Theoretical and Econometric Issues in Analysing the Military Expenditure-Growth Nexus

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Abstract:

This paper surveys some of the theoretical and econometric issues involved in estimating growth models that include military spending. In particular, it critically evaluates the commonly used Feder-Ram model, detailing its problems and limitations and suggesting a more acceptable theoretical approach. It also surveys the econometric issues involved in estimating these models and uses a panel of 28 countries study to evaluate the different approaches and to draw some suggestions for the development of future research.

Comments welcome
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1. Introduction

There is now a large body of empirical literature investigating the economic effects of military spending, with no consensus as to what these effects might be. One reason for the variety of results is the variety of studies. 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 provided a variety of specifications for different samples of countries. 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.

One interesting feature of the debate has been the popularity of particular types of models, in particular the Feder-Ram model. This supply-side model was originally developed to analyse the impact of the export sector on economic growth in developing economies. Using it for military spending allows the military sector to be treated as one sector in the economy and the externality effect of the sector and its differential productivity effect to be distinguished within a single-equation model. These apparent advantages have led to it having a profile within the defence economics area well beyond what it has achieved in other areas and has contributed to a failure of the area to embrace important new developments in the general growth and development literature.

This paper surveys some of the theoretical and econometric issues involved in estimating the commonly used Feder-Ram model, detailing its problems and limitations. It then moves on to suggest a more acceptable theoretical approach and compares the estimation results from the two approaches. Section 2 provides an overview of the theoretical approaches, with Section 3 then providing an outline and detailed critique of the Feder-Ram model and Section 4 developing an alternative Solow-type growth model. Section 5 considers the estimation methods used for cross country analyses, Section 6 reports the results of estimating a Feder-Ram model for a panel of 28 countries and Section 7 presents the estimation results for the Solow-type growth model. Finally, section 8 presents some conclusions.

2. Modelling the Economic Effects of Military Spending

Theoretically, any evaluation of the impact of military spending on growth is contingent on the theoretical perspective used. Neoclassical models generally adopt a supply-side perspective with a focus on the trade off between 'guns and butter'. Keynesian models see military spending simply as one component of government spending and focus on the demand side, although when used in econometric models an aggregate production function does give them a neoclassical flavour. A group of institutional economists focus on the damaging impact of the military industrial complex on the economy. Marxists views range from underconsumptionist arguments suggesting a positive impact of military spending through the prevention of realisation crises to arguments suggesting possible negative impact on the profit rate (Dunne, 1990).

When we move to empirical analyses, it is necessary to determine the level of abstraction at which the analysis is to be presented and to operationalise the theory to form an applied model. This leads to a variety of empirical work from applied econometric to more focussed institutional case study analyses. When statistical analysis is undertaken, it is generally based on the Keynesian or neoclassical approaches, as these are most amenable to the creation of formal models, though some studies adopt a more ad hoc approach. The studies differ in terms of the country coverage, the use of time-series versus cross-section data, the time period covered and the empirical methods used (see Dunne, 1996).

In general the literature has identified a number of channels by which military spending and production can influence the economy one way or another. It can take skilled labour away from civil production, but on the other hand can enhance training of the workforce, particularly in developing economies where the military may provide valuable skills. It can take the best capital equipment from civil industry to produce a high-technology enclave, but there may well be positive externalities of the development of the military sector on the civil sector. It can lead to damaging wars, but may maintain peace and lead to economic benefits from more prosperous allies. It can stimulate demand in a stagnant economy and lead to growth, but may create bottlenecks in a constrained economy. Finally, it may slow down development through the fostering of a militaristic ideology, but on the other hand nationalist attitudes may increase effort and output, and the military force and ideology may be used to control the workforce. Clearly whether these effects end up being positive or negative overall is an empirical question and the result is likely to differ across countries (Dunne, 1996).

Following the ad hoc approach of Benoit's original study, which found a positive effect of military spending on growth in developing countries, an impressive literature has been built up using econometric analysis of single-equation reduced-form equations and simultaneous equation models, which model both direct and indirect effects (Smith, 2000). In addition, macroeconometric models have been used to simulate the likely impact of changes in military spending at country and international level (Gleditsch et al, 1996).

