipment sector on economic growth as no significant estimates are generated for the initial expenditure without control variables. Neither does the output show any significant estimates when a one-year lag is added to the model. The same result is generated when control variables are added to the model which implies that expenditures in the military equipment sector does not have any effect on economic growth during the first and second year after the initial expenditure.

Table 3 **Regression for military equipment expenditures**

	(1) growth	(2) growth	(3) growth	(4) growth	(5) growth	(6) growth
ln meq_{it}	.001		-.002	-.002		-.003
	(.004)		(.004)	(.004)		(.004)
ln meq_{it-1}		.004	.005		0	.002
		(.004)	(.004)		(.004)	(.003)
ln y_{it-1}				-.095***	-.094***	-.095***
				(.021)	(.021)	(.021)
ln s_{it}				.049***	.049***	.048***
				(.014)	(.014)	(.014)
ln $(g + n_{it} + d)$				-.023**	-.023**	-.023**
				(.008)	(.008)	(.008)
ln $educ_{it}$				-.005	-.007	-.005
				(.029)	(.027)	(.028)
Intercept	.018	.032*	.028	1.112***	1.118***	1.113***
	(.019)	(.019)	(.022)	(.241)	(.241)	(.242)
Observations	622	622	622	622	622	622
R-squared	.263	.265	.265	.457	.456	.457

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

The results are unexpected but explainable. It was argued that military expenditures in the equipment sector affect technical parameter A due to increased spending on R&D. However, the estimates do not support that statement. This could be explained, as military R&D may not generate new technology until years after the R&D process starts and thus will not yield profit until years after the initial investment. It would be interesting to analyze the long run effects of expenditures in the military equipment sector and the effects on economic growth, but such analysis falls outside the scope of this study.

Second, control variables for physical capital investments, the approximation of (g+n+d), and the initial value of GDP per worker show significant estimates with the correct coefficient signs for all models. Physical investments should have a positive elasticity to economic growth and increase economic growth per worker, as the augmented Solow model suggest that an increase in physical capital generate more output per worker. The approximation of Harrod neutral technological advancements, number of workers growth rate and physical capital depreciation rate (g+n+d) should have a negative elasticity on economic growth as an increase in (g+n+d) suggests there is less capital per worker and thus decreases output per worker. Furthermore, the negative coefficients of the real value of GDP per worker the preceding year are expected as high initial values of GDP per worker would generate less growth. The augmented Solow theory suggests low-income countries will eventually catch up with rich countries if g and d is constant across countries, as low-income countries have not yet reached their steady state levels. The estimates for education as a control variable show no significant estimates but an unexpected coefficient sign. This phenomenon is common in growth regressions and can be explained by using number of years schooling as a proxy for human capital. True levels of human capital have not changed much in many countries which statistically leads to a temporal negative relationship between the proxy for human capital used in regressions and economic growth (Yakovlev, 2007).

Furthermore, the residual plot shows random scatters around 0 which suggests that the specified model is well suited for linear regression. Also, the issues with serial correlation and heteroscedasticity seems to have been taken care of as no real pattern are shown in the residual plot. There are a few outliers which may influence the estimates, but overall, the model seems well specified. Also, the FGLS estimator generate similar estimates which suggests the results are robust. The residual plot and the FGLS estimates can be reviewed in appendix C.

Expenditures in the Personnel Sector

The regression output for military personnel expenditures in table 4 reveals interesting results. First, the regression estimates show no immediate effect of military expenditures in the personnel sector on GDP per worker when no control variables are included in the model. The coefficient sign changes from positive to negative when a one-year lag is added to the model but there are no significant estimates.

The interesting estimates are the positive elasticities for military expenditure in the personnel sector one year after the initial expenditure. The estimates are significant at $p < 0.05$ for model 2, 5 and 6. When control variables are added to the model together with current expenditures, the regression output shows a positive elasticity of 0.034 % significant at $p < 0.05$. In other words, a 1% increase in military expenditures in the personnel sector generate a 0.034%

increase in GDP per worker growth one year after the initial expenditure. The marginal delayed effect of expenditures in the military personnel sector can be seen in figure 2.

