Models of Military Expenditure and Growth: A Critical Review

J Paul Dunne,
University of the West of England
and University of Cape Town

Ron Smith
Birkbeck College, University of London

Dirk Willenbockel
Middlesex University Business School

December 2004

Abstract:

This paper reviews some of the theoretical and econometric issues involved in estimating growth models that include military spending. While the mainstream growth literature has not found military expenditure to be a significant determinant of growth, much of the defence economics literature has found significant effects. The paper argues that this is largely the product of the particular specification, the Feder-Ram model, that has been used in the defence economics literature but not in the mainstream literature. The paper critically evaluates this model, detailing its problems and limitations and suggests that it should be avoided. It also critically evaluates two alternative theoretical approaches, the Augmented Solow and the Barro models, suggesting that they provide a more promising avenue for future research. It concludes with some general comments about modelling the links between military expenditure and growth.

Keywords: Military expenditure; models; growth

Corresponding author:
Prof J Paul Dunne,
School of Economics, HLSS,
University of the West of England,
Frenchay Campus,
Bristol, BS16 1 QY
Tel: 0117-328-2053
Email: *John2.Dunne@uwe.ac.uk*

Earlier versions of this paper under the title 'Theoretical and Econometric Issues in Analysing the Military Expenditure-Growth Nexus were presented to the Peace Science Society Panel Session, *American Economics Association/ASSA Annual Meetings*, Atlanta January 2002, the *Sixth Annual Conference on Econometric Modelling for Africa,* University of Pretoria, July 2001 and the *Eighth Annual Conference on Economics and Security*, Bristol 2004. We are grateful to the participants for comments and the ESRC for support, for Smith under grant L138251003 and for Dunne under R00239388.

1. Introduction

There is now a large body of empirical literature investigating the economic effects of military spending, with little consensus as to what these effects might be. The early cross-country correlation analyses of Benoit (1973;1978) quickly gave way to a variety of econometric models, reflecting different theoretical perspectives. Keynesian, neoclassical and structuralist models were applied using a variety of specifications, econometric estimators and types of sample in cross-section, time-series or panels. The diversity of results led to arguments for case studies of individual countries and relatively homogeneous groups of countries. Dunne (1996) provides a survey of this work.

The mainstream growth literature has not found military expenditure to be a significant factor in explaining growth. For instance, Sala-i-Martin et al. (2004) consider 67 variables, including the initial share of military spending, as possible determinants of growth 1960-1996 in a cross-section of 88 countries. Using Bayesian averaging, they find 18 variables that appear significant, with a posterior inclusion probability of better than 10%. The share of military spending ranks 45, with a probability of 2.1%. There are many similar findings. In contrast to this, many papers in the defence economics literature have found military expenditure to be a significant determinant of growth. The difference seems to come largely from the use of different models. In defence economics the Feder-Ram model tends to be widely used, while it is not used in the mainstream growth literature. Given the disjunction between the mainstream growth literature and the defence economics literature it seems useful to provide a review of the issues and contrast the approaches. In this paper we provide a critical review of the theoretical models used to investigate the link between military expenditure and growth and conclude that the Feder-Ram model should not be used. However, there are other approaches that suggest that defence economics may be able to contribute to the growth debate.

To set the scene, section 2 surveys the types of linkage that there might be between military expenditure and output, then reviews issues about type of data used in empirical work and the identification problem. Section 3 examines the Feder-Ram model, Ram (1995). We argue that it suffers severe theoretical and econometric problems and should be avoided. Section 4 reviews the augmented Solow model, which has been widely used in the more general growth literature and applied to military expenditure by Knight et al. (1996). Section 5 reviews the Barro (1990) model, also popular in the growth literature and applied to military expenditure by Aizenman and Glick (2003). Section 6 draws some conclusions.

2. The Economic Effects of Military Spending

As background, this section will look at the channels through which military expenditure may influence output, the type of data used, and the identification problem. The vast literature on the economic effects of military expenditure has suggested a large number of different channels through which military expenditure may influence output. Smith (2000) and Dunne (1996), provide more detail and references, but here we will briefly list them to indicate the range of possibilities, rather than provide references or evaluation. They can be broadly grouped into demand effects, supply effects and security effects.