Overall, the results of the empirical work have tended to show an insignificant or negative impact of military spending on economic growth in developing countries and a clearer negative impact in developed economies, through military spending being at the expense of investment rather than consumption. Such a summary does, however, hide the diversity of literature and results. Much of the earlier cross-section analyses found that the sample selection was important and this led to calls for more case studies. The time-series analyses of individual economies and of relatively homogenous groups of economies that resulted have improved understanding, but have also produced diverse results. For this reason there is still considerable mileage in developing cross-country studies, particularly when these develop the approach used, for example using new theoretical models or panel data methods. This paper does both.

3. The Feder-Ram Model Revisited

When undertaking econometric studies of the military expenditure growth nexus, the simple Feder-Ram model has something of a fascination for defence economists, mainly because of its ability to explicitly treat externality effects of the military on the non-military sector.

Following the lead of Biswas and Ram[1986], who first adapted Feder [1983,1986]'s model of the exports-growth nexus in developing countries for a cross-country study of the link between military spending and economic growth, numerous empirical contributions to the guns-and-butter debate have employed variants of the same approach.[1] Deger and Sen[1995:284] 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 [1995:283]), or at least "fairly well grounded in the neoclassical production-function framework" (Biswas and Ram [1986:367]).[2] The popularity of the approach lies certainly in the suggestion of a fast-track link from theoretical model to econometric specification with a fairly negligible amount of formal complexity.

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 the set-up allows for external effects of military production on civilian production activity:

(1) $M = M(L_m, K_m)$, $C = C(L_c, K_c) = M^q c(L_c, K_c)$.

The factor endowment constraints are given by

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

and domestic income is

(3) $Y = C + M$.

As a matter 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

[1] See Ram (1995) for a survey up to the early 1990s, and Antonakis[1997], Sezgin[1997] Batchelor, Dunne and Saal[1999] 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. Alexander[1990, 1995], Huang and Mintz[1991], Murdoch, Pi and Sandler[1997], Antonakis[1999], Nikolaidou[1999].

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) $$\frac{M_L}{C_L} = \frac{M_K}{C_K} = 1 + m$$

or equivalently

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

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

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

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

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

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

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

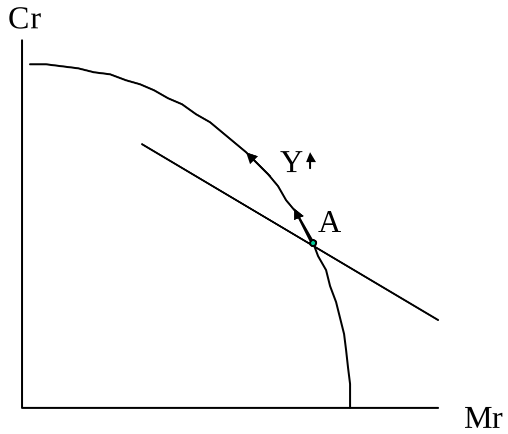
Variants of (5) and (5') have been estimated using cross-country data (e.g Biswas and Ram [1986]), time series data for individual countries (e.g. Huang and Mintz [1991], Ward et al. [1993], Sezgin [1997], Antonakis [1999], Batchelor Dunne and Saal [2001]), and pooled cross-section time-series data (e.g. Alexander [1990], Murdoch et al. [1997]).

Before turning to a number of practical econometric problems associated with the approach, the notion of a marginal factor productivity differential between sectors in (4) deserves a closer look from a theoretical perspective, since it appears to be a source 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, in a pooled cross-section time-series analysis for nine industrialized countries, Alexander [1990:50] estimates μ=-0.88 and concludes "that the defence sector is 88% less productive than the 'rest' of the economy". Ward, Davis and Chan [1993] estimate a negative sign of ì for Taiwan and conclude "that in comparison to the civilian sector..., the military sector is considerably less efficient". Sezgin[1997:404] comments his finding of a negative ì 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[1997:652n] paraphrasing Atesoglu and Mueller[1990:20]: "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 unwittingly 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, which is reached when C production cannot be raised without giving up some M production or vice versa, 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').