Table 4 **Regression for military personnel expenditures**

	(1) growth	(2) growth	(3) growth	(4) growth	(5) growth	(6) growth
ln mpl_{it}	.013		-.009	.015		-.012
	(.01)		(.022)	(.013)		(.017)
ln mpl_{it-1}		.02**	.027		.023**	.034**
		(.008)	(.018)		(.011)	(.014)
ln y_{it-1}				-.097***	-.099***	-.099***
				(.021)	(.021)	(.021)
ln s_{it}				.052***	.054***	.054***
				(.013)	(.013)	(.013)
ln $(g + n_{it} + d)$				-.022**	-.022**	-.022**
				(.008)	(.008)	(.008)
ln $educ_{it}$				-.002	-.001	-.003
				(.025)	(.024)	(.025)
Intercept	.069	.096**	.088*	1.211***	1.269***	1.259***
	(.047)	(.037)	(.043)	(.255)	(.264)	(.265)
Observations	622	622	622	622	622	622
R-squared	.265	.268	.269	.46	.464	.465

Robust standard errors are in parentheses

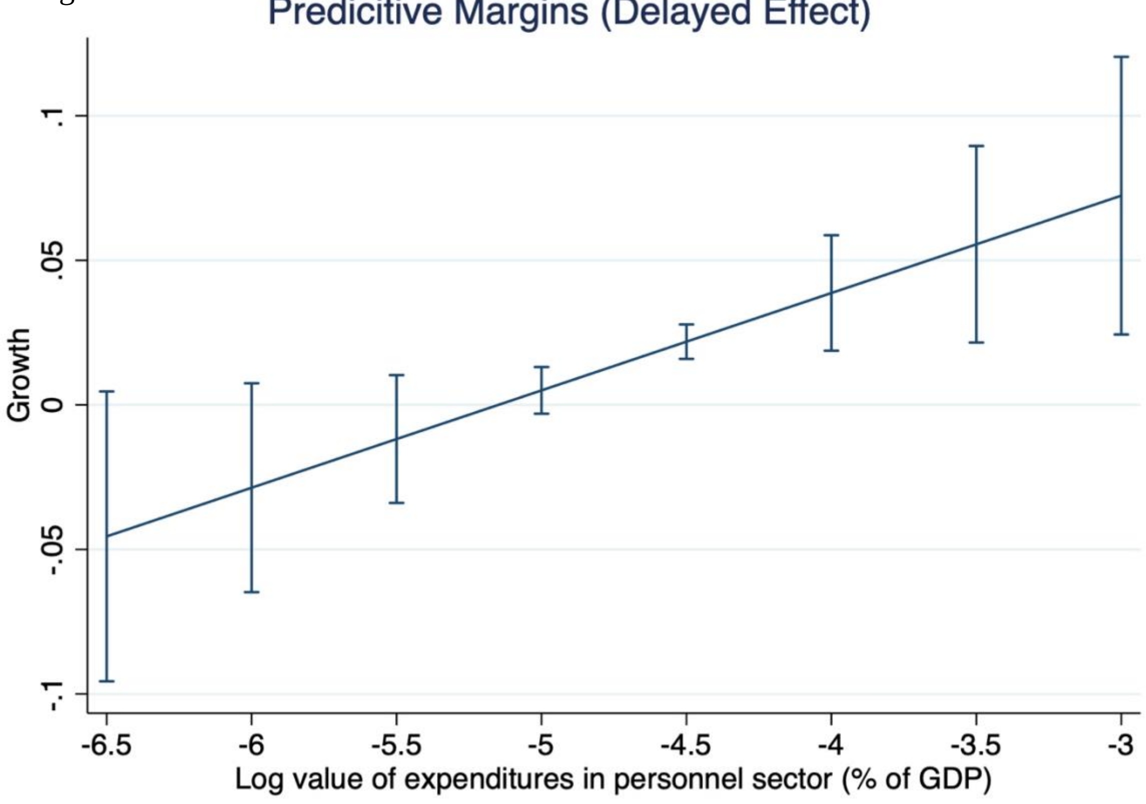
**** p<.01, ** p<.05, * p<.1*

As argued in the theory section, an increase in personnel expenditures could mean that more people enter the military. This could initially lead to a decrease in output per worker as new workers are not as efficient in production. However, no such conclusion can be made from this analysis as the estimate in the full model came back negative, but not significant.