Demand effects operate through the level and composition of expenditure. The most obvious is the Keynesian multiplier effect, an exogenous increase in military spending increases demand and, if there is spare capacity, increases utilisation and reduces unemployment of resources. Underconsumption theories reverse this causation and explain military expenditure by the government's need to manage demand. Military expenditures have opportunity costs and may crowd out other forms of expenditure, such as investment. The extent and form of crowding out following an increase in military spending will depend on prior utilisation and how the increase is financed. The government budget constraint requires that an increase in military expenditure be financed by: cuts in other public expenditure, increased taxes, increased borrowing or expansion in the money supply. There is a large literature on war finance. The way the increase is financed will have further effects, e.g. a larger deficit may raise real interest rates, which feeds back on the economy. Increases in military expenditure will also change the composition of industrial output, with input-output effects. Similar arguments apply to cuts in military expenditure, though the effects may not be symmetric.

Supply effects operate through the availability of factors of production (labour, physical and human capital and natural resources) and technology, which together determine potential output. Some of the demand effects, e.g. crowding out of investment, may also have supply effects by changing the capital stock. The literature differs in whether the focus is on total output, including that used by the military, or just civilian output. Conscription and other forms of coercion as well as ideological fervour may increase the mobilisation of factors of production, particularly during times of perceived threat of war, but the resources mobilised are mainly used for military purposes. Clearly resources used by the military are not available for civilian use, but there may be externalities. Training in the armed forces may make workers more or less productive when they return to civilian employment. Military R&D may have commercial spin-offs.

Security of persons and property from domestic or foreign threats is essential to the operation of markets and the incentives to invest and innovate. To the extent that military expenditure increases security it may increase output. Adam Smith noted that the first two duties of the state were 'that of protecting the society from the violence and invasion of other independent societies….that of protecting, as far as possible, every member of society from the injustice or oppression of every member of it'. In many poor countries, war and lack of security are major obstacles to development. However, military expenditure may be driven not by security needs but by a rent seeking military industrial complex and military expenditures may provoke arms races or damaging wars and in such cases there would not be positive security effects.

Many of these effects are contingent, depending on such things as the degree of utilisation, how the military expenditure is financed, the externalities from military spending and the effectiveness of military expenditure in countering the threat. These factors are likely to vary over countries and over time, with the consequence that the economic effect of military spending will also vary. The time horizons of these effects are very different, some are quite short-run others very long-run. All these measurements have to be done within the context of a particular model. Gleditsch et al. (1996) contains a large number of studies using country specific models. Here our focus is on cross-country growth models and these tend to neglect the complicated linkages listed above in favour of a simple reduced form relationship between output and military spending, motivated in various ways.

In principle there is a distinction between models of the level of output and the growth rate, in practice the distinction is less important. If we have an output equation, e.g. for log per-capita income, which includes lagged or initial output as they invariably do:

$$y_t = \alpha + \lambda y_{t-1} + \beta' x_t + \varepsilon_t$$

it can always be written as a growth equation

$$\Delta y_t = \alpha + (\lambda - 1) y_{t-1} + \beta' x_t + \varepsilon_t$$

where Δy_t the change in the logarithm of output measures the growth rate.

Given data for countries $i = 1, 2, ..., N$ data, for years $t = 0, 1, 2, ..., T$ there are two main ways the relationship has been estimated. The most popular estimates the long-run cross-section relationship:

$$y_{iT} - y_{i0} = \alpha + (\lambda_c - 1) y_{i0} + \beta_c' x_i + \varepsilon_i$$

where y_{i0} is the logarithm of initial output and y_{iT} the logarithm of final output and x_i may be initial or average values of the other variables. This uses the between country variation. The main alternative uses the within country variation and estimates the fixed-effect panel relationship:

$$\Delta y_{it} = \alpha_i + (\lambda_p - 1) y_{i,t-1} + \beta_c' x_{it} + \varepsilon_{it}$$

This allows intercepts to differ, but assumes that the slopes are the same across countries, though this is not an innocuous assumption, see Lee et al (1997). The time periods used may be annual, five-yearly or ten-yearly.

The theory discussed in section 4, suggests that the country intercepts α_i will be correlated with y_{i0} and possibly x_i so the cross-section estimates, which ignore this, would be biased. However, the higher-frequency panel data may suffer larger measurement errors than long-run averages used in the cross-section. The fixed effect estimators will tend to exacerbate measurement error when the right hand side variables are more time persistent than the errors in measurement. Hauk and Wacziarg (2004) conduct a Monte Carlo study to investigate the relative importance of the two biases and conclude that the measurement error bias is greater than the endogeneity bias, so that traditional OLS on cross-sectional averages perform best. The debate about the relative advantages of panel and cross-section seems likely to persist and it is possible that the between country and within country regressions measure different things.