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.[5] 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

[4] This list of illustrative quotations could be continued *ad lib*. See e.g. Huang and Mintz [1991:36], Alexander[1995: 14] Murdoch, Pi and Sandler [1997:209] for further examples.

[5] 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.

calculation of Y is higher than the social cost of producing another unit of Cr in terms of Mr (1/MRT).

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. In early studies the model was estimated using cross sectional data. In this case the main problem was multicollinearity between the final two terms in the estimating equation in equation 5' and a concern with using possibly insignificant coefficients to compute the externality effect. Expanded versions of the model added to this problem. When the model was estimated using time series data the multicollinearity problem remained and others were added. Firstly, there was often a lack of independent exogenous variation in the data, though this has been overcome to some degree by the use of the panel data methods discussed below. Secondly the model is specified in growth rates which limits the dynamics to a single lags. Attempts to provide a more general specification increased the problems of multicollinearity and identification of the composite coefficients. All of these problems go some way to explain the variation in the results encountered in the empirical analyses and when combined with problems of interpretation led to a sense of dissatisfaction in a number of studies.

4. Developing a Growth Model with Military Spending

The deficiencies of the Feder-Ram model lead us to consider an alternative route. This section develops a model of the effect of military spending on growth performance based on a modified Solow growth model with Harrod-neutral technical progress as operationalised for cross-country analysis by Mankiw, Romer and Weil [1992] and adapted for panel data analysis by Knight, Loayza and Villanueva [1993] and Islam [1995] among others. The incorporation of military expenditure follows Knight, Loayza and Villanueva [1996;1993]. 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

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

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

(2) $$A(t) = A_o e^{gt} m(t)^{q} \,,$$

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

(3) $$\dot{k}_e = s k_e^{a} - (g+n+d)k_e \;\Leftrightarrow\; \frac{\partial \ln k_e}{\partial t} = s e^{(a-1)\ln k_e} - (g+n+d) \,,$$

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

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

Linearizing (3) via a truncated Taylor series expansion around the steady state and using (4), we get

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

and since $\ln y_e := \ln [Y/(AL)] = \alpha \ln k_e$,

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

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

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

Equation (6) approximates the *transitory* dynamics of output per effective labour unit in a neighbourhood of the steady state. In order to operationalize (6) for empirical work, we integrate (6) forward from t-1 to t and get

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

Using (2), (7) and (8), y_e is related to observable per capita income $y := Y/L$ via

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

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

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

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.

Equation (9) suggests the dynamic panel data model

(11) $$\ln y_{i,t} = \gamma \ln y_{i,t-1} + \sum_{j=1}^{4} \beta_j \ln x_{j,i,t} + \eta_t + \mu_i + \nu_{i,t}$$

where $x_1 = s = (I+dK)/Y$, $x_2 = n+g+d = \Delta L/L + 0.05$, $x_3 = m = M/Y\ P$, $x_4 = m_{t-1}$;
$\gamma = e^z > 0$, $\beta_1 = (1-e^z)\alpha/(1-\alpha) > 0$, $\beta_2 = -\beta_1 < 0$, $\beta_3 = \theta$, $\beta_4 = -e^z\theta = -\gamma\beta_3$, $\eta_t = g(t-(t-1)e^z)$, $\mu_i = (1-e^z)A_o$.

For the empirical analysis we follow Knight et al[1993] and Islam[1995] in treating s, n as variant across countries and time, while g and d are taken to be uniform time-invariant constants and A_o is country-specific but, by construction, time-invariant.