Furthermore, when new workers are as efficient as former workers and have learnt how to operate machines to the same extent, output per worker should return to its former levels. However, the estimates indicate an additional increase in output per worker, suggesting that workers become more efficient than before. The theory does not explain why the delayed positive effects are greater than the initial negative effects and therefore further research to explain this phenomenon is encouraged.

Second, the real value for GDP per worker the preceding year, investments and the approximation for (g+n+d) show expected coefficient signs and are significant. Also, the OLS estimator generates negative coefficient signs and are not significant for education. As argued before, this is common in growth regressions (Yakovlev, 2007).

Figure 2



Furthermore, the residual plot from the predicted growth value estimations with country fixed effects, year fixed and robust standard errors, show a random scatter around 0. Again, the model seems well specified. However, the FGLS estimator generates an initial negative elasticity of 0.021% and a delayed positive elasticity of 0.02% significant values at $p < 0.1$ for military expenditures in the personnel sector when control variables are included in the model which would mean that the effects off set each other. The estimates from the FGLS estimator support the theoretical framework but makes the interpretation of the full impact a bit more difficult as the OLS estimator suggest an additional delayed effect. Further research to analyze the effects of military expenditures in the personnel sector is encouraged. The residual plot and the FGLS estimates can be reviewed in appendix C.

Expenditures in the ”Other” Sector

The regression output for military expenditures in the “other” sector in table 5 shows similar results as for the military equipment sector. First, there seem to be no effect for the initial expenditure on growth. While there is a negative estimate significant at $p < 0.1$ when the lagged variable is included in the model but without control variables, this effect disappears when control variables are included. The same goes for the lagged variable which show positive estimates significant at $p < 0.05$ and $p < 0.01$ without the control variables, but insignificant when control variables are added to the model. Thus, expenditures in the other sector does not seem to have any effects on economic growth.

Again, the results are unexpected but explainable. For example, R&D may not affect technical parameter A until years after the initial investment, thus there may not be any economic effects initially. Furthermore, expenditures in the other sector could be used for increased special skills training. As there are no visible effects on economic growth, the fact of simply serving in the military may be more efficient than the actual training. In regard to the R&D factor, it would be interesting to investigate the long run effects of expenditures in the “other” sector.

Table 5 **Regression for military expenditures in “other” sector**

	(1) growth	(2) growth	(3) growth	(4) growth	(5) growth	(6) growth
ln mot_{it}	.003		-.016*	.001		0
	(.006)		(.008)	(.007)		(.008)
ln mot_{it-1}		.014**	.026***		.002	.002
		(.006)	(.009)		(.007)	(.007)
ln y_{it-1}				-.094***	-.094***	-.094***
				(.021)	(.021)	(.021)
ln s_{it}				.049***	.048***	.048***
				(.014)	(.014)	(.014)
ln $(g + n_{it} + d)$				-.023**	-.023**	-.023**
				(.008)	(.009)	(.008)
ln $educ_{it}$				-.006	-.005	-.005
				(.026)	(.026)	(.026)
Intercept	.025	.087***	.061*	1.117***	1.114***	1.114***
	(.029)	(.031)	(.031)	(.241)	(.242)	(.244)
Observations	622	622	622	622	622	622
R-squared	.263	.27	.274	.456	.457	.457

Robust standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

Second, the estimates for the real value of GDP per worker the preceding year, as well as the rate of investments and the approximation of (g+n+d) shows expected coefficient signs and are significant once again. The coefficient signs for education are negative but not significant for which again can be explained by proxy of using number of years schooling as a proxy for human capital (Yakovlev, 2007).

Furthermore, the residual plot generates similar scatters as previous models, suggesting that serial correlation and heteroscedasticity have been dealt with. Also, the FGLS estimator show similar estimates as the OLS estimator when control variables are included which suggests the results are robust. The residual plot and the FGLS estimates can be reviewed in appendix C.