To examine the identification issues suppose there is a system in the logarithms of output and military expenditure of the form:

$$y_t = \beta_1 m_t + \gamma_1 x_t$$
$$m_t = \beta_2 y_t + \gamma_2 z_t$$

The first equation is the output or growth equation and x_t are all the other factors that determine output, including the error term and lagged output. The second equation is a demand for military expenditure equation and z_t includes all the other factors, influencing military spending, including the error term, threats against which military spending is effective and possible measures of the potential for rent-seeking behaviour by the military industrial complex. We might expect $\beta_1 < 0, \beta_2 > 0$, but we only require that $\beta_1 \beta_2 \neq 1$. The reduced form is

$$y_t = (1 - \beta_1 \beta_2)^{-1} (\gamma_1 x_t + \beta_1 \gamma_2 z_t)$$
$$m_t = (1 - \beta_1 \beta_2)^{-1} (\beta_2 \gamma_1 x_t + \gamma_2 z_t)$$

The association between output and military expenditure will depend on the productivity factors shifting x_t, and the threat factors shifting z_t. Thus we may observe high military expenditure and high growth (South Korea, and Taiwan) where both the threats and productivity are high; low military expenditure and low growth (Sub-Saharan Africa) where both are low (there are many threats but not of the type that military spending is effective against); low military expenditure and high growth (Germany and Japan after World War II) and high military expenditure and low growth (former Soviet Union). Smith (2000) discusses these issues in more detail. The model can be formally identified if there are variables in x_t that are not in z_t and vice versa. Simultaneous systems usually make assumptions that ensure that this is the case, but they may not always be plausible. For instance, it is common to assume that the threat does not enter the output equation, but our discussion of security effects above suggests that there may be such effects. Rather than try to estimate β_2 it is often assumed to be unity, giving a constant share of output. Using the share of military expenditure in the output equation may also reduce the endogeneity problem, since the share of military expenditure is likely to be less correlated with output shocks than the level of military spending.

3. The Feder-Ram Model

Biswas and Ram (1986), adapted Feder's (1983,1986) model of the effect of exports on growth in developing countries for a cross-country study of the effect of military spending and economic growth. Since then numerous empirical contributions to the guns-and-butter debate have employed variants of the same approach.[1] Deger and Sen [1995] characterise the Feder-Biswas-Ram externality model as "a splendid empirical workhorse to investigate the impact of military expenditure on growth". The approach is generally seen to provide a formal justification for the inclusion of military expenditure as an explanatory variable in a single-equation growth regression analysis, which is "grounded in the neoclassical theory of growth" (Mintz and Stevenson [1995]), or at least "fairly well grounded in the neoclassical production-function framework" (Biswas and Ram [1986:367]).[2] The popularity of the approach lies in the appearance of a direct link from theoretical model to econometric specification.

The basic two-sector version of the model distinguishes between military output (M) and civilian output (C).[3] Both sectors employ homogeneous labour (L) and capital (K), and military production has external effects on civilian production:

(1) $$M = M(L_m, K_m) \quad , \quad C = C(L_c, K_c) = M^{\theta} c(L_c, K_c) \, .$$

The factor endowment constraints are given by

(2) $$L = \sum_{i \in S} L_i \quad , \quad K = \sum_{i \in S} K_i \quad , \quad S = \{m, c\}$$

and domestic income is

[1] See Ram (1995) for a survey up to the early 1990s, and Antonakis (1997), Sezgin (1997) Batchelor, Dunne and Saal (2000) for more recent examples of the genre.
[2] For similar pronouncements see e.g. Antonakis (1999:503) or Atesoglu and Mueller (1990:20) among many others.
[3] For multisectoral extensions of the model see e.g. Huang and Mintz (1991), Murdoch, Pi and Sandler (1997), Antonakis (1999), Athanassiou et al (2002).

(3) $Y = C + M$.

Of course, the summation of "butter" and "guns" in (3) is only admissible if C and M are understood to represent monetary output *values* rather than output *quantities*. It will be helpful for subsequent reference to make the implicit price normalisation in (3) transparent by re-writing it in the equivalent form

(3') $Y = P_c Cr(L_c, K_c) + P_m Mr(L_m, K_m)$,

where P_m and P_c denote the (constant unitary) money prices associated with the real output quantities Mr and Cr. The model allows the *values* of the marginal products of both labour (M_L, C_L) and capital (M_K, C_K) to differ across sectors by a constant uniform proportion, i.e.

