The military expenditure – economic growth nexus revisited: evidence from the United Kingdom

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Robert Hanson and Joo Young Jeon*

The Military Expenditure – Economic Growth Nexus Revisited: Evidence from the United Kingdom

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Abstract: The relationship between government defence expenditure and economic growth is a debated topic. This study uses UK data for the period of 1960–2012 and applies two of the most prevailing theories used within the literature, the 'Feder-Ram' and the 'augmented Solow' models, to assess this question. We utilise traditional model specifications, alongside extensively altered versions of both models, enabling a comprehensive comparison between them. The alterations to the models include re-evaluating how core variables are expressed, inclusion of measures of conflict, the impact of recession, etc. The results show that the augmented Solow model outperforms the Feder-Ram model, and we provide some explanations for this result. In addition, our results suggest that military expenditure has a positive effect on economic growth within the UK, implying that the decision to reduce defence spending may have been detrimental to the UK economy.

Keywords: military expenditure; economic growth; UK; Feder-Ram; augmented Solow

JEL Classification: D74; H56; O41; O45

1 Introduction

Military expenditure is a core component amongst governments around the world that ensures the security of a nation or state. Defence budgets are usually set as a percentage of a country's Gross Domestic Product (GDP), typically ranging between

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***Corresponding author: Joo Young Jeon**, Department of Economics, University of Reading, Reading RG6 6AA, UK, E-mail: j.jeon@reading.ac.uk. https://orcid.org/0000-0001-6855-1659
Robert Hanson, United Kingdom Royal Air Force, London, UK, E-mail: robhanson90@hotmail.co.uk

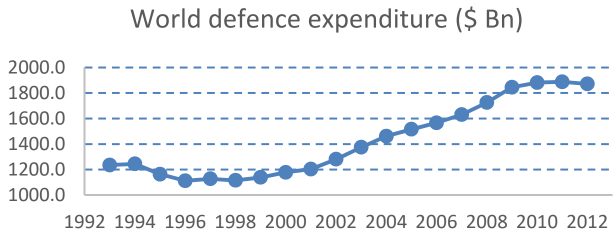

Figure 1: Trend in world defence expenditure. Note: Expenditure measured in billion USD at constant 2021 prices. Source: SIPRI.

1.0 % (Japan) to 8.5 % (Saudi Arabia) with a global average of 2.5 % of GDP (SIPRI 2013). While this may seem relatively insignificant as a percentage, aggregate military expenditure amounts to an estimated $1756 billion per annum in 2012 (SIPRI 2013). Until recently, military expenditure has continued to increase annually up until 2012, in which a decrease of 0.4 % in defence spending was observed relative to 2011. This decline can be attributed to the financial crisis of 2007 and the subsequent recession, leading to reductions in aggregate government spending. Please see Figure 1.

In response to the Global Financial Crisis, the UK underwent a Strategic Defence and Security Review (SDSR) in October of 2010 in an attempt to rectify the Ministry of Defence's (MOD) £38 billion budget deficit (Government 2010), while also bringing the UK's military into alignment with the current requirements and restraints faced by the UK as a result of the shift in economic climate. The SDSR aimed to achieve a reduction of between 10 and 20 % in the MOD's budget by essentially reducing both manpower and equipment employed by the tri-services (British Army, Royal Air Force, and Royal Navy collectively). The net result of the SDSR targeted to see employment within the defence sector reduced substantially with nearly 50,000 serving personnel made redundant by 2018 (Government 2010), and this target was more or less achieved. To date, the SDSR has been heavily criticised by the media. It is also speculated that the military budget, among others, was severely distorted first due to the Brexit, and then due to the COVID-19 pandemic. In this study we analyse the military expenditure and economic growth nexus in the UK from the 1960s, until the speculation of the Brexit.

Presently there is a large amount of literature covering theoretical and empirical aspects of the defence-growth nexus. However, as we show in the next section, there is a distinct lack of any scholarly consensus on the true influence of military expenditure on economic growth. This lack of agreement within the literature, while perplexing, provides incentives for further country-specific investigation into this subject. As we show later, there are evidences of positive, negative, mixed, and no effect of military expenditure on long term economic growth.

This paper aims to investigate the defence-growth nexus for the relatively untouched country, the United Kingdom. We aim to determine the significance of military expenditure on economic growth in the UK via the application of the two most dominant growth models. In addition, we modify these models to include a number of controls – enabling noteworthy conflicts and periods of austerity to be accounted for. We focus on the time period of 1960–2012 in order to avoid the effects of Brexit and the pandemic, since those merit their own deeper inspection.

This analysis provides two academic contributions. First, it adds to the literature on military expenditure – economic growth nexus, but specifically for the UK. The empirical analyses and the related directional effects (hypotheses from the literature) tested in the part come from this aim. Second, it provides a comparison between the two most popular theoretical models (the Feder-Ram model and the augmented Solow model) with the aim of identifying which model is best suited for empirical application within the UK. Policy-wise, the results of this paper may inform the policymakers in the UK (with some caution regarding the robustness) about the optimal military expenditure in the age of austerity, and which measure (model) to use to do so. We find that empirically, the augmented Solow model performs better than the Feder-Ram model, both in itself, and when we extend the models and run various robustness checks. Moreover, we find that for the time period considered, the military expenditure had a positive effect on the economic growth in the UK.

The rest of the paper is organised as follows. Section 2 provides a detailed review of the literature focusing on the formation of a number of schools of thought and the consequential outcomes that they provide, followed by a number of recent additions to the literature which require some consideration when conducting research into the topic. Section 3 recalls the theoretical models used within this research, outlining the advantages and downfalls of each. This is followed by the explanation of data and the economic methods employed in Section 4. Results of the regression estimations are displayed in Section 5, and conclusions and policy implications are discussed, along with suggestions for further research in Section 6.

2 Literature Review

2.1 Theoretical Development

The defence-growth nexus within the literature appears to stem predominantly from the empirical cross-country analyses by Benoit (1973, 1978). This has led to the formation of numerous econometric and subsequently theoretical models. Previous research conducted into the area illustrates a distinct lack of a rigorous theoretical framework and instead forms empirical models of a somewhat ad hoc nature. As a result of this, varying schools of thought have put forward theories in an attempt to advance the understanding behind the ambiguous effects of military spending on economic growth.

The Keynesian demand side models, which build on the work of Smith (1980), relate military expenditure to economic growth via the multiplier effect as seen in a recent empirical study by Pieroni, d'Agostino, and Lorusso (2008). The lack of consideration towards supply side factors, however, have driven empirical studies to incorporate such functions into the model's framework (see Deger and Smith 1983). Further studies carried out by Romer (2000) and Taylor (2000) in which modifications to the traditional IS-LM/AS-AD frameworks are made. The results of these studies provide viable alternatives to the traditional Keynesian model, and complement the traditional models used amongst the literature. Very recently, Elveren, Töngür, and Myers (2023) propose a post-Keynesian model to understand military spending and growth relationship.

The counterpart to the Keynesian model is the neo-classical supply side model which comprises the original work of Feder (1983, 1986) with additions made by Biswas and Ram (1986) and Ram (1986) and is hence referred to as the 'Feder-Ram' model. This influential model forms a framework consisting of two-sectors originally – that of the military and civilian (Feder 1983); with the belief that the private and public sectors have differing productivity levels of labour and hence the effect on economic growth will invariably differ with each sector. The model has since evolved to include a range of other variables, including industrial/non-industrial sectors, as proposed by Feder's four factor model (Feder 1986) in an attempt to further the understanding within the defence-growth nexus. Additional studies by Adams, Behrman, and Boldin (1991) and Macnair et al. (1995) suggest that the inclusion of factors such as exports and other government sectors can yield more fruitful outcomes.

Due to the inclusion of military expenditure as an explanatory variable within the single equation economic growth framework, the Feder-Ram model has established itself as one of the preferred approaches when modelling military expenditure. Dunne, Smith, and Willenbockel (2005) attribute the model's popularity to its direct link from a theoretical model to an econometric specification. Unlike the Keynesian models, the Feder-Ram model utilises supply side variables (the neo-classical production function) which may account for its widespread adoption as a starting framework when dealing with defence spending and economic growth. Similarly, the model has strong theoretical roots (Mintz and Huang 1990, 1991) which are unlike other models that incorporate ad hoc additions in their specifications (Heo 2010).

The model is not without its limitations, however. Dunne, Smith, and Willenbockel (2005) have criticised the framework for its econometrical downfalls. The inclusion of the military spending growth rate as an explanatory variable causes a simultaneity problem within the model.[1] It is highly probable that a problem with multicollinearity within the last two variables of the model may arise when conducting regressions. This may lead to artificially larger standard errors and therefore may further lead to imprecise estimates and the construction of incorrect conclusions. The use of ordinary ridge regression (ORR) has been employed in some studies (Mintz and Huang 1991) in an attempt to solve the multicollinearity problem. El-Dereny and Rashwan (2011) confirm that all types of ridge regressions (ordinary ridge regression (ORR), generalised ridge regression (GRR) and direct ridge regression (DRR)) are preferential to ordinary least squares (OLS) regressions in the presence of multicollinearity, hence providing a viable alternative should the problem arise within this study. Further to these issues, the model itself is static (contains no lags) which reduces its effectiveness in explaining the outcomes of changes in military spending. On a similar note, the causality relationship between growth and military spending is not accounted for; that is to say that while military expenditure today can affect growth today (in terms of GDP), today's GDP ultimately determines tomorrow's military spending. By allowing the explanatory variables to include such lags, the explanatory power of the model can be improved. Sezgin (2000) building on his previous work (Sezgin 1997), added lags to his four-factor Feder-Ram model and concluded that 'the statistical results are highly improved' (Sezgin 2000). Yildirim and Öcal (2016) conduct regressions using varying techniques, amongst which included an augmented Feder-Ram model containing lags. The results (unsurprisingly) indicate that of the conducted regressions, the most preferred model selection was that of the augmented Feder-Ram model.