Conclusion

In conclusion, the purpose of this study is to examine the possible effects of expenditures in different military sectors and the effects on economic growth, in order to fill the research gap in existing literature. Using a quantitative approach, analyzing NATO countries' military expenditures in the equipment sector, personnel sector and "other" sector, this study finds some interesting results. First, expenditures in the equipment sector and "other" sector does not generate any significant results, suggesting that expenditures in the equipment sector and "other" sector does not have any effect on economic growth. However, expenditures in the equipment sector and "other sector" may not affect economic growth until years after the initial expenditure, as it takes time for R&D to provide the production sector with new technology.

Second, expenditures in the military personnel sector seem to generate a positive effect on economic growth, one year after the initial expenditure. The offsetting effects can be explained by new workers learning how to operate machines to the same extent as former workers, but potential additional increases are subjects for further research. The findings add to previous literature by arguing that expenditures in the military personnel sector may contribute to additional positive externalities through the supply channel.

Earlier studies have shown inconclusive results where military spending have had both negative and positive effects on economic growth. Negative findings point to reduced investment possibilities, reduced availability of factors for production as well as the trade-off of increased military spending and reduced spending in other government funded institutions. Positive findings point to the benefits from technological spin-offs from the military to the private sector as well as increased security on markets. However, all previous studies have analyzed the effects of total military spending on economic growth. This study rather disaggregates military spending into NATO's sectors of expenditures in the equipment sector, personnel sector and "other" sector, in order to fill the research gap in existing literature.

The findings may contribute to important implications for politicians as it increases their understanding of how their decisions may influence the economy. For example, this study argues that expenditures in the equipment sector or "other" sector will not affect economic growth in the first two years. Thus, decisions to increase budgets of these sectors should not be based on economic factors, but rather security reasons. Furthermore, an increase of expenditures in the personnel sector may generate long-term positive outcomes and actually increase economic growth, although the magnitude of the effects can be debated. Therefore, politicians could use this study to justify their decision to increase expenditures in the military personnel sector, as it may have long-term positive externalities on economic growth.

Some econometric issues surround panel data in general, which are also present in this analysis. Therefore, the models include fixed effects and robust standard errors in order to deal with autocorrelation, heteroscedasticity and cross-sectional dependence. Also, a robustness check using an alternative estimator in FGLS have been made in order to ensure the validity of the study.

There are plenty of potential future research to suggest. First, it would be interesting to see the long-term effects of military R&D expenditures on economic growth. While there are studies suggesting that military R&D drives private R&D, and that R&D in general drive technological development (e.g. Moretti et al., 2019), no studies have examined the direct long-term effects from military R&D expenditures on economic growth. Second, it would be interesting to see whether the efficiency of other government institutions affect budget allocation decisions in the military. Third, further research for explaining the delayed effects of possible additional increase in output per worker due to increases in military personnel expenditures is advisable. Another area of possible future research is to replicate this study and control for business cycles. The average business cycle lasts for five years and the fluctuations could affect the estimates. Thus, analyzing expenditures in different military sectors on economic growth with five-year averages would potentially improve existing literature even further.

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Appendix A

Theoretical derivation

Using an aggregate neoclassical production function with augmenting technical progress as the fundamental equation, like Dunne et al. (2005), the theoretical equation can be illustrated as follows:

(1)

$$Y(t) = K(t)^{\alpha}[A(t)L(t)]^{1-\alpha}$$

where Y is aggregate real income, or GDP, K is real capital stock, L is labor, α is output elasticity with respect to capital and A is a technical parameter. Technical parameter A evolves according to:

(2)

$$A(t) = A_0 e^{gt} meq(t)^{\theta} mpl(t)^{\phi} mot(t)^{\sigma}$$

Where A_0 is the initial value of A, meq is military spending as a share of GDP in equipment sector, θ is the elasticity of long-run military equipment expenditure share of steady state income, mpl is military spending as share of GDP in personnel sector, ϕ is the elasticity of long-run military personnel expenditure share of steady state income, mot is military spending as a share of GDP in other sectors, σ is the elasticity of long-run military expenditure share of steady state income in other sectors, and g is the exogenous rate of Harrod-neutral technical progress.