(4) $$\frac{M_L}{C_L} = \frac{M_K}{C_K} = 1 + \mu$$

or equivalently

(4') $$\frac{P_m Mr_L}{P_c Cr_L} = \frac{P_m Mr_K}{P_c Cr_K} = 1 + \mu..$$

(4') serves to highlight the fact that comparisons of marginal factor productivities across different production sectors necessarily depend on the prices used in the evaluation of sectoral outputs.

Proportional differentiation of (3) with (1) and (2) yields the growth equation

(5) $$\hat{Y} = \frac{C_L L}{Y}\hat{L} + C_K \frac{I}{Y} + \left(\frac{\mu}{1+\mu} + C_M\right)\frac{M}{Y}\hat{M} ,$$

where the hat notation indicates proportional rates of change and I = dK denotes net investment. Using the fact that the final term in (1) entails a constant elasticity of C with respect to M, (5) can be restated in the form

(5') $$\hat{Y} = \frac{C_L L}{Y}\hat{L} + C_K \frac{I}{Y} + \left(\frac{\mu}{1+\mu} - \theta\right)\frac{M}{Y}\hat{M} + \theta\hat{M} ,$$

which permits - at least in principle - the separate identification of the externality effect and the "marginal factor productivity differential effect".

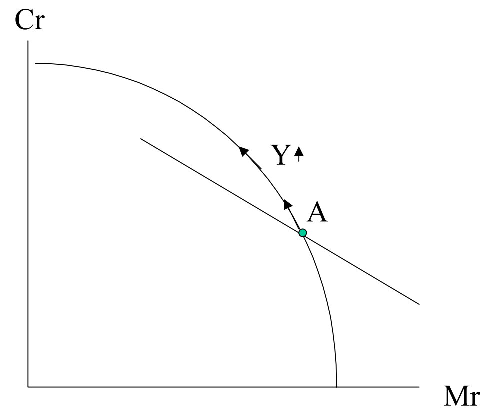
Variants of (5) and (5') have been estimated using cross-country data (e.g Biswas and Ram (1986)), time series data for individual countries (e.g. Huang and Mintz (1991), Ward et al. (1993), Sezgin (1997), Antonakis (1999), Batchelor et al. (2001)), and pooled cross-section time-series data (e.g. Murdoch et al. (1997)).

The notion of a marginal factor productivity differential between sectors in (4) is the source of a number of interpretational pitfalls. In the empirical literature, a non-zero μ is customarily interpreted to reflect a situation where one sector is "less efficient" or "less productive" in its factor use than the other due to the presence of some sort of organisational slack or X inefficiency afflicting that sector. For instance, Ward et al. (1993) estimate a negative sign of μ for Taiwan and conclude "that in comparison to the civilian sector..., the military sector is considerably less efficient". Sezgin (1997) comments on his finding of a negative μ for Turkey: "It means that the civilian sector is more productive than the defence sector, because defence is less subject to the rigours of market discipline". Similarly Antonakis (1997) paraphrasing Atesoglu and Mueller (1990): "Without strong competitive pressure to induce ... efficiency in the management and use of resources, it can be argued that marginal factor productivities are lower in the defence sector".[4]

Such interpretations are not consistent with the underlying theoretical model. Although this point seems to have gone unnoticed in the literature, technical efficiency in production holds in the model by assumption: By imposing uniformity of the factor productivity differential for both factors via (4), studies based on the two-sector Feder-Ram model in fact assume that the economy produces on the efficient frontier of the production possibility set (e.g. point A in Figure 1). In the present context, technical efficiency in production, is reached when C production cannot be raised without giving up some M production or vice versa. This requires the equalization of the marginal rates of technical substitution (MRTS) between labour and capital across production sectors. Since $MRTS_M = Mr_K/Mr_L$ and $MRTS_C = Cr_K/Cr_L$, the efficiency condition can be restated in the form $Mr_K/Mr_L = Cr_K/Cr_L$ which is equivalent to assumption (4').

[4] This list of illustrative quotations could be continued *ad lib*. See e.g. Huang and Mintz (1991), Alexander (1995) Murdoch et al. (1997) for further examples.