The deficiencies apparent within the Feder-Ram model reduce its value within empirical research (Dunne, Smith, and Willenbockel 2005). These downfalls have led to the application of the 'augmented Solow growth model' within the literature. Building upon the original work of Solow (1956) and Swan (1956), it was introduced by Mankiw, Romer, and Weil (1992) and was first used to identify the link between military spending and economic growth by Knight, Loayza, and Villanueva (1996). The augmented Solow model is developed initially from a neo-classical production function not too dissimilar from that observed in the Feder-Ram model. In terms of composition, like the Feder-Ram model, the augmented Solow model features the economic growth rate as the dependant variable. Unlike the Feder-Ram model, the augmented Solow includes a term which represents the labour augmenting technical progress and uses a single-sector to produce one good as opposed to the two-sector seen in the Feder-Ram model. Knight, Loayza, and Villanueva (1996) construct both

1 Assume for simplicity that the military expenditure growth rate was to remain constant, it is therefore apparent that changes to economic growth will be strongly linked to subsequent changes in military expenditure.

time series and panel data sets and apply the augmented Solow model to determine the effect of military spending on growth and conclude that military spending has growth-retarding effects. The augmented Solow model features lags of military expenditure and GDP making it dynamic, and hence econometrically more preferable compared to the static Feder-Ram model.

2.2 Further Additions to the Literature

Previous literature has proven valuable in providing the basis for a theoretical framework when modelling military spending and its effects on economic growth. However, the extent to which conclusions attained in the literature can be related to policy implications, remains questionable. Due to the varying nature of the aforementioned literature in both theoretical approach and school of thought, empirical econometric modelling, time periods observed, and countries studied, the outcomes of such research have often led to conflicting conclusions with regards to the impact of military spending on economic growth. Even in the last few years, the relationship between military expenditure and economic growth has been investigated for South Africa (Phiri 2019), India (Abdel-Khalek, Mazloum, and El Zeiny 2019), Jordan (Dimitraki and Win 2021), Turkey (Khalid and Habimana 2021) to name a few. These studies often select different models and arrive at different conclusions. The ambiguity within these studies can be partially attributed to the lack of empirical data when conducting econometric analyses, a factor which is paramount if a strong conclusion is to be found. The availability of an additional 20 years of data since the last major sustained state of political and military tension – the Cold War, as well as the inclusion of the Iraq and Afghanistan conflicts, has aided research into identifying relationships between economic growth and military spending.

Alptekin and Levine (2012) run a meta-analysis on such studies and find that while military expenditure does not have a negative effect on economic growth overall, it has a positive effect for the developed countries. Dunne and Tian (2013) also update and extend previous research – with the outcome of a survey covering almost 170 studies. The survey concludes that more recent studies provide evidence of a negative effect of military expenditure on economic growth. Awaworyi Churchill and Yew (2018) conduct a meta-analysis where they find a mixed result instead. The positive effect of military expenditure on growth is pronounced for developed countries, but not necessarily developing countries. In another meta-analysis, Yesilyurt and Yesilyurt (2019) find results that are consistent with the hypothesis of no effect. They further find that certain study characteristics appear significant determinants of the effect of military expenditure on growth, but there does not appear to be a simple pattern and different characteristics are significant in their three samples. These provide evidence that military expenditure can have a negative significant effect on economic growth or a null effect. These are inconsistent with the theoretical work conducted by Benoit (1973) in which military expenditure was determined to have a positive association with economic growth.

Studies incorporating the non-linear effects of military expenditure are also prevalent due to the greater availability and range of observations amongst data. Yakovlev (2007) investigates the effect of arms trade alongside military expenditure and economic growth via utilisation of the augmented Solow model and a reformulated Barro model. He concludes that the augmented Solow model provides more robust estimates than that of the Barro model, but more importantly that military expenditure has a positive effect on countries that are net exporters of arms while it is the opposite for the net importers of arms.

This area of literature is quite sizeable and evolving. However, these meta-analyses and summary studies provide an overall mixed result on (i) the effectiveness of the model selected, as well as (ii) the direction of the effect of military expenditure on economic growth. Indeed, using various econometric methods, a positive relationship between military expenditure and economic growth is found by Atesoglu (2002, 2009) in the USA, Farzanegan (2014) and McDonald (2012) in Iran, Oriavwote and Eshenake (2013) in Nigeria, Wijeweera and Webb (2009) in Sri Lanka, and Sezgin (2000) in Turkey among others. Similarly, D'Agostino, Dunne, and Pieroni (2012) and Deger and Smith (1983) in LDCs, Smith (1980) and Keller, Poutvaara, and Wagener (2009) in OECD countries, Knight, Loayza, and Villanueva (1996) in multiple countries, Mylonidis (2008) and Malizard (2016) in the European Union, Wijeweera and Webb (2012) in Sri Lanka, Manamperi (2016) in Greece and Turkey, among others find a negative relationship. Null relationship is found by Dunne (1996) in the LDCs, Kollias and Paleologou (2010) and Dunne and Nikolaidou (2012) in the EU15, Heo (2010) in the United States, Abdel-Khalek, Mazloum, and El Zeiny (2019) in India, Alexander and Hansen (2004), Ward et al. (1995), Yakovlev (2007), Yildirim and Öcal (2016) in multiple countries. Finally, mixed results with different theoretical or econometric model specifications, or due to different dataset are found by Aizenman and Glick (2006), Cuaresma and Reitschueler (2004), Elveren and Hsu (2016), Dunne and Tian (2015), Emmanouilidis and Karpetis (2020), Julide and Sezgin (2002), Nikolaidou (2016) etc.

2.3 Contribution to the Literature

Among the long list of studies, covered above, many methodological models are used. In this study we employ both the Feder-Ram, and the Solow models. Methodologically our study fits within this area and complements McDonald (2012) who consider both models like ours, D'Agostino, Dunne, and Pieroni (2012) who use the two models and an endogenous growth model, Wijeweera and Webb (2012), who use the Feder-Ram and a military Keynesian model, and Dunne (1996) who uses a survey and the Keynesian method. The novelty of our study is using a single country data, and thoroughly compare the Feder-Ram and the Solow models with various extensions and robustness conditions.

In the same line, this study provides a unique and refreshing view on the defence-growth relationship, boasting the only time series study focused on the UK to date. Unlike previous country-specific studies, this paper incorporates a larger timeframe of observations, thus furthering the robustness of the models employed. Previous methods used to formulate variables in both models are re-evaluated, with proposed changes implemented to create better fitting models. These suggested methodological improvements may prove fruitful for future advancements within the defence-growth nexus.

To the best of our knowledge, this paper is the first to include structural breaks in military spending in the form of the global recession (and previous recessions) into both the Feder-Ram and augmented Solow models, providing an analytical perspective into the decision to cut defence spending in times of austerity. This outlook is further supplemented with the inclusion of conflict measures, allowing the effects of the conflict in Afghanistan to be quantified. The inclusion of arms exports/imports offers an opportunity to branch out beyond military expenditure, providing a final model capable of attaining a level of diverseness unseen in the literature previously. Finally, military expenditure is disaggregated and regressed in both models to highlight how individual components of defence spending affect growth, a technique which has yet to be seen for this type of study, hence potentially yielding benefits when addressing the defence-growth nexus in future research.

3 Theoretical Modeling

3.1 The Evolution of the Feder-Ram Based Defence-Growth Model

As mentioned in Section 2, the Feder-Ram growth model is one of the most prevalent models employed within the literature to explain the defence-growth relationship. While many variations of the model have been utilised, the core composition of the model is ultimately derived from a neo-classical perspective. Originally, Feder (1983) claimed that economic growth is related to fluctuations in the labour and capital outputs through an underlying production function. This led to the disaggregation of total output within an economy into two sectors: exports and non-exports. Biswas and Ram (1986) and Ram (1986), following on from Feder's work, proposed an alternative two sector model comprised of a government and private sector, which became the traditional Feder-Ram two sector model used within the literature. Further, Mintz and Huang (1990, 1991) further disaggregated total output by introducing a third sector – defence, on the basis that military production differentials may differ from that of other government sectors.

For this empirical investigation, a three sector Feder-Ram type model will be used. The model employed consists of an aggregate production function which assumes a three-sector economy consisting of: a military production function (M), a non-defence production function (N) and a civilian production function which accounts for the rest of the economy (C). The model is considered to be 'fairly well grounded in the neo-classical production-framework' (Biswas and Ram 1986; p. 367) and provides a direct link from a theoretical model to an applied econometric specification (Dunne, Smith, and Willenbockel 2005). The model assumes that all sectors employ homogenous labour and capital (L and K respectively) and can be presented formally as:

$$M = M\left(L_{m,}K_m\right) \tag{1}$$

$$N = N\left(L_{n,}K_n\right) \tag{2}$$

$$C = C\left(L_{c,}K_{c,}M, N\right) \tag{3}$$

The inclusion of M and N, within equation (3) captures the externality effect that military and non-military production have on the rest of the economy.

The allocations of inputs within sectors are denoted by the subscripts such that the sum of each input is equal to that of the respective aggregate output for that factor of production within the economy. More formally:

$$L_m + L_n + L_c = L \tag{4}$$

$$K_m + K_n + K_c = K \tag{5}$$

As output has been separated into three differing sectors, aggregate output within an economy (Y) can thus be written as:

$$Y = M + N + C \tag{6}$$

where the values of M, N and C are understood to represent the monetary output values as opposed to the output quantities.

We are therefore able to express aggregate output within an economy as a function of its respective capital and labour inputs from each sector:

$$Y = M + N + C = f(L, K) = M_l + M_k + N_l + N_k + C_l + C_k \tag{7}$$

where Y is national income (measured in Gross Domestic Product, GDP).

Taking the differential of military and non-military sectors with respect to the rest of the economy, C, allows comparisons between the marginal productivities of both sectors:

$$\frac{M_l}{C_l} = \frac{M_k}{C_k} = (1 + \delta_m) \tag{8}$$

$$\frac{N_l}{C_l} = \frac{N_k}{C_k} = (1 + \delta_n) \tag{9}$$

where δ_i represents the productivity differential between the defence/non-defence sectors and the civilian sector.

A growth equation can be obtained by differentiating equation (6) with equations (1)–(3) with constraints as per (4) and (5):

$$\widehat{Y} = \frac{C_l L}{Y}\widehat{L} + C_k \frac{I}{Y} + \left(\frac{\delta_m}{1 + \delta_m} + \theta_m\right) \frac{M}{Y}\widehat{M} + \theta_m \widehat{M} + \left(\frac{\delta_n}{1 + \delta_n} + \theta_n\right) \frac{N}{Y}\widehat{N} + \theta_n \widehat{N} + \varepsilon \tag{10}$$

where I is the derivative of capital (K) and is representative of net investment within an economy, θ represents the externality effect of both the military and non-military sectors as mentioned previously and ˆ denotes respective growth rates.