According to this specification, expenditures in military equipment sector, military personnel sector and other military expenditures affect technical parameter A, which potentially has a permanent level effect on income. When combining with standard Solow model assumptions of an exogenous saving rate s, constant labor force growth rate n and capital depreciation d, one can observe dynamics of capital accumulation where capital per effective worker $k_e = K/(AL)$ can, according to Dunne et al. (2005), be described by:

(3)

$$k_e = sk_e^{\alpha} - (g + n + d)k_e$$

where s denotes the share of physical capital investment in aggregate income, n is labor force growth and d is capital depreciation. The steady state physical capital stock levels are:

(4)

$$k_e^* = [\frac{s}{g + n + d}]^{1/(1-\alpha)}$$

According to Dunne et al., (2005), the transitory dynamics of income per effective worker $y_e = Y/AL$ near steady state levels are approximated by:

(5)

$$\frac{\partial \ln y_e}{\partial\ t} = (\alpha - 1)(g + n + d)[\ln y_e(t) - \ln y_e^*]$$

where the steady state level of output per effective worker is:

(6)

$$y_e^* = [\frac{s}{g + n + d}]^{\alpha/(1-\alpha)}$$

By using Dunne et al.'s (2005) integration of (t-1) to (t) of the transitory dynamics for output per effective worker, the equation can be used for empirical analysis:

(7)

$$\ln y_e(t) = e^z \ln y_e(t-1) + (1 - e^z) \ln y_e^*, \qquad z \equiv (\alpha - 1)(g + n + d)$$

Using equation 2, 6 and 7, the final equation for observable income per worker y = Y/L look as follows:

(8)

$$\ln y(t) = e^{z} \ln y_e\,(t-1) + (1-e^{z})\left(ln\,A_0 + \frac{\alpha}{1-\alpha}\ [ln\ \ s - \ln(g+n+d)]\right) + \theta \ln meq(t) - e^{z}\ \theta \ln meq(t-1) + \phi \ln mpl\ (t) - \ e^{z}\phi \ln mpl(t-1) + \sigma \ln mot(t) - e^{z}\sigma \ln mot(t-1) + (t - (t-1)e^{z})g$$

For a more detailed explanation of the derivation of the model, please see Dunne et al. (2005).

Appendix B

Multicollinearity - VIF test

Variance inflation factor all sectors

	VIF	1/VIF
lag1 gdpworker	59.491	.017
ln meq	4.129	.242
ln mpl	8.489	.118
ln mot	10.809	.093
ln invest	1.93	.518
ln gnd	1.131	.884
ln educ	13.788	.073
Mean VIF	18.159	.

Variance inflation factor military equipment sector

	VIF	1/VIF
lag1 gdpworker	58.26	.017
ln meq	3.274	.305
ln invest	1.901	.526
ln gnd	1.106	.904
ln educ	9.433	.106
Mean VIF	16.98	.

Variance inflation factor military personnel sector

	VIF	1/VIF
lag1 gdpworker	58.071	.017
ln mpl	8.373	.119
ln invest	1.9	.526
ln gnd	1.109	.902
ln educ	13.279	.075
Mean VIF	17.198	.

Variance inflation factor military other sector

	VIF	1/VIF
lag1 gdpworker	59.462	.017
ln mot	8.538	.117
ln invest	1.901	.526
ln gnd	1.12	.893
ln educ	10.074	.099
Mean VIF	18.503	.

Appendix C

FGLS estimators

Regression with FGLS estimator Equipment Sector

	(1) growth	(2) growth	(3) growth	(4) growth
ln meq_{it}	.002*	.001	.001	.002
	(.001)	(.003)	(.001)	(.003)
ln meq_{it-1}		.001		0
		(.003)		(.003)
ln y_{it-1}			-.008***	-.008***
			(.002)	(.002)
ln s_{it}			.027***	.027***
			(.007)	(.007)
ln $(g + n_{it} + d)$			-.062***	-.062***
			(.004)	(.004)
ln $educ_{it}$			.019***	.019***
			(.007)	(.007)
Intercept	0	.017*	-.021	-.021
	(0)	(.01)	(.027)	(.028)
Observations	622	622	622	622
Pseudo R^2	.z	.z	.z	.z