Figure 1



$\mu<0$: P<MRT

The suggestion that a non-zero μ measures the presence of some sort of *sector-specific* inefficiency in the use of resources is flawed. A non-zero μ arises whenever the implicit price ratio $P = P_m/P_c$ used in the evaluation of real GDP deviates from the marginal rate of transformation (MRT) between Cr and Mr, which measures the amount of "butter" society must give up in order to produce another "gun". When P < MRT as in Figure 1a, $\mu<0$ and real GDP as calculated according to (3') would indeed rise if resources are moved from military to civilian production, or vice versa if P>MRT and $\mu>0$ (Figure 1b). However, the GDP growth via factor re-allocation is *not* a result of shifting resources from a sector with inefficient *intrasectoral* resource management due to lacking competitive pressure to a sector with less organizational slack. In the case of Figure 1, real GDP rises by moving resources from M to C, because in Point A the value of a unit of Cr in terms of Mr goods (1/P) used in the calculation of Y is higher than the social cost of producing another unit of Cr in terms of Mr (1/MRT). The potential counter-argument that the approach is supposed to capture some sort of off-the-production function behaviour is invalid. The production functions (1) which are used for the derivation of the empirical growth equation (5) are specified for a given invariant level of intra-sectoral organizational or X-efficiency. The model is by construction incapable of accounting for intra-sectoral organizational inefficiencies.

The deeper question whether such a resource move which raises measured real GDP is actually socially desirable cannot be answered without knowledge as to whether the relative price P used in the calculation of Y adequately reflects the social marginal rate of substitution, i.e. the rate at which "society" is willing to trade off M for C. If it does, a non-zero μ reflects a situation where the economy-wide product mix and thus the intersectoral factor allocation in the economy as a whole is inefficient, yet this has nothing to do with lacking effort or ability to transform inputs into outputs in the individual sectors.

In addition to these theoretical issues, there are a number of econometric problems in estimating the Feder-Ram model. Nothing in the derivation of equation (5') indicates what are to be regarded as variables and what are to be regarded as parameters. In practice estimation involves a regression of the form

(5'') $\hat{Y} = \beta_1 \hat{L} + \beta_2 \frac{I}{Y} + \beta_3 \frac{M}{Y} \hat{M} + \beta_4 \hat{M} + \varepsilon$

This treats capital (with share of investment as the variable) and labour (with the growth rate as the variable) asymmetrically and it is not obvious that $C_L L / Y$ should be regarded as constant β_2, while $C_K I / Y$ should be split into a parameter and a variable, $\beta_3 I / Y$. It is not clear where the errors come from and why it should be reasonable to treat them as white noise. There is no other source of technological progress except the military externality, though this can be handled in an ad hoc fashion by including an intercept in (5''). There is a severe simultaneity problem having the growth rate of military expenditure on the right hand side, since if the share of military expenditure is constant, variations in the growth in output will determine the growth of military expenditure. Multicollinearity between the final two terms may cause large standard errors and imprecise estimates of the externality parameter. The model is static, no lagged regressors or dependent variables, which is a major problem both in time-series where slow adjustment is pervasive and in cross-section, where it is well known that initial income is an important determinant of growth.

While there have been some developments of the Feder-Ram model to try to overcome its limitations, including the recent contribution by Crespo Cuaresma and Reitschuler (2004) which allows for a nonlinear effect of military spending, there seem to be strong theoretical and econometric reasons not to use the Feder-Ram model. This might explain why , in the 1980s the Feder approach was widely used in the empirical exports-growth and government expenditure-growth literatures, but now is rarely used outside the defence economics literature. We now turn to two models that have a stronger pedigree in the growth economics literature.

4. The Augmented Solow model

The augmented Solow growth model was introduced by Mankiw et al. (1992) and used to measure the effect of military expenditure on growth by Knight et al. (1996). The key assumption is that the military spending share m:= M/Y affects factor productivity via a *level* effect on the efficiency parameter which controls labour-augmenting technical change.

The starting point is an aggregate neoclassical production function featuring labour-augmenting technological progress

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

where Y denotes aggregate real income, K is the real capital stock, L is labour, and the technology parameter A evolves according to

(7) $A(t) = A_o e^{gt} m(t)^{\theta}$,

where g is the exogenous rate of Harrod-neutral technical progress and m is the share of military expenditure in GDP. According to this specification, a permanent change in m does not affect the long-run steady-state growth rate, but has potentially a permanent level effect on per-capita income along the steady-state growth path and affects transitory growth rates along the path to the new steady-state equilibrium.