A modification to the original model proposed by the literature is postulated in which military and non-military government spending are expressed as a ratio of total government spending, G, as opposed to total output, Y, as presented in equation (10). The rationale behind this proposed modification is that economic output can vary dramatically each year and while GDP determines defence budgets implicitly, it is ultimately down to the government's spending budget, as illustrated below:

c

$$\widehat{Y} = \frac{C_l L}{Y}\widehat{L} + C_k \frac{I}{Y} + \left(\frac{\delta_m}{1 + \delta_m} + \theta_m\right) \frac{M}{G}\widehat{M} + \theta_m \widehat{M} + \left(\frac{\delta_n}{1 + \delta_n} + \theta_n\right) \frac{N}{G}\widehat{N} + \theta_n \widehat{N} + \varepsilon \tag{11}$$

The model is developed further with the inclusion of the arms sector along with a number of control variables in an attempt to improve upon the empirically limited traditional model:

$$\begin{aligned} \widehat{Y} = {} & \frac{C_l L}{Y}\widehat{L} + C_k \frac{I}{Y} + \left(\frac{\delta_m}{1 + \delta_m} + \theta_m\right) \frac{M}{G}\widehat{M} + \theta_m \widehat{M} + \left(\frac{\delta_n}{1 + \delta_n} + \theta_n\right) \frac{N}{G}\widehat{N} + \theta_n \widehat{N} \\ & + \frac{AE}{Y}\widehat{AE} + \frac{AI}{Y}\widehat{AI} + \pi + R + MI + HI + \varepsilon \end{aligned} \tag{12}$$

where AE, AI, represent arms exports and imports respectively, π is inflation, R is a recession dummy, and MI, HI represent dummy variables for medium and high intensity conflicts.

The model is progressed further by disaggregating the components of military expenditure with the intent of illustrating the sections affecting economic growth the most:

$$\hat{Y} = \frac{C_l L}{Y}\hat{L} + C_k\frac{I}{Y} + \left(\frac{\delta_{EQ}}{1+\delta_{EQ}} + \theta_{EQ}\right)\frac{EQ}{G_{t-1}}\widehat{EQ} + \theta_m\widehat{EQ} + \left(\frac{\delta_{PE}}{1+\delta_{PE}} + \theta_{PE}\right)\frac{PE}{G_{t-1}}\widehat{PE}$$
$$+ \theta_m\widehat{PE} + \left(\frac{\delta_{IN}}{1+\delta_{IN}} + \theta_{IN}\right)\frac{IN}{G_{t-1}}\widehat{IN} + \theta_m\widehat{IN} + \left(\frac{\delta_{OT}}{1+\delta_{OT}} + \theta_{OT}\right)\frac{OT}{G_{t-1}}\widehat{OT}$$
$$+ \theta_m\widehat{OT} + \left(\frac{\delta_n}{1+\delta_n} + \theta_n\right)\frac{N}{G}\hat{N} + \theta_n\hat{N} + \varepsilon \quad (13)$$

where EQ is defence equipment expenditures, PE is military personnel expenditures, IN is defence infrastructure expenditures and OT is other expenditures not categorised by the previous sections.

The ease of conversion from a theoretical model to that of an empirically measurable econometric one; combined with the relatively straight forward measurability of the variables has cemented this model within the defence-growth literature. In addition to this, the flexibility of the types of empirical data used has further contributed to the model's prevalence within the literature. However, while the preference for Feder-Ram type models remains strong within the literature, there are a number of issues which question the validity of the model. From a theoretical perspective, it is not possible to isolate the economy into discrete sectors (Alexander 1990). This is because while it is sufficient to account for each sector individually (as presented in the Feder-Ram model), it is not possible to measure the interaction between those sectors. McDonald (2012) illustrates this by explaining that growth within the private sector would subsequently lead to an influx in tax revenue, thus leading to larger defence and non-defence government sectors but that the Feder-Ram model is incapable of capturing this relationship.

Another issue with this model comes with the interpretation of the productivity differential, δ_i. Studies which include a nonzero δ_i have previously concluded with one sector becoming more (or less) efficient in comparison (see Ward, David, and Steve 1993). Dunne, Smith, and Willenbockel (2005) argue that this is not the case, but rather it is merely due to deviations in the implicit price ratio of defence/non-defence and civilian sectors in the formation of the measurements of GDP.

From an econometric perspective, there is a 'severe simultaneity problem' (Dunne, Smith, and Willenbockel 2005; p. 456) which arises from the inclusion of the military expenditure growth rate in the right-hand side of the equation. If a government sets the share of its military expenditure as a constant ratio, then invariably fluctuations in economic growth will hence determine military expenditure growth. Similarly, there is a potential problem of multicollinearity within the last four terms of equation (10): the defence share of GDP, non-defence share of GDP, defence spending increase, and non-defence public spending increase. This occurs as the variables are highly correlated with each other often as a result of the way the non-defence government expenditure is calculated.[2]

Finally, there is an issue with potential misspecification bias within the model. Alexander and Hansen (2004) claim that the construction of the multi-sector model may lead to omitting statistically significant variables (such as exports) and may subsequently lead to results affected by biases, thus causing further concerns over the accuracy of reported regressions.

3.2 The Augmented Solow Model

According to Dunne, Smith, and Willenbockel (2005), the deficiencies in the Feder-Ram model mentioned previously, are severe enough to hinder its empirical value when explaining the defence-growth relationship. Instead, they argue for an alternative framework, comprised of a more traditional method of modelling growth – the Solow growth model modified to incorporate Harrod-neutral technical progress.[3] This augmented Solow model provides an explanation for economic growth via the accumulation of both human and physical capital.

The augmented Solow model is reliant on two main assumptions: first, the way in which military expenditure affects economic growth (i.e. the causality between the two) works in the same way as in the Feder-Ram model. Second, unlike the Feder-Ram model, which is based upon a sectoral approach, the augmented Solow model assumes that fluctuations in the share of military expenditure of GDP, *m (=M/Y)*, affect productivity within the individual composing factors via a levelling effect on the efficiency parameter which influences Harrod-neutral (labour augmenting) technological change. Alternatively, *m* affects the total factor productivity within the economy.[4]

To formally model the augmented Solow framework, an aggregate neo-classical production function with labour-augmenting technological progress is employed:

$$Y(t) = K(t)^{a}[A(t)L(t)]^{1-a} \tag{14}$$

where Y represents aggregate real income, K is the real capital stock, L is labour, and A represents the technology parameter which can be represented as:

2 Empirically this has been calculated by subtracting military expenditure from total government expenditure and thus the two variables are inevitably linearly related.

3 Technology is said to be Harrod-neutral if it is seen to be labour augmenting and differs from traditional Solow-neutral innovations which is considered to be capital augmenting.

4 The total factor productivity of an economy is essentially output unaccounted for after all other factors of production are considered and can be used as a proxy for technological growth.

$$A(t) = A_0 e^{gt} m(t)^{\theta} \quad (15)$$

where g represents the exogenous rate of Harrod-neutral technical progress and m is the share of military expenditure relative to GDP. The levelling effect mentioned previously, can be identified from equations (11) and (12) as a permanent change in m has no effect on the long-run steady growth rate, but clearly has an effect on income in the transition to a steady-state level but also in the growth rates occurring along the path to such a steady-state level.

Employing the standard Solow model assumptions of a constant savings rate (s), constant labour force growth rate (n), and constant rate of capital depreciation (d) the dynamics of capital accumulation can be modelled as follows:

$$\dot{k}_e = sk_e^a - (g+n+d)k_e \Leftrightarrow \frac{\partial \ln k_e}{\partial t} = se^{(a-1)\ln k_e} - (g+n+d) \quad (16)$$

where $k_e = K/[AL]$ which depicts the ratio of capital-labour with a as the constant capital-output elasticity. The steady state level of k_e is given by:

$$k_e^* = \left[\frac{s}{g+n+d}\right]^{1/(1-a)} \quad (17)$$

Equation (13) can be linearised via a truncated Taylor series expansion around the steady state k_e^* as given by equation (14):

$$\frac{\partial \ln k_e}{\partial t} = (a-1)(g+n+d)[\ln k_e(t) - \ln k_e^*] \quad (18)$$

Since $\ln y_e = \ln[Y/(AL)] = a \ln k_e$ (rearranged from (11)):

$$\frac{\partial \ln y_e}{\partial t} = (a-1)(g+n+d)[\ln y_e(t) - \ln y_e^*] \quad (19)$$

Thus, a formal representation of the steady-state level of output per effective labour unit is:

$$y_e^* = \left[\frac{s}{g+n+d}\right]^{a/(1-a)} \quad (20)$$

Equation (16) illustrates the structure of output per effective labour unit through the transition to a steady-state level. However, in order to make (16) viable for empirical econometric work, it must be integrated forward one period, from $t-1$ to t:

$$\ln y_e(t) = e^z \ln y_e(t-1) + (1-e^z)\ln y_e^*, z \equiv (a-1)(n+g+d) \quad (21)$$

The variable, y_e, can be linked to GDP per capita, $y = Y/L$, by equations (12), (17), and (18):

$$\ln y(t) = e^{z} \ln y(t-1) + (1-e^{z})\left\{\ln A_0 + \frac{a}{1-a}\left[\ln s - \ln(g+n+d)\right]\right\} + \theta \ln m(t) - e^{z}\theta \ln m(t-1) + (t-(t-1)e^{z})g \tag{22}$$

In a steady-state, equation (19) reduces to:

$$\ln y^{*}(t) = \ln y_{e}^{*} + \ln A_0 + \theta \ln m^{*} + gt \tag{23}$$

where θ is the elasticity of steady-state income with respect to the long run military expenditure ratio of GDP, m. As Dunne, Smith, and Willenbockel (2005) explain, a permanent 1 % increase in the variable, m, causes a θ % shift in the steady-state per-capita income path (i.e. GDP per capita).

The augmented Solow model is thus empirically applied in the following format:

$$\Delta \ln y(t) = \beta_0 + \beta_1 \ln y(t-1) + \beta_2 \ln s + \beta_3 \ln(g+n+d) + \beta_4 \ln m(t) + \beta_5 \ln m(t-1) + \varepsilon \tag{24}$$

where $\beta_1 = e^{z} - 1$; $\beta_2 = (1-e^{z})a/(1-a)$; $\beta_3 = -(1-e^{z})a/(1-a)$

The traditional augmented Solow model presented in equation (24) is modified in a similar manner to the Feder-Ram model shown in equation (11) by constructing military spending, $m = \frac{M}{Y_{t-1}}$, as a ratio of government spending rather than GDP, $mg = \frac{M}{G_{t-1}}$.

$$\Delta \ln y(t) = \beta_0 + \beta_1 \ln y(t-1) + \beta_2 \ln s + \beta_3 \ln(g+n+d) + \beta_4 \ln mg(t) + \beta_5 \ln mg(t-1) + \varepsilon \tag{25}$$

where Δ represents the difference or change, y is national income in GDP, s is the savings ratio share as a proportion of GDP, n is the labour force growth rate, g represents technological progress (typically proxied by total factor productivity), d is capital depreciation, and m represents the share of military expenditure in GDP.