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Regression with FGLS estimator for Personnel Sector

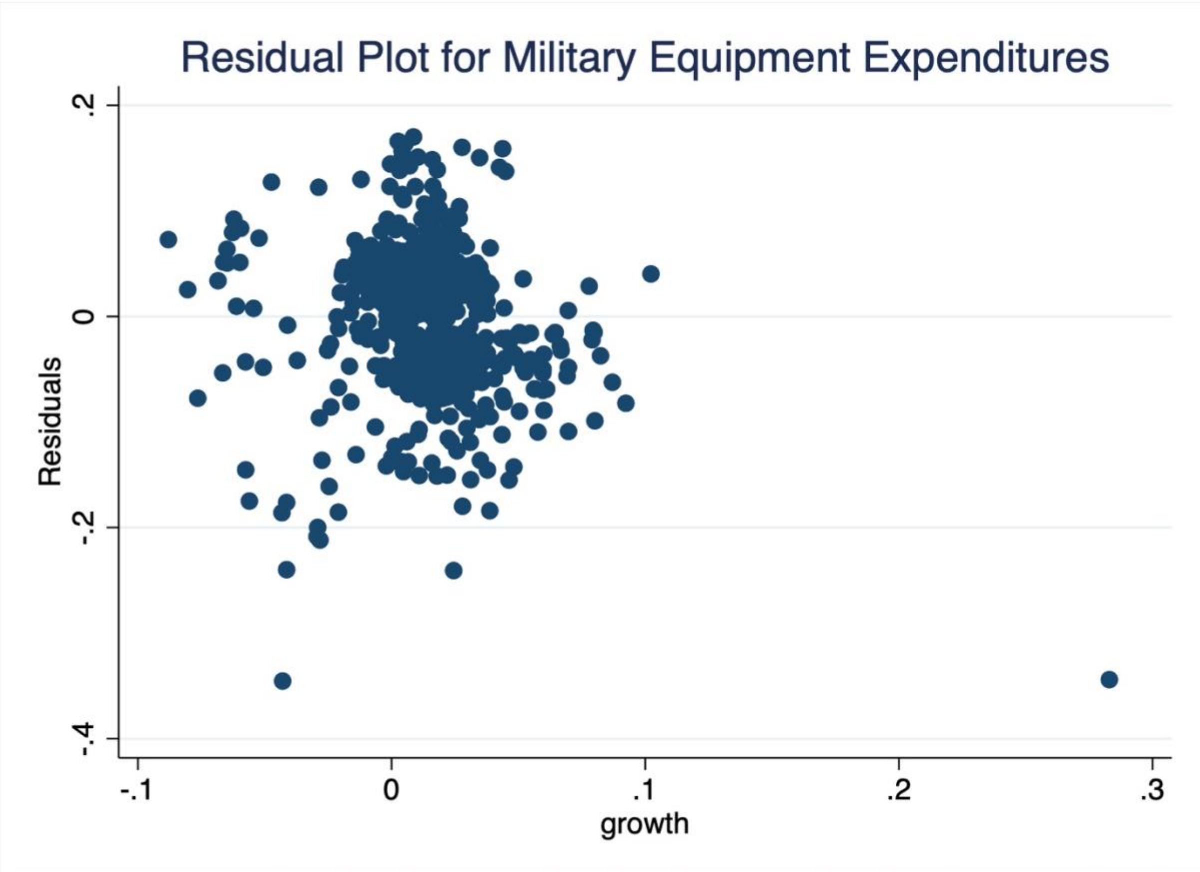
	(1) growth	(2) growth	(3) growth	(4) growth
ln mpl_{it}	.004	-.012	-.002	-.021*
	(.003)	(.012)	(.003)	(.011)
ln mpl_{it-1}		.017		.02*
		(.013)		(.011)
ln y_{it-1}			-.008***	-.008***
			(.002)	(.002)
ln s_{it}			.025***	.026***
			(.007)	(.007)
ln $(g + n_{it} + d)$			-.063***	-.063***
			(.004)	(.004)
ln $educ_{it}$			.018**	.019**
			(.008)	(.008)
Intercept	.039**	.024	-.039	-.035
	(.016)	(.015)	(.026)	(.026)
Observations	622	622	622	622
Pseudo R^2	.z	.z	.z	.z