Together with the standard Solow model assumptions of an exogenous saving rate s, a constant labour force growth rate n, and a given rate of capital depreciation d, the dynamics of capital accumulation are described by

$$(8) \qquad \dot{k}_e = sk_e^{\alpha} - (g+n+d)k_e \iff \frac{\partial \ln k_e}{\partial t} = se^{(\alpha-1)\ln k_e} - (g+n+d),$$

where k_e:=K/[AL] denotes the effective capital-labour ratio and α is the constant capital-output elasticity. The steady-state level of k_e is

$$(9) \qquad k_e^* = \left[\frac{s}{g+n+d}\right]^{1/(1-\alpha)}.$$

Linearizing (8) via a truncated Taylor series expansion around the steady state and using (9), we get

$$(10) \qquad \frac{\partial \ln k_e}{\partial t} = (\alpha-1)(g+n+d)[\ln k_e(t) - \ln k_e^*]$$

and since ln y_e:= ln [Y/(AL)] = αln k_e,

$$(11) \qquad \frac{\partial \ln y_e}{\partial t} = (\alpha-1)(g+n+d)[\ln y_e(t) - \ln y_e^*],$$

where the steady-state level of output per effective labour unit is

$$(12) \qquad y_e^* = \left[\frac{s}{g+n+d}\right]^{\alpha/(1-\alpha)}.$$

Equation (11) approximates the *transitory* dynamics of output per effective labour unit in a neighbourhood of the steady state. In order to operationalize (11) for empirical work, we integrate it forward from t-1 to t and get

$$(13) \qquad \ln y_e(t) = e^z \ln y_e(t-1) + (1-e^z)\ln y_e^* \;\;,\;\; z \equiv (\alpha-1)(n+g+d).$$

Using (7), (12) and (13), y_e is related to observable per capita income y:= Y/L via

$$(14) \qquad \begin{aligned} &\ln y(t) = e^z \ln y(t-1) + (1-e^z)\left\{\ln A_o + \frac{\alpha}{1-\alpha}[\ln s - \ln(n+g+d)]\right\} \\ &\quad + \theta \ln m(t) - e^z \theta \ln m(t-1) + (t-(t-1)e^z)g \end{aligned}.$$

Note that in the steady state per capita income evolves according to

$$(15) \qquad \ln y^*(t) = \ln y_e^* + \ln A_0 + \theta \ln m^* + gt,$$

hence θ represents the elasticity of steady-state income with respect to the long-run military expenditure share, i.e. a permanent one-percent increase in m shifts the steady-state per-capita income path by θ percent. The equation is usually estimated in cross section, using data for an initial year and a final year in the form

$$\Delta \ln y(t) = \beta_0 + \beta_1 \ln y(t-1) + \beta_2 \ln s + \beta_3 \ln(n+g+d)] + \beta_4 \ln m(t) + \beta_5 \ln m(t-1) + \varepsilon \qquad (16)$$

where $\beta_1 = e^z - 1;\ \beta_2 = (1-e^z)\alpha/(1-\alpha);\ \beta_3 = -(1-e^z)\alpha/(1-\alpha);$ etc.

Knight et al (1996) like others who estimate it on panel data treat s and n as varying across countries and time, though they should be steady state values for each country, while g and d are taken to be uniform time-invariant constants. Initial technology, A_o is country-specific but, by construction, time-invariant, which in cross-section will be correlated with initial income. The model can be augmented to deal with human capital as in Mankiw et al. [1992].

Like in the Feder-Ram model the dependent variable is the growth rate and it is a function of the share of investment (equal to savings) and the rate of growth of the labour force, though the functional forms are different. Military expenditure appears as current and lagged share rather than growth rate and the product of growth rate and share. The dynamics are explicit leading to the addition of initial income. Unlike Feder-Ram, it is a one sector model rather than a two sector model, there is only a single good produced. Military expenditure influences output in a rather ad hoc way, since there is little reason to expect the share of military expenditure to change technology. There is no explicit recognition that through the budget constraint, changing military expenditure should change the savings rate. Again the error term is ad hoc, an explicit derivation based on stochastic technology and labor force growth is given in Lee et al. (1997), who make other criticisms of this model. The theory is much tighter with testable restrictions on the estimated coefficients, and the distinction between variables and parameters is clearer though the $(n+g+d)$ term appears both as a parameter in z and as a variable. The assumption that the share of capital is constant across countries may also be problematic.

In principle, because the theory is so tight, these issues could be explicitly investigated. However, because the theory is so tight, it excludes a range of other variables, e.g. institutions, which many economists think important. Therefore, more recent empirical work on growth has used more ad hoc models looking for variables that are not only significantly, but are robustly related to growth, in the sense that they are significant whatever the specification. How one establishes robustness remains a matter of debate, Sala-i-Martin et al. (2004) is one approach, Bleaney and Nishiyama (2002) a different approach.