Again, like the Feder-Ram models, the augmented Solow model is improved upon with the inclusion of the arms sectors, along with a number of control variables:

$$\Delta \ln y(t) = \beta_0 + \beta_1 \ln y(t-1) + \beta_2 \ln s + \beta_3 \ln(g+n+d) + \beta_4 \ln mg(t) + \beta_5 \ln mg(t-1) + \ln \frac{AE}{Y_{t-1}} + \ln \frac{AI}{Y_{t-1}} + \ln \pi + R + MI + HI + \varepsilon \tag{26}$$

The augmented Solow model is also disaggregated into the four components of military expenditure as per the Feder-Ram model in equation (13) to provide a further comparison between the two theories:

$$\Delta \ln y(t) = \beta_0 + \beta_1 \ln y(t-1) + \beta_2 \ln s + \beta_3 \ln(g+n+d) + \beta_4 \ln eq(t) + \beta_5 \ln eq(t-1) + \beta_6 \ln pe(t) + \beta_7 \ln pe(t-1) + \beta_8 \ln in(t) + \beta_9 \ln in(t-1) + \beta_{10} \ln ot(t) + \beta_{11} \ln ot(t-1) + \varepsilon \tag{27}$$

The dependant variable is economic growth rate – as in the Feder-Ram model, but unlike the Feder-Ram model, the augmented Solow model contains an exogenously determined variable; technological growth, which follows the traditional growth literature more closely.

There are a number of advantages of employing the augmented Solow growth model over the Feder-Ram model. First, research has shown that the augmented Solow model can account for a much larger proportion of growth when compared to Feder-Ram type models.[5] Second, the model is dynamic due to its inclusion of the lagged variables of output and military expenditure. This differs from the static Feder-Ram model and is particularly useful when explaining the defence-growth relationship as the full extent of changes in military expenditure on growth are not felt immediately, but rather in the subsequent time periods. Further to this, the exclusion of variables such as non-defence government spending reduces the problem of multicollinearity which is present within the Feder-Ram model.

While the augmented Solow model is considered a 'tighter' model with clearer distinctions between variables and more flexibility on the testing of restrictions (Dunne, Smith, and Willenbockel 2005), it remains the lesser adopted counterpart to Feder-Ram style models. There are a number of possible reasons for this. For instance, while the model is developed upon the theoretically sound Solow model, the addition of military expenditure is considered somewhat ad hoc as there is 'little reason to expect the share of military expenditure to change technology' (Dunne, Smith, and Willenbockel 2005; p. 458). Similarly, the model is typically only applied to studies employing cross-country panel data rather than individual countries with time series data. This is due to the difficulties that occur when interpreting results, coupled with the scarcity of necessary data such as depreciation rates and technology progress change (Atesoglu 2009).

4 Data and Method

4.1 Data

To estimate the models, data for the UK between the periods 1960–2012 was collated. GDP is chosen as a measure of total output over Gross National Product (GNP) due to the requirement of capturing output produced solely by the UK. The Feder-Ram model uses GDP growth rate as a dependant variable while the augmented Solow

5 According to Mankiw, Romer, and Weil (1992), the augmented Solow models can account for nearly 80 % of cross-country variation in growth, while the Feder-Ram type models typically account for around 66 % (Mintz and Huang 1990)

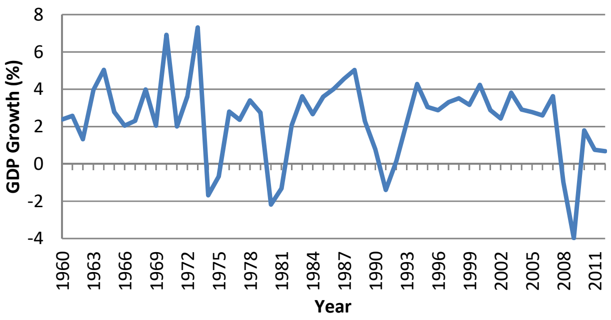

Figure 2: GDP growth for the UK for the period 1960–2012.

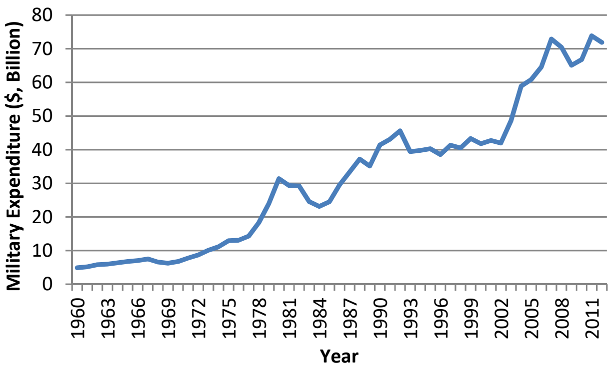

Figure 3: Military expenditure for the UK for the period 1960–2012.

model uses the natural log of GDP. This data was obtained via the World Bank and is given as a percentage and US dollars at 2000 prices respectively (Figure 2).

Military expenditure figures were taken from the UK Public Spending Database and converted from pounds to dollars at 2000 prices and conforms to the North Atlantic Treaty Organisation (NATO) definition of military expenditure (Figure 3).[6] While the use of data from the Stockholm International Peace Research Institute (SIPRI) is well established within the literature, the lack of observations before 1988 limits its usefulness when conducting country specific time series regressions.[7] However, for robustness UK Public Spending and SIPRI data for the years 1966–2012 are compared below (Figure 4):

6 This includes all current and capital expenditures on the armed forces, including peacekeeping forces; defence ministries and other government agencies engaged in defence projects.

7 As the reduced observations becomes a substantial limiting factor when reporting results.

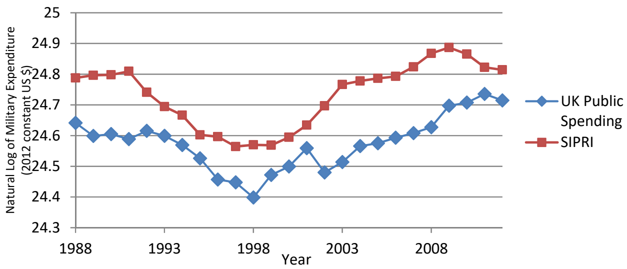

Figure 4: Comparison of SIPRI and UK public spending database military expenditures, 1988–2012.

While there is a small discrepancy between the values, the overall trends observed are similar – implying that the UK Public Spending data has validity.[8] Disaggregated military expenditure data was collated via annual reports published by NATO and included percentages of total military expenditure spent on; equipment, personnel, infrastructure, and other uncategorised expenditure.[9] Non-defence government expenditures are constructed by subtracting defence spending from total government expenditure in 2000 prices obtained from the World Bank. Employed labour growth rate is chosen over population growth rate due to the larger range of movement observable in the long run and was obtained from the World Bank Database. Gross domestic investment, annual inflation rates and depreciation rates were also obtained from the World Bank. Two binary variables are used as a proxy for conflict intensity: *med ints* and *hi ints*, with data obtained from the international Peace Research Institute of Oslo (PRIO).[10] The former denotes a 1 if the number of deaths for the respective year lies between 25 and 999 (medium intensity conflict) and zero if otherwise, with the latter assigned a 1 if the number of battle-related deaths exceeds 1000 (high intensity) and zero if otherwise.[11] The threshold values for the conflict variables used are ascribed as per the categories of conflict defined within the PRIO Armed Conflict Dataset (2013). Finally, total factor productivity is used as a proxy for technological growth and was obtained from the Total Economy Database (TED).

8 This could be attributed to systematic errors such as the conversion of both military expenditures into constant 2012 us dollar prices, and the differences in methods used to record such data.

9 Other expenditures include operations and maintenance expenditures, other R&D expenditures and expenditures not allocated among above-mentioned categories.

10 Where armed conflict is defined as a contested incompatibility, which concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state (PRIO 2013).

11 Deaths include that of serving members of the UK armed forces and the opposing force.

4.2 Empirical Strategy

Given that the data used is time series, there are a number of econometric concerns which must be addressed. First, the use of non-stationary variables may induce spurious results within time series regressions (Granger and Newbold 1974), thus each variable used must be tested for the presence of a unit root. The Augmented Dickey-Fuller test (Dickey and Fuller 1979) is applied along with the Phillips-Perron unit root test (Phillips and Perron 1988) for robustness, the results of which can be seen in Appendix Table 3. The results of the unit root test report that the variable depicting the share of gross domestic investment in GDP (I/Y) within the Feder-Ram model and the inflation rate control variable contained a unit root, thus the first difference was taken to render the variables stationary. As the augmented Solow model uses log changes, stationarity was not an issue. But unit root tests are reported in the Appendix for completeness.

Second, there is a potential issue with autocorrelation within the models due to their longitudinal design. To test for this, Durbin-Watson and Durbin's Alternative tests (Durbin and Watson 1950) are employed along with the Breusch-Godfrey serial correlation Lagrange multiplier test for robustness (Breusch 1979; Godfrey 1978).[12] The results of the above indicated that serial correlation was not present amongst the models employed in this paper.

Thirdly, there is a potential problem of multicollinearity within the last four variables of the basic Feder-Ram model (Dunne, Smith, and Willenbockel 2005). This is addressed by observing the Variance Inflation Factor (VIF) on the regressions to determine the presence of multicollinearity (the results are in the Appendix Tables 4–7), coupled with multivariate correlation matrices for robustness. Both tests indicate a significant level of multicollinearity when the externality effects of the defence and non-defence government sectors are included, causing issues with determining the significance of affected variables. Hence, the Ordinary Ridge Regression (ORR) is applied in the Feder-Ram models (see Mintz and Huang 1990). Further to this, the externality variables are transformed by taking the first difference – which notably reduces the VIF values but at the expense of turning the externality effects into short run variables.