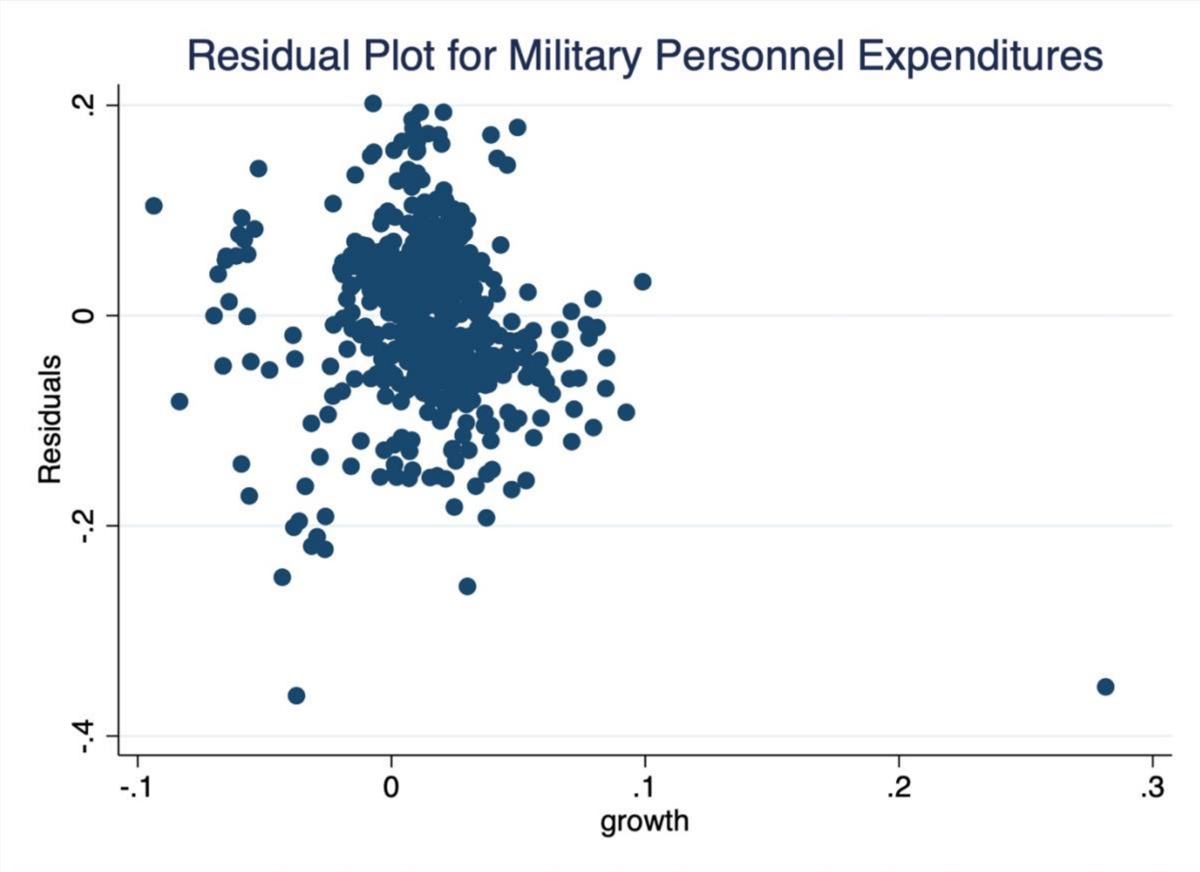
Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