5. The Barro Model

Aizenman and Glick (2003) start from the fact that the impact of military expenditure on growth is found to be non-significant or negative. They conjecture that this finding arises from non-linearities. As the basis for their investigation they use the Barro (1990) growth model which explicitly allows for forms of government expenditure, financed by taxes, which can influence output through the production function and has an explicit utility function for the representative agent which the government maximises. The government expenditure then has a non-linear effect on growth produced by the interaction between the productivity enhancing and tax distorting effects of increases in government expenditure. We will not present the full Barro model, because Aizenman and Glick, like Barro, do not explicitly estimate the theoretical equation, which is complex, but just use the theory to suggest variables. Thus, like most of the recent literature, they do not get explicit parametric restrictions of the type in the augmented Solow model.

The interesting innovation in Aizenman and Glick (2003) is that output is influenced by security, military expenditure relative to the threat. Such security effects were discussed in section 2. For many countries, this seems more plausible than military expenditure influencing technology. Their theoretical model suggests that military expenditure induced by external threats should increase output, by increasing security; while military expenditure induced by rent seeking and corruption should reduce growth, by displacing productive activities.

They run cross-section regressions explaining growth 1989-98 for 91 countries including as controls: log initial per capita GDP, education, population growth and the investment share. When the share of military expenditure is included it has a negative but insignificant coefficient. They then include a measure of the threat based on war years and the product of military expenditure and the threat. The coefficient of military expenditure becomes more negative and significant; the coefficient of the threat is negative (higher threat reduces output as expected) though insignificant; and the coefficient of the interaction term is positive and significant. When the threat is low, military expenditure reduces output, when the threat is high military expenditure increases output as the theory suggests. This negative effect of military expenditure on output tends to hold primarily in the more corrupt countries. Whether this result will prove robust to changes in the set of control variables remains to be seen and they note this as an area for further research.

6. Conclusions

The Holy Grail of applied econometrics is a tight theoretical model, which fits the data well. Like the Holy Grail, such models are hard to find. Within the defence economics literature, the Feder-Ram model seemed to offer a tight theoretical model. This paper has argued that: it is prone to theoretical misinterpretation, and the usual interpretations are mistaken; it suffers severe econometric problems, particularly simultaneity bias and lack of dynamics; and it provides too narrow a list of possible influences on growth. Thus our conclusion is that the Feder-Ram model should be avoided and that the defence economics literature should tend to converge with the mainstream growth economics literature. The augmented Solow model used by Knight et al. (1996) has fewer theoretical weaknesses, but is too narrow given the range of variables that have been found significant determinants of growth and it is implausible that the main effect of the share of military expenditure is through technology. The reformulation of the Barro model used by Aizenman and Glick (2003), which allows for security effects on output seems potentially more promising. Security is measured by military expenditure relative to the threat and this produces a non-linear effect of military expenditure. Military expenditure has a positive effect on output when the threat is high and a negative effect when threat is low. In refining growth models to allow for such non-linearities, defence economists have a comparative advantage since in estimating demand for military expenditure functions they have obtained considerable experience in measuring threats and other factors that influence military expenditures. Thus there is a theoretical as well as an econometric reason for estimating simultaneous systems that explain both military expenditures and output.

REFERENCES

Aizenman, Joshua and Reuven Glick (2003) Military Expenditure, Threats and Growth, NBER Working Paper 9618.

Alexander, W. Robert J. (1995) Defence Spending: Burden or Growth-Promoting? *Defence and Peace Economics* 6, 13-25.

Antonakis, Nicholas (1997) Defence Spending and Growth in Greece: A Comment and Further Empirical Evidence. *Applied Economics Letters* 4, 651-5.

Antonakis, Nicholas (1999) Guns versus Butter: A Multisectoral Approach to Military Expenditure and Growth with Evidence from Greece, 1960-1993. *Journal of Conflict Resolution* 43, 501-20.

Atesoglu, H. Sonmez and Michael J. Mueller (1990) Defence Spending and Economic Growth. *Defence Economics* 2, 19-27.

Athanassiou et al (2002) “Military SpendingExpenditure, Economic Growth and the Opportunity Cost of Defense”. Chapter 13 in Jurgen Brauer and J Paul Dunne (eds) (2002) *" Arming the South The Economics of Military Expenditures, Arms Production and Trade in Developing Countries"*, 291-317. Palgrave.