Breusch-Pagan/Cook-Weisberg tests (Breusch and Pagan 1980) are carried out to check for the presence of heteroscedasticity along with Ramsey RESET tests for model misspecification, with both tests indicating no significant problems. Finally, the Portmanteau test for autocorrelation is applied to the residuals of the regressions as a means of diagnostics checking each model.

12 Durbin's Alternative test is used in the augmented Solow as there is a lagged dependent variable which creates bias in Durbin-Watson stats.

When transforming variables into log changes within the augmented Solow model, absolute log values were constructed in order to avoid issues regarding the log of negative values. Each initially negative absolute log value was subsequently multiplied by –1. This method was chosen in favour of translating the variables prior to logging, as the intercepts of the regressions are shifted when the latter technique is used. By using absolute log values, the interpretation of the intercept remains unaltered, but the chosen technique is considerably more arduous.

4.3 Preliminary Analyses

Preliminary testing was conducted by constructing a Vector Auto Regressive (VAR) model consisting of GDP and military expenditure.[13] The results indicate that the first lag of military expenditure has a negative, albeit insignificant effect on GDP, with the second lag having a positive, yet insignificant effect also.[14]

In order to identify the optimal number of lags to include within the augmented Solow autoregressive distributed lag model, a selection criterion is applied. The Akaike information criterion (AIC) is chosen over the Bayesian information criterion (BIC) to determine lag length due to its reduced penalisation of free parameters and the ability to select an appropriate lag given an ambiguous model (Burnham and Anderson 2002). The results (in Appendix Table 10) report that one lag of military expenditure is optimal, and hence military expenditure and a one period lag of military expenditure will be implemented in the augmented Solow model. This is similar to Heo (2010) in the case of the US but differs from McDonald (2012) who determined that two lags were optimal for the US.

Further, the Johansen cointegration test is applied to determine whether there is cointegration between military expenditure and economic growth. The results (in Appendix Table 11) indicate that there is no evidence of cointegration between the two variables.

In a similar manner to that of Dunne and Smith (2010), causality between the two variables is identified via the conducting of a Granger Causality tests with two lags of each variable. The results of the test imply that there is no evidence that military expenditure Granger-causes GDP. Conversely, there is evidence at the 10 % level to suggest that GDP Granger-causes military expenditure.[15] However, as Dunne and Smith (2010) note the results of Granger Causality tests are sensitive to a number of

13 The first difference of both variables is used to avoid spurious regressions.

14 Results of the VAR are reported in Appendix Table 8, with evidence of VAR stability in Appendix Table 9.

15 For full results refer to Appendix Table 12.

variables including the number of lags, number of variables within the VAR and number of observations amongst other factors.

The result of the Granger Causality test is unsurprising given that military expenditure is a component of government expenditure which is determined, in part, by GDP. Similarly, as the literature review has highlighted, the effects of military expenditure on GDP are somewhat ambiguous, hence prompting a requirement for further research to be conducted into the defence-growth nexus. Also, given thias, we stick to one lag in our regression analysis.

5 Regression Results

The results of the Feder-Ram and augmented Solow regressions are reported in Tables 1 and 2. Turning first to the overall performance and fit of the models, it is

Table 1A: Feder-Ram models.

Dependant variable: economic growth rate, $\widehat{Y}$	**Coefficient (standard error)**			
Variables	**Model 10**	**Model 10a**	**Model 11**	**Model 12**
Constant	1.7969***	2.2929***	2.2630***	2.6924***
	(0.3689)	(0.3627)	(0.3314)	(0.5039)
Capital investment, $\frac{I}{Y_{t-1}}$	0.0240	0.1369	0.0243	0.0040
	(0.0185)	(0.1876)	(0.1862)	(0.1430)
Labour, $\widehat{L}$	0.7349***	0.7428***	0.6727***	0.3977**
	(0.1881)	(0.2011)	(0.1945)	(0.1966)
Defence expenditures, $\frac{D}{Y}\widehat{D}$	−4.5708**	−0.7894	–	–
	(2.0139)	(0.6940)	–	–
Defence sector externality, $\widehat{D}$	0.2217*	–	0.0544	–
	(0.1156)	–	(0.0137)	–
Non-defence expenditures, $\frac{N}{Y}\widehat{N}$	−1.8399**	0.4561**	–	–
	(0.7368)	(0.1789)	–	–
Non-defence sector externality, $\widehat{N}$	0.7247**	–	0.5049**	–
	(0.3022)	–	(0.2081)	–
First difference, defence sector externality, $\widehat{D}$	–	0.0636*	–	0.0021
	–	(0.0438)	–	(0.0314)
First difference, non-defence sector externality, $\widehat{N}$	–	−0.0309	–	0.0321**
	–	(0.0432)	–	(0.0172)
Defence expenditures as share of lagged gov	–	–	−0.2795	−0.2250
spending, $\frac{D}{G_{t-1}}\widehat{D}$	–	–	(0.5606)	(0.2062)
	–	–	0.4886**	0.0438

Table 1A: (continued)

Dependant variable: economic growth rate, $\widehat{Y}$	Coefficient (standard error)			
Variables	**Model 10**	**Model 10a**	**Model 11**	**Model 12**
Non-defence expenditures as share of lagged gov spending, $\frac{N}{G_{t-1}}\widehat{N}$	–	–	(0.1889)	(0.0324)
First difference, inflation, Π	–	–	–	−0.1061*
	–	–	–	(0.0920)
Recession dummy	–	–	–	−3.6893***
	–	–	–	(0.8921)
Medium intensity conflict dummy	–	–	–	0.1130
	–	–	–	(0.2485)
High intensity conflict dummy	–	–	–	−1.122*
	–	–	–	(0.6664)
Arms exports, $\frac{AE}{Y}\widehat{AE}$	–	–	–	0.3506
	–	–	–	(1.064)
Arms imports, $\frac{AI}{Y}\widehat{AI}$	–	–	–	−1.8769
	–	–	–	(3.2157)
R squared	0.359	0.315	0.369	0.651
Durbin Watson stat	1.692	1.581	1.611	2.059
Breusch-Godfrey P-value	0.253	0.114	0.134	0.661
F stat	4.31***	3.28***	4.31***	7.70***

*$P < 0.10$, **$P < 0.05$, ***$P < 0.01$.

Table 1B: Feder-Ram models contd.

Dependant variable: economic growth rate, $\widehat{Y}$	Coefficient (standard error)	
Variables	**Model 13**	**Model 13a**
Constant	2.2688***	2.6791***
	(0.5147)	−0.4733
Capital investment, $\frac{I}{Y_{t-1}}$	0.2111	0.0063
	(0.03517)	(0.0254)
Labour, $\widehat{L}$	0.8205***	0.3610**
	(0.2316)	(0.1878)
First difference, non-defence sector externality, $\widehat{N}$	0.0175	0.0041
	(0.0388)	(0.0313)
Non-defence expenditures as share of lagged gov spending, $\frac{N}{G_{t-1}}\widehat{N}$	0.0382	0.1572*
	(0.0345)	(0.0233)
First difference, inflation, Π	–	−0.1373*
	–	(0.0957)

Table 1B: (continued)

Dependant variable: economic growth rate, $\hat{Y}$	**Coefficient (standard error)**	
Variables	**Model 13**	**Model 13a**
Recession dummy	–	−4.5262***
	–	(1.0717)
Medium intensity conflict dummy	–	0.4532
	–	(0.0507)
High intensity conflict dummy	–	−0.8634*
	–	(0.3686)
Arms exports, $\frac{AE}{Y}\widehat{AE}$	–	1.0981*
	–	(0.7420)
Arms imports, $\frac{AI}{Y}\widehat{AI}$	–	−0.9271
	–	(0.0956)
Military equipment expenditure, $\frac{EQ}{G_{t-1}}\widehat{EQ}$	−5.2862	−7.6811
	(3.1243)	(5.2115)
Military equipment expenditure growth, $\widehat{EQ}$	0.0238	0.0160*
	(0.0204)	(0.0150)
Military personnel expenditure, $\frac{PE}{G_{t-1}}\widehat{PE}$	−2.2906	−2.4335*
	(5.6495)	(2.1113)
Military personnel expenditure growth, $\widehat{PE}$	−0.0211	−0.0095*
	(0.3940)	(0.2956)
Military infrastructure expenditure, $\frac{IN}{G_{t-1}}\widehat{IN}$	−0.2432	−0.2760
	(0.8550)	(0.6631)
Military infrastructure expenditure growth, $\widehat{IN}$	−0.0012	−0.0030
	(0.0033)	(0.0027)
Military other expenditure, $\frac{OT}{G_{t-1}}\widehat{OT}$	9.2211	−0.0048
	(6.6070)	(0.0184)
Military other expenditure growth, $\widehat{OT}$	−0.0049	−0.0048
	(0.2390)	(0.1839)
R squared	0.325	0.702
Durbin Watson stat	1.784	1.75
F stat	1.67*	6.33***

*$P < 0.10$, **$P < 0.05$, ***$P < 0.01$.

clear that the Feder-Ram models, despite their preference within the literature, underperform on all levels when compared to the augmented Solow models. With an R-squared value of 0.315 in the model's simplest form, the Feder-Ram appears to explain substantially less variation in economic growth when compared to the augmented Solow model in its basic form which has an *R*-squared value of 0.586.[16]

16 Equation (10) reports an *R*-squared value of 0.359, however the severe problems of multicollinearity present within the model limit its validity econometrically, hence equation (10a) is used as the basis for reporting.

Table 2A: Augmented Solow models.