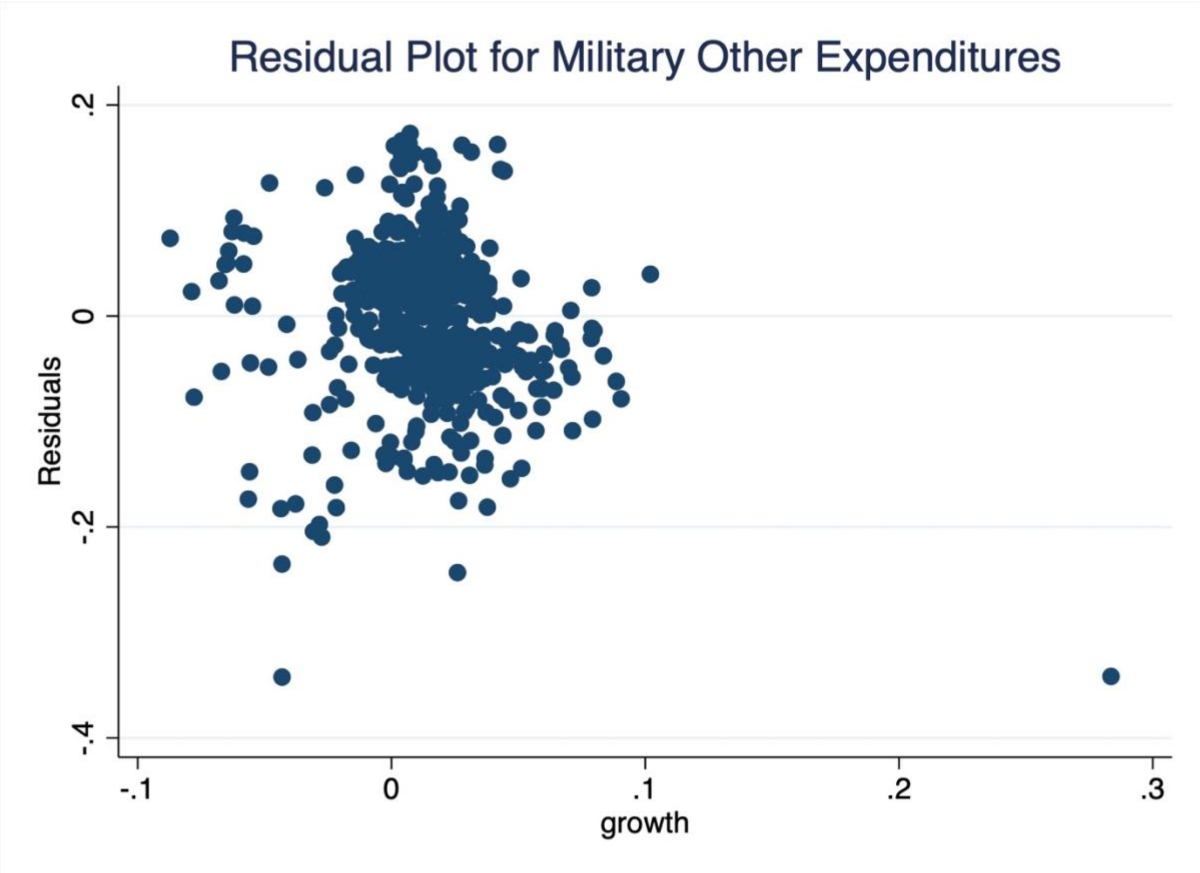
Regression with FGLS estimator for "other" Sector

	(1) growth	(2) growth	(3) growth	(4) growth
$\ln mot_{it}$	.004**	-.01	.002	-.003
	(.002)	(.006)	(.002)	(.006)
$\ln mot_{it-1}$		.015**		.005
		(.006)		(.006)
$\ln y_{it-1}$			-.007***	-.007***
			(.002)	(.002)
$\ln s_{it}$			.026***	.026***
			(.007)	(.007)
$\ln (g + n_{it} + d)$			-.06***	-.059***
			(.004)	(.004)
$\ln educ_{it}$			.016**	.016*
			(.008)	(.008)
Intercept	.042***	.028**	-.015	-.012
	(.012)	(.012)	(.029)	(.029)
Observations	622	622	622	622
Pseudo R^2	.z	.z	.z	.z

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*




Residual Plot for Military Personnel Expenditures
Residuals
.2
0
-.2
-.4
-.1
0
.1
.2
.3
growth


Residual Plot for Military Other Expenditures
Residuals
.2
0
-.2
-.4
-.1
0
.1
.2
.3
growth