Barro, Robert J (1990) Government Spending in a Simple Model of Endogenous Growth, *Journal of Political Economy*.

Batchelor, Peter, Paul Dunne and David Saal (2000) Military Spending and Economic Growth in South Africa, *Defence and Peace Economics* 11, 553-571.

Benoit, E (1973) *Defence and Economic Growth in Developing Countries*. Boston: Lexington Books.

Benoit, E. (1978) Growth and Defence in LDCs. *Economic Development and Cultural Change* 26, 271-80.

Biswas, Basudeb and Rati Ram [1986] Military Expenditure and Economic Growth in Less Developed Countries: An Augmented Model and Further Evidence. *Economic Development and Cultural Change* 34, 361-72.

Bleaney, Michael and Akira Nishiyama (2002) Explaining Growth: A Contest between Models, *Journal of Economic Growth* 7, 43-56.

Crespo Cuaresma, Jesus and Gerhard Reitschuler (2004) A Non-Linear Defence Growth Nexus? Evidence from the US Economy. *Defence and Peace Economics* 15, 71-82.

Deger, Saadet and Somnath Sen (1995) Military Expenditure and Developing Countries. In: Keith Hartley, Todd Sandler (eds): *Handbook of Defense Economics*. Amsterdam: Elsevier, 275-307.

Dunne, Paul (1996) Economic Effects of Miltary Spending in LDCs: A Survey. In: Gleditsch, et al. (1996). 439-464.

Feder, Gershon [1983] On Exports and Economic Growth. *Journal of Development Economics* 12, 59-73.

Feder, Gershon (1986) Growth in Semi-Industrial Countries: A Statistical Analysis. In: Hollis Chenery, Sherman Robinson, Moshe Syrquin: *Industrialization and Growth: A Comparative Study*. New York: Oxford University Press, 263-82.

Gleditsch, Nils Petter, Adne Cappelen, Olav Bjerkholt, Ron Smith and Paul Dunne (eds) (1996) *The Peace Dividend*. (Contributions to Economic Analysis Series). Amsterdam: North Holland.

Hauk, William R and Romain Wacziarg (2002) A Monte Carlo Study of Growth Regressions, *NBER Working Paper* 296 [*DW: check number –should be higher]*.

Huang, Chi and Alex Mintz (1991) Defence Expenditures and Economic Growth: The Externality Effect. *Defence Economics* 3, 35-40.

Knight, Malcolm, Norman Loayza and Delano Villanueva (1996) The Peace Dividend: Military Spending Cuts and Economic Growth. *IMF Staff Papers* 43, 1-44.

Lee, Kevin, M Hashem Pesaran and Ron P Smith (1997) Growth and Convergence in a Multi-country Empirical Stochastic Solow Model, *Journal of Applied Econometrics*, 12, 4, 357-392.

Mankiw, N. Gregory, David Romer and David N. Weil (1992) A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics* 107, 407-37.

Mintz, Alex and Randolph T. Stevenson (1990) Defense Expenditures, Economic Growth, and the "Peace Dividend": A Longitudinal Analysis of 103 Countries. *Journal of Conflict Resolution* 39, 283-305.

Murdoch, James C., Chung-Ron Pi and Todd Sandler (1997) The Impact of Defense and Non-Defense Public Spending on Growth in Asia and Latin America. *Defence and Peace Economics* 8, 205-24.

Ram, Rati (1995) Defense Expenditure and Economic Growth. In: Keith Hartley, Todd Sandler (eds): *Handbook of Defense Economics*. Amsterdam: Elsevier, 251-73.

Sala-i-Martin, Xavier, Gernot Doppelhofer and Ronald I Miller (2004) Determinants of Long term growth: A Bayesian Averaging of Classical Estimates (BACE) approach, American Economic Review, September, 94,4, 813-835.

Smith, Ron P (2000) Defence Expenditure and Economic Growth in *Making Peace Pay: A Bibliography on Disarmament and Conversion*. In: Nils Petter Gleditsch, Goran Lindgren, Naima Mouhleb, Sjoerd Smith and Indra de Soysa (eds.) *Making Peace Pay: A Bibliography on Disarmament and Conversion*. Laremont: Regina Books, 15-24. .

Sezgin, Selami (1997) Country Survey X: Defence Spending in Turkey. *Defence and Peace Economics* 8, 381-409.

Ward, Michael D, David R. Davis and Steve Chan (1993) Military Spending and Economic Growth in Taiwan. *Armed Forces & Society* 19, 533-50.