Dependant variable: economic growth rate, $\Delta \ln y_t$	Coefficient (standard error)		
Variables	**Model 24**	**Model 25**	**Model 26**
Constant	0.0400***	0.0343***	0.0375***
	(0.1181)	(0.0093)	(0.0131)
GDP$_{t-1}$, $\ln y_{t-1}$	0.128319***	0.6414***	0.6417***
	(0.1005)	(0.8898)	(0.0902)
First difference, capital investment, $\ln \frac{s}{y}$	0.0004	–	–
	(0.0001)	–	–
First difference, capital investment share of lagged GDP, $\ln \frac{s}{y_{t-1}}$	–	−0.0015	−0.0014
	–	(0.0013)	(0.0012)
Labour, technical progress and depreciation, $\ln(g+n+d)$	0.0731***	0.2437***	0.0235***
	(0.0111)	(0.0060)	(0.0085)
Defence expenditure, $\ln d$	−0.2151	–	–
	(0.1946)	–	–
Defence expenditure$_{t-1}$, $\ln d_{t-1}$	0.3692**	–	–
	(0.1933)	–	–
Defence expenditure share of lagged gov spending, $\ln \frac{d}{g_{t-1}}$	–	0.5946***	0.5994***
	–	(0.0653)	(0.0759)
Defence expenditure share of lagged gov spending$_{t-1}$, $\ln \frac{d}{g_{t-1}}{t-1}$	–	0.2159	0.0387
	–	(0.0560)	(0.0530)
Inflation, $\ln \Pi$	–	–	0.0161*
	–	–	(0.0128)
Recession dummy	–	–	−0.0330**
	–	–	(0.0165)
Medium intensity conflict dummy	–	–	0.0109
	–	–	(0.0147)
High intensity conflict dummy	–	–	−0.0322**
	–	–	(0.0179)
Arms exports expenditures share of lagged GDP, $\ln \frac{ae}{y_{t-1}}$	–	–	0.0031
	–	–	(0.1527)
Arms imports expenditures share of lagged GDP, $\ln \frac{ai}{y_{t-1}}$	–	–	−0.0064
	–	–	(0.0096)
R squared	0.586	0.841	0.894
Durbin's Alternative *P*-value	0.4391	0.5497	0.1508
F stat	12.74***	46.69***	26.74***

*$P < 0.10$, **$P < 0.05$, ***$P < 0.01$.

The modifications to the way in which the military spending variables are composed prove fruitful as both *R*-squared values are improved. However, it is clear that the augmented Solow model benefits from this adjustment far more relative to the Feder-Ram model. As expected, the addition of the control variables improves the fit of both models, with the Feder-Ram model seeing the largest improvement. The

Table 2B: Augmented Solow models contd.

Dependant variable: economic growth rate, $\Delta \ln y_t$	**Coefficient (standard error)**	
Variables	**Model 27**	**Model 27a**
Constant	0.0271***	0.0435***
	(0.009)	(0.0168)
GDP$_{t-1}$, ln y_{t-1}	0.1671***	0.1383***
	(0.1353)	(0.1408)
First difference, capital investment share of lagged GDP, ln $\frac{s}{y_{t-1}}$	0.0038**	0.0043**
	(0.0016)	(0.0016)
Labour, technical progress and depreciation, ln $(g + n + d)$	0.2682**	0.2289*
	(0.0109)	(0.1238)
Military equipment expenditure, ln *eq*	0.0063	0.0631
	(0.0783)	(0.0876)
Military personnel expenditure, ln *pe*	−0.1185***	−0.0974***
	(0.0330)	(0.0314)
Military infrastructure expenditure, ln *in*	−0.0012	−0.0013
	(0.0019)	(0.0019)
Military other expenditure, ln *ot*	−0.0285	−0.0268
	(0.0244)	(0.0227)
Lagged military equipment expenditure, ln eq_{t-1}	−0.1500**	−0.1358*
	(0.0808)	(0.0747)
Lagged military personnel expenditure, ln pe_{t-1}	−0.0115	−0.0233
	(0.0414)	(0.0399)
Lagged military infrastructure expenditure, ln in_{t-1}	−0.0015	−0.0029*
	(0.0018)	(0.0017)
Lagged military other expenditure, ln ot_{t-1}	0.0206	0.0071
	(0.0247)	(0.0228)
Inflation, ln Π	–	0.0219
	–	(0.01787)
Recession dummy	–	−0.0508**
	–	(0.0236)
Medium intensity conflict dummy	–	−0.0044
	–	(0.0190)
High intensity conflict dummy	–	−0.03551*
	–	(0.0230)
Arms exports expenditures share of lagged GDP, ln $\frac{ae}{y_{t-1}}$	–	0.0400**
	–	(0.0232)
Arms imports expenditures share of lagged GDP, ln $\frac{ai}{y_{t-1}}$	–	−0.0050
	–	(0.0069)
R squared	0.813	0.876
Durbin's Alternative *P*-value	0.3169	0.1753
F stat	15.47***	13.71***

*$P < 0.10$, **$P < 0.05$, ***$P < 0.01$.

disaggregation of military spending also improves the fit of both models when compared to their basic forms, with the disaggregated Feder-Ram model including controls in model 13a (Table 1B), proving to have the best fit relative to the other Feder-Ram models. This is not the case with the augmented Solow model however, as the model with the best *R*-squared value is instead the modified original model with the inclusion of control variables as seen in model 26 (Table 2A).

All *F*-tests are significant at the 1 % level, except model 13 that is significant at the 10 % level. The above findings are in line with previous literature which suggests that Feder-Ram models typically account for around 66 % of variance in economic growth (Mintz and Huang 1990), with the augmented Solow accounting for nearly 80 % of cross-country variation in growth (Mankiw, Romer, and Weil 1992). This difference in explanatory power between the models is likely to be attributable to the theoretical framework in each model rather than the estimation methods used. As Dunne, Smith, and Willenbockel (2005) highlight, the Feder-Ram model has no solid theoretical grounding. In contrast, the augmented Solow model has a strong background within the growth literature, unlike the Feder-Ram model which has predominantly been confined to use within defence literature (McDonald 2012). Hence, it is evident that the augmented Solow model accounts for a larger proportion of economic growth relative to the Feder-Ram model, thus supporting the view of the literature presently (see Mankiw, Romer, and Weil 1992; Mintz and Huang 1990).

Turning to the effects of military expenditure on economic growth within the Feder-Ram models, the regressions report a negative coefficient in each measurement of defence spending at varying significance levels. Model 10 reports significance at the 5 % level and implies that for a 1 % increase in defence spending as a share of lagged government expenditure, a decline of −4.57 % in UK GDP is experienced. This is a considerably large value, although the large degree of multicollinearity present between variables may have inflated the value, and as such reduces the validity of such a conclusion.

Models 10a, 11 and 12, which are econometrically superior models in comparison, fail to report any significance in the military expenditure estimates. The disaggregated model in model 13a reports that military personnel expenditures have a negative effect on growth at the 10 % significance level and implies that for a 1 % increase in personnel expenditure as a share of government spending, a decline of −2.43 % occurs within GDP. Therefore, there seems to be a negative relationship in the case of models 10 and 13a. However, there is no evidence to suggest the same amongst the remaining Feder-Ram models. Similarly, the significant econometric problems within model 10 reduce the evidence supporting this. More robust models reported later also show no evidence of a significant effect.

The employed labour growth rate is positive and significant throughout all Feder-Ram models, along with the non-defence sector expenditure to varying degrees of significance. The short run externality effects appear positive and significant for the non-defence sector. However, just as the defence expenditure proved to have no significant effect for the most part, the same can be said for the defence externality effect. These results are akin to that of Mintz and Huang (1990, 1991) and Dunne, Smith, and Willenbockel (2005) and highlight the poor overall performance of the model.

Note that, while the effects of the disaggregated military spending proved insignificant, the externality effects of both personnel and equipment spending were significant and negative at the 10 % level. This infers that for the Feder-Ram models, albeit only with a single sector and at the lowest statistically significant level, the effect is insignificant. However, for completeness the results of the augmented Solow model must be referred to.

Turning to the additional control variables included in models 12 and 13a, the effects of recession are predictably negative and significant at the 1 % level in both instances. Moving on to the conflict proxies, it appears that medium-intensity conflict has a positive effect on growth; however, this is not significant. The high-intensity conflict proxy has negative coefficients at the 10 % level of significance. This provides further evidence to the hypothesised negative effects of military expenditure on growth. Further to this, the significant and negative effect of high intensity conflict within the Feder-Ram models yields evidence supporting it. Again, however, the augmented Solow model must be referred to before the result can be validated.

Finally, the inclusion of arms imports/exports proves insignificant in the traditional Feder-Ram type models, however arms exports appear positive and significant at the 10 % level. This is in partial agreement with Yakovlev (2007) who runs a similar analysis and Elveren and Hsu (2016) who implement a Marxist structure. Both studies conclude that net arms export (import) should have a positive (negative) effect on economic growth. The insignificance of arms imports is in line with Dunne (2008), who predicts no effect of either export or import.

Turning to the augmented Solow models in Table 2, there is a stark contrast in the coefficients of military expenditure. The traditional model implied by the literature (model 24), reports no significant effect of military spending within the same period, but suggests a positive relationship in the subsequent period that is significant at the 5 % level. A 1 % increase in military expenditure is estimated to increase economic growth by 0.369 % in the subsequent period. When military expenditure is expressed as a ratio of lagged government spending, the relationship previously observed is reversed. In models 25 and 26, current military spending as a ratio of lagged government spending is positive and significant at the 1 % level in both instances.

The model suggests that a 1 % increase in military spending increases UK GDP growth by around 0.59 % in the subsequent year, reflecting the results of Heo (2010) and McDonald (2012). The lag of this variable appears smaller in magnitude but insignificant suggesting that the effects of military expenditure are most established during the current period and the following year. These results evidently contrast those obtained from the Feder-Ram models which, for the majority of models, proved insignificant albeit tending towards a negative effect. However, the evidence presented in Table 2 by the augmented Solow models provides significant evidence that military expenditure does not have a negative effect on economic growth within the UK.

Moving on to the effects of military spending within the disaggregated models (models 27, 27a), it is apparent that the only significant component of military spending in the first period is personnel expenditure (significant at the 1 % level). The effect in both instances is negative, albeit relatively small at around 0.1 % of GDP. As per the previous models, the succeeding lags prove insignificant; however, lagged equipment expenditure yields a negative effect at the 5 % level in model 27 and at the 10 % level in model 27a. This, like the Feder-Ram model, means that not only do the differing components of military expenditure effect economic growth on varying levels, but also the time taken for these effects to influence growth varies by component.

In line with macroeconomic theory, total output within the UK in the previous year has a positive and significant effect at the 1 % level across all augmented Solow models, along with the sum of labour, technological progress, and deprecation at the 1 % level for models 24, 25 and 26, and at the 5 and 10 % levels for 27 and 27a respectively. It is noteworthy that capital investment is not significant at any degree across the first three models; however, this could be attributed to the variable being first differenced due to its non-stationary – altering the interpretation of the variable to reflect the short-run effect of capital investment, which may, in fact, be significant in the long-run.

Moving on to the inflation control variable, a distinct difference is apparent in contrast to the results obtained in Table 1. While the coefficients are positive in both models 26 and 27a, they are only significant in model 26 at the 10 % level. While these results conflict with those obtained from the Feder-Ram models, it is noteworthy that at such low levels of magnitude and significance, the impact of inflation within the model becomes somewhat negligible.

Focusing on the recession and conflict dummy variables it is again unsurprising that recession has a significantly negative impact on growth in both instances. In contrast to the Feder-Ram models, the effect is not as significant (only at the 5 % level), nor is it as severe in magnitude. The conflict proxies follow a similar pattern to those within the Feder-Ram model, again with the high intensity variable showing evidence of a negative impact on economic growth, significant at the 5 % level in both occurrences. This is more statistically significant in comparison to the Feder-Ram models and highlights the detrimental effect that military expenditure as a result of conflict has on economic growth. The results presented in Table 2 are reflective of those obtained in Table 1 with the Feder-Ram model. This yields strong evidence that while military expenditure not necessarily has a negative and significant effect on economic growth, conflict is detrimental to growth regardless. This is likely to be a result of the opportunity cost of participating in such conflicts, as the foregone investment used to support said conflicts could be more beneficial to growth if spent elsewhere.

Finally, turning to the effects of arms trade there are no significant results reported in the traditional model (model 26), however in the disaggregated model, arms expenditure as a ratio of lagged GDP proves positive and significant (at the 5 % level). This is in line with the results obtained from the Feder-Ram regressions and as mentioned previously, goes against the predictions of Dunne, Smith, and Willenbockel (2005). Ultimately it is difficult to judge whether the coefficients are correct in sign, magnitude, and significance due to the unique nature of the study. Each country is different and invariably, cross-country studies are unlikely to portray accurate representations for each country.

6 Discussions

This paper examines the relationship between military expenditure and economic growth within the UK for the period 1960–2012, employing both the Feder-Ram and the augmented Solow models in order to assess the validity of each in conjunction as a tool for the UK government, and also to determine whether the domination of the Feder-Ram model within defence literature is just. It is also one of the first time series analysis of the military expenditure growth nexus in the UK. The preliminary research conducted initially provided a valuable overview into the initial effects of defence spending on economic growth. While the opening hypotheses speculated that military expenditure and economic growth would be cointegrated, this turned out to be false in the case of the UK.

Previously, the use of supply-side Feder-Ram type specifications to model the defence-growth relationship prevailed within the literature. Dunne, Smith, and Willenbockel (2005), amongst others, argue that the model is inherent with econometric issues which raise concerns over its validity as a tool for policy implementation. This, coupled with the fact that the Feder-Ram model is seldom seen within mainstream growth literature poses further questions into the extent of the models' usefulness. Instead, the augmented Solow growth model is recommended due to its concrete background within the growth literature and ease of transition from a theoretic model to an econometric one. The benefits of the augmented Solow model are at the expense of modelling the externality effects of both the defence and non-defence sectors present within the Feder-Ram model. Given the poor performance and limitations of the Feder-Ram model, it is clear that the extensive usage of the model within the defence-growth literature can be questioned. Instead, models established within modern growth literature such as the augmented Solow model, adaptations of Barro's growth model (see Aizenman and Glick 2006) and the modern

Keynesian-based models (see Atesoglu 2002) should have a considerably larger preference when considering the defence-growth nexus.

Large increases in the UK's defence budget as a result of its involvement in Iraq war in 2003, and consequently in Afghanistan, have been suppressed in the last decade due to the Strategic Defence and Security Review (SDSR) of 2010. The SDSR has proven injurious to the UK defence budget, with the extent of the cuts still being observed, and defence expenditures only recently surpassing pre-SDSR figures. Given the recent times of austerity in both the UK and the rest of the world, the present (and potential future)[17] involvements that the UK has committed to, have highlighted the increasing requirement for sustained expenditure in order to meet operational objectives imposed on the armed forces.

Based on the results of the augmented-Solow model, it is evident that there is a significant and quantitatively positive effect of military expenditure in the case of the UK. Thus, there are important policy implications which should be taken away from the empirical results reported above. As the results of the regressions illustrate, the predominant effect of military expenditure is felt one period after a change in spending. Given the fragile condition of the UK economy at the time, a reduction in military spending may have been a potential factor in the eventual 'double dip' recession and subsequently may have prolonged recovery. While other variables may have had a greater influence on GDP growth at the time, the results reported above provide a compelling argument against the timeliness of the SDSR.

Second, the results presented show strong evidence of a negative relationship between GDP growth and periods of high intensity conflict that require higher defence budget. This also matches with the meta-analysis by Alptekin and Levine (2012) that show such beneficial effects for developed countries. From a strictly economical perspective, this may pave the path for higher military expenditure. It is duly noted however, that the long-term effects of conflict is negative, and the government may have other objectives to pursue.

The empirical findings of the Feder-Ram models suggest that military expenditure has no statistically significant effect on economic growth, albeit the disaggregated model reports a negative effect with regards to military personnel expenditure, at a low level of significance. The augmented Solow model, in contrast, reports evidence of a statistically significant positive effect of lagged military expenditure when expressed as a ratio of GDP, as per the literature, with improved significance exhibited when expressed as a ratio of lagged government spending. The disaggregate form of the augmented Solow model yields similar results to that of the Feder-Ram model, with

17 These include operations in, but not limited to, Libya, Cyprus, Northern Ireland, and the Falkland Islands.

evidence of a negative, albeit considerably more significant, relationship with personnel expenditure and GDP. Unlike the Feder-Ram model however, the lag of military equipment expenditure has a significant and negative effect with lagged military infrastructure expenditure to a lesser degree of significance.

The augmented Solow model suggests that the other explanatory variables within the specification have a significant impact on economic growth in comparison to Feder-Ram models. The inclusion of arms trade within the disaggregated models yields significant and positive results in both instances, with regards to arms exports, with the augmented Solow reporting a considerably higher level of significance. The proxies for conflict yield interesting results, with conflicts of high intensity producing a significant and negative effect on economic growth across both models.

The lack of any significant relationship between defence spending and economic growth within the Feder-Ram models reflects the performance of the model as a whole. When compared to the augmented Solow models, the Feder-Ram models consistently explained a smaller proportion of the variation in economic growth. Correspondingly, the *F*-tests reinforce this view, with the *F*-tests reported in the augmented Solow models outperforming that of its counterpart in every instance. One possible explanation for this may be due to possible misspecification within the Feder-Ram models, occurring from the ad hoc addition of certain sectors leading to further problems such as multicollinearity – present within the Feder-Ram models in this paper.

In sum, the augmented Solow model appears to avoid many of the problems inherent within the Feder-Ram model, while providing larger explanatory power along with a more concrete theoretical grounding. Thus, in the case of the United Kingdom, the application of the Feder-Ram model in favour of the augmented Solow model is unjust. Although this paper is in favour of the augmented Solow model, other models such as Barrows endogenous growth model should not be overlooked.

It is clear, however, that further research must be conducted in order to forge advancements within the defence-growth literature. The reluctance to move on from the Feder-Ram model is unquestionably a hindrance amongst the literature, which in order to remedy, must be dropped in favour of more modern and sophisticated models such as the augmented Solow model. In time series studies such as this, observation numbers are a clear limiting factor. While core variables are often readily available, it is inevitable that the more obscure ones are considerably harder to find, restricting the scope of future investigations.

Appendix

Appendix Table 3: Unit root tests for Feder-Ram and augmented Solow models.

Unit root test for:	**Change in GDP, Δ *GDP***		
	Test statistic	**10 % critical value**	***P*-value**
Augmented Dickey-Fuller	−5.210	−2.600	0.0000
Phillips-Perron	−5.063	−2.600	0.0000
Unit root test for:	**Capital investment, $\frac{I}{Y}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−12.681	−2.599	0.0000
Phillips-Perron	−15.010	−2.599	0.0000
Unit root test for:	**Labour, $\dot{L}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−12.681	−2.599	0.0000
Phillips-Perron	−15.010	−2.599	0.0000
Unit root test for:	**Changes in defence spending share of GDP, $\frac{D}{Y}\dot{D}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−4.391	−2.928	0.0003
Phillips-Perron	−4.379	−2.928	0.0003
Unit root test for:	**Changes in non-defence government spending share of GDP, $\frac{N}{Y}\dot{N}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−4.997	−2.599	0.0000
Phillips-Perron	−4.913	−2.599	0.0000
Unit root test for:	**Changes in defence spending share of government spending, $\frac{D}{G}\dot{D}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−4.372	−2.599	0.0003
Phillips-Perron	−4.359	−2.599	0.0003
Unit root test for:	**Changes in non-defence government spending share of government spending, $\frac{N}{G}\dot{N}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−4.916	−2.928	0.0000
Phillips-Perron	−4.828	−2.928	0.0000

Appendix Table 3: (continued)

Unit root test for:	**Change in GDP, Δ *GDP***		
	Test statistic	**10 % critical value**	***P*-value**
Unit root test for:	**Defence sector externality, $\dot{D}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−4.884	−2.599	0.0000
Phillips-Perron	−4.846	−2.599	0.0000
Unit root test for:	**Non-defence sector externality, $\dot{N}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−4.893	−2.599	0.0000
Phillips-Perron	−4.806	−2.599	0.0001
Unit root test for:	**Arms exports, $\frac{AE}{Y}\widehat{AE}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−11.117	−2.599	0.0000
Phillips-Perron	−10.918	−2.599	0.0000
Unit root test for:	**Arms imports, $\frac{AI}{Y}\widehat{AI}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−6.146	2.599	0.0000
Phillips-Perron	−6.127	−2.599	0.0000
Unit root test for:	**Military equipment expenditure, $\frac{EQ}{G_{t-1}}\widehat{EQ}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−7.482	2.599	0.0000
Phillips-Perron	−7.501	−2.599	0.0000
Unit root test for:	**Military personnel expenditure, $\frac{PE}{G_{t-1}}\widehat{PE}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−7.118	−2.599	0.0000
Phillips-Perron	−7.124	−2.599	0.0000
Unit root test for:	**Military infrastructure expenditure, $\frac{IN}{G_{t-1}}\widehat{IN}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−6.755	−2.599	0.0000
Phillips-Perron	−6.745	−2.599	0.0000

Appendix Table 3: (continued)

Unit root test for:	**Change in GDP, Δ *GDP***		
	Test statistic	**10 % critical value**	***P*-value**
Unit root test for:	**Military other expenditure, $\frac{OT}{G_{t-1}}\widehat{OT}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−6.073	−2.599	0.0000
Phillips-Perron	−6.100	−2.599	0.0000
Unit root test for:	**Military equipment expenditure growth, $\widehat{EQ}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−5.755	2.599	0.0000
Phillips-Perron	−5.739	−2.599	0.0000
Unit root test for:	**Military personnel expenditure growth, $\widehat{PE}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−5.281	−2.599	0.0000
Phillips-Perron	−5.264	−2.599	0.0000
Unit root test for:	**Military infrastructure expenditure growth, $\widehat{IN}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−8.645	−2.599	0.0000
Phillips-Perron	−8.749	−2.599	0.0000
Unit root test for:	**Military other expenditure growth, $\widehat{OT}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−5.849	−2.599	0.0000
Phillips-Perron	−5.778	−2.599	0.0000
Unit root test for:	**Change in logged GDP, Δ ln *GDP***		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−4.650	−2.600	0.0001
Phillips-Perron	−4.594	−2.600	0.0001
Unit root test for:	**Capital investment lagged GDP, ln $\frac{I}{Y_{t-1}}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−7.536	−2.930	0.0000
Phillips-Perron	−7.707	−2.930	0.0000

Appendix Table 3: (continued)

Unit root test for:	**Change in GDP, Δ *GDP***		
	Test statistic	**10 % critical value**	***P*-value**
Unit root test for:	**Labour, ln ($g + n + d$)**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−5.023	−2.928	0.0000
Phillips-Perron	−5.030	−2.928	0.0000
Unit root test for:	**Military spending share in lagged GDP, ln *m***		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−11.063	−2.930	0.0000
Phillips-Perron	−11.223	−2.930	0.0000
Unit root test for:	**Military spending share in lagged gov spending, ln $\frac{d}{g_{t-1}}$**		
	Test statistic	10 % critical value	*P*-value
Augmented Dickey-Fuller	−11.063	−2.930	0.0000
Phillips-Perron	−11.223	−2.930	0.0000

Appendix Table 4: Variance inflation factor results for Feder-Ram models 10–12.

Feder-Ram models 10–12	**Variance inflation factor (VIF)**			
Variables	**Model 10**	**Model 10a**	**Model 11**	**Model 12**
Capital investment, $\frac{I}{Y_{t-1}}$	1.10	1.13	1.14	1.34
Labour, $\widehat{L}$	1.13	1.116	1.16	2.21
Defence expenditures, $\frac{D}{Y}\widehat{D}$	22.92	4.11	–	–
Defence sector externality, $\widehat{D}$	20.69	–	3.86	–
Non-defence expenditures, $\frac{N}{Y}\widehat{N}$	163.43	4.12	–	–
Non-defence sector externality, $\widehat{N}$	152.54	–	3.88	–
First difference, defence sector externality, $\widehat{D}$	–	4.06	–	3.98
First difference, non-defence sector externality, $\widehat{N}$	–	4.40	–	4.92
Defence expenditures as share of lagged gov spending, $\frac{D}{G_{t-1}}\widehat{D}$	–	–	4.37	4.42
Non-defence expenditures as share of lagged gov spending, $\frac{N}{G_{t-1}}\widehat{N}$	–	–	4.07	5.28

Appendix Table 4: (continued)

Feder-Ram models 10–12	Variance inflation factor (VIF)			
Variables	**Model 10**	**Model 10a**	**Model 11**	**Model 12**
First difference, inflation Π	–	–	–	2.73
Recession dummy	–	–	–	2.71
Medium intensity conflict dummy	–	–	–	2.05
High intensity conflict dummy	–	–	–	2.02
Arms exports, $\frac{AE}{Y}\widehat{AE}$	–	–	–	1.47
Arms imports, $\frac{AI}{Y}\widehat{AI}$	–	–	–	1.35
Mean VIF	60.30	3.10	3.12	2.88

Appendix Table 5: Variance inflation factor results for Feder-Ram models 13–13a.

Feder-Ram models 13–13a	Variance inflation factor (VIF)	
Variables	**Model 13**	**Model 13a**
Capital investment, $\frac{I}{Y_{t-1}}$	4.42	4.75
Labour, $\widehat{L}$	2.16	2.26
First difference, non-defence sector externality, $\widehat{N}$	4.53	4.79
Non-defence expenditures as share of lagged gov spending, $\frac{N}{G_{t-1}}\widehat{N}$	2.26	2.38
First difference, inflation Π	–	3.31
Recession dummy	–	4.38
Medium intensity conflict dummy	–	1.99
High intensity conflict dummy	–	2.39
Arms exports, $\frac{AE}{Y}\widehat{AE}$	–	1.72
Arms imports, $\frac{AI}{Y}\widehat{AI}$	–	1.39
Military equipment expenditure, $\frac{EQ}{G_{t-1}}\widehat{EQ}$	2.20	2.51
Military equipment expenditure growth, $\widehat{EQ}$	2.34	2.50
Military personnel expenditure, $\frac{PE}{G_{t-1}}\widehat{PE}$	4.65	4.94
Military personnel expenditure growth, $\widehat{PE}$	4.63	4.92
Military infrastructure expenditure, $\frac{IN}{G_{t-1}}\widehat{IN}$	2.01	2.16
Military infrastructure expenditure growth, $\widehat{IN}$	1.50	1.64
Military other expenditure, $\frac{OT}{G_{t-1}}\widehat{OT}$	2.25	2.51
Military other expenditure growth, $\widehat{OT}$	2.23	2.50
Mean VIF	2.93	3.21

Appendix Table 6: Variance inflation factor results for augmented Solow models 24–26.

Augmented solow models 24–26	Variance inflation factor (VIF)		
Variables	**Model 24**	**Model 25**	**Model 26**
GDP $t-1$, ln y_{t-1}	1.19	2.37	2.89
First difference, capital investment, ln $\frac{s}{y}$	1.09	–	–
First difference, capital investment share of lagged GDP, ln $\frac{s}{y_{t-1}}$	–	1.36	1.56
Labour, technical progress and depreciation, ln$(g+n+d)$	1.19	2.37	2.28
Defence expenditure, ln d	1.10	–	–
Defence expenditure $t-1$, ln d_{t-1}	1.09	–	–
Defence expenditure share of lagged gov spending, ln $\frac{d}{g_{t-1}}$	–	2.50	3.05
Defence expenditure share of lagged gov spending$_{t-1}$, ln $\frac{d}{g_{t-1}}{}_{t-1}$	–	1.45	1.49
Inflation, ln Π	–	–	1.34
Recession dummy	–	–	1.33
Medium intensity conflict dummy	–	–	2.06
High intensity conflict dummy	–	–	2.08
Arms exports expenditures share of lagged GDP, ln $\frac{ae}{y_{t-1}}$	–	–	1.15
Arms imports expenditures share of lagged GDP, ln $\frac{ai}{y_{t-1}}$	–	–	1.15
Mean VIF	1.13	1.90	1.80

Appendix Table 7: Variance inflation factor results for augmented solow models 27–27a.

Augmented solow models 27–27a	Variance inflation factor (VIF)	
Variables	**Model 27**	**Model 27a**
GDP$_{t-1}$, *ln* y_{t-1}	1.67	1.72
First difference, capital investment share of lagged GDP, ln $\frac{s}{y_{t-1}}$	1.48	1.56
Labour, technical progress and depreciation, ln$(g+n+d)$	2.45	2.82
Military equipment expenditure, ln eq	1.99	2.03
Military personnel expenditure, ln pe	2.56	3.09
Military infrastructure expenditure, ln in	1.38	1.39
Military other expenditure, ln ot	2.34	2.61
Lagged military equipment expenditure, ln eq_{t-1}	1.56	1.93
Lagged military personnel expenditure, *ln* pe_{t-1}	1.36	2.64
Lagged military infrastructure expenditure, ln in_{t-1}	1.01	1.24
Lagged military other expenditure, ln ot_{t-1}	2.04	2.29
Inflation, ln Π	–	1.52
Recession dummy	–	1.68
Medium intensity conflict dummy	–	2.09
High intensity conflict dummy	–	2.26
Arms exports expenditures share of lagged GDP, ln $\frac{ae}{y_{t-1}}$	–	1.42
Arms imports expenditures share of lagged GDP, ln $\frac{ai}{y_{t-1}}$	–	1.26
Mean VIF	1.80	1.97

Appendix Table 8: VAR model with two lags, GDP and military expenditure.

Sample: 1963-2012 Lags: 2		Coefficient (standard error)
GDP (first differenced)	First lag GDP	0.5703***
		(0.2203)
	Second lag GDP	−0.3751*
		(0.2233)
	First lag military expenditure	−7.8781
		(7.8702)
	Second lag military expenditure	0.2095
		(8.0743)
	Constant	4.76e+10***
		(1.70e+10)
Military expenditure (first difference)	First lag GDP	0.0108*
		(0.0064)
	Second lag GDP	−0.0117*
		(0.0065)
	First lag military expenditure	−0.1162
		(0.2318)
	Second lag military expenditure	0.2423
		(0.2379)
	Constant	1.18e+09***
		(5.02e+08)

*P < 0.10, **P < 0.05, ***P < 0.01.

Appendix Table 9: VAR stability condition.

Eigen value	Modulus
0.2102599 + 0.5744609i	0.611731
0.2102599 − 0.5744609i	0.611731
0.5032038	0.503204
−0.469638	0.469638

All eigenvalues lie inside the unit circle. VAR satisfies stability condition.

Appendix Table 10: Lag selection criteria.

Sample: 1963–2012							Number of observations: 50	
Lag	**Log likelihood (LL)**	**Likelihood ratio (LR)**	**Degrees of freedom (df)**	***P*-value**	**Final prediction error (FPE)**	**Akaike's information criterion (AIC)**	**Schwarz's Bayesian information criterion (SBIC)**	**Hannan and Quinn information criterion (HQIC)**
0	129.2				2E-05	−5.0881	−5.01156*	−5.05892*
1	134.1	9.8381*	4	0	0.0002*	−5.12481*	−4.89537	−5.0374
2	135.8	3.421	4	0	2E-05	−5.0332	−4.65082	−4.8876

Appendix Table 11: Johansen test for cointegration.

Sample:		**1962–2012**			
Number of observations:		**50**			
Lags:		**2**			
Maximum rank	**Parms**	**Log likelihood (LL)**	**Eigen value**	**Trace statistic**	**5 % critical value**
0	6	−2533.48		3.3150*	15.41
1	9	−2531.84	0.06219	0.0402	3.76
2	10	−2531.82	0.00079		

Appendix Table 12: Granger causality test for GDP and military expenditure.

Initial variable	Excluded variable	Chi^2	Degrees of freedom (df)	*P*-value
GDP	Military expenditure	1.0127	2	0.603
Military expenditure	GDP	4.8198	2	0.09

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