This model can be augmented to deal with human capital. Following Mankiw, Romer and Weil [1992], human capital is introduced into the model by re-specifying the aggregate production function as[6]

(1') $$Y(t) = K(t)^a \, H(t)^b \, [A(t)L(t)]^{1-a-b} \, ,$$

where H denotes the human capital stock. Human capital per effective labour unit, h_e:= H/(AL), and physical capital per effective worker evolve according to

(12) $$\dot{h}_e(t) = s_h y_e(t) - (n+g+d)h_e(t) \, , \ \dot{k}_e(t) = s_k y_e(t) - (n+g+d)k_e(t) \, ,$$

where s_h and s_k denote respectively the ratio of human and of physical capital investment to income, and human capital is assumed to depreciate at the same rate d as physical capital. The steady-state capital stock levels are

(13) $$k_e^* = \left[\frac{s_h^b \, s_k^{1-b}}{g+n+d}\right]^{1/(1-a-b)} \, , \ h_e^* = \left[\frac{s_h^{1-a} \, s_k^a}{g+n+d}\right]^{1/(1-a-b)} \, .$$

Proceeding in similar fashion to the derivation of (6), the transitory dynamics of income per effective worker in a neighbourhood of the steady state are approximated by

(6') $$\frac{\partial \ln y_e}{\partial t} = (\mathbf{a} + \mathbf{b} - 1)(g+n+d)[\ln y_e(t) - \ln y_e^*] \, ,$$

and the equation for income per actual worker which provides the basis for the empirical analysis is now

(9')
$$\ln y(t) = e^z \ln y(t-1) + (1-e^z)\left\{\ln A_o + \frac{\mathbf{a}}{1-\mathbf{a}-\mathbf{b}}\ln s_k + \frac{\mathbf{b}}{1-\mathbf{a}-\mathbf{b}}\ln s_h - \frac{\mathbf{a}+\mathbf{b}}{1-\mathbf{a}-\mathbf{b}}\ln(n+g+d)]\right\}$$
$$+\mathbf{q}\ln m(t) - e^z\mathbf{q}\ln m(t-1) + (t-(t-1)e^z)g$$

suggesting the dynamic panel model specification

[6] See Temple(2001:908) for some critical reflection on the plausibility of this specification.

(11’) $\ln y_{i,t} = g \ln y_{i,t-1} + \sum_{j=1}^{5} \boldsymbol{b}_j \ln x_{j,i,t} + \boldsymbol{h}_t + m_i + \boldsymbol{n}_{i,t}$

where x_5 = ÄH/Y, ã=e^z>0, $â_1$=(1-e^z)á/(1-á-â)>0, $â_2$= -($â_1$+$â_5$)<0, $â_3$=è, $â_4$= -e^zè = -ã$â_3$, $â_5$=(1-e^z)â/(1-á-â)>0, $ç_t$ = g(t-(t-1)e^z) = g(1-e^z)t +ge^z, $ì_i$ = (1-e^z)$A_{o,i}$.

These models have been developed explicitly to deal with panel data and the estimation methods available are discussed in the next section.

5. Estimation Methods

A major problem in estimating growth models has been the lack of independent exogenous variation in the data. One way of overcoming this has been by pooling cross section and time series data for a relatively homogenous group of countries (Murdoch et al, 1997). There is a problem that the cross section and time series parameter may be measuring different things, the former the long run and the latter the short run effects. The pooled relation is then a weighted average of the two. Growth equations have been most successful in cross sections, because of the difficulties of distinguishing the cyclical demand side effects from medium term supply side growth effects.

Panel data methods provide a variety of approaches to attempt to deal with some of these issues, with pooling the simplest form and fixed effect and random coefficient estimators providing more flexible approaches. The pooled OLS approach

(14) $y_{it} = \boldsymbol{a} + \boldsymbol{b}\, x_{it} + u_{it}$

assumes all parameters are the same for each country and invariant across time. The fixed effects estimator

(15) $y_{it} = \boldsymbol{a}_i + \boldsymbol{b}\, x_{it} + u_{it}$

allows the intercept to differ across countries which ignores all information in the cross sectional relation. Time fixed effects can also be allowed for separately or together with country fixed effects in a two-way fixed effect model:

(16) $y_{jt} = \boldsymbol{a}_t + \boldsymbol{a}_i + \boldsymbol{b}\, x_{it} + u_{it}$

In dynamic models of the form

(17) $y_{it} = \boldsymbol{a}_i + \boldsymbol{b}\, x_{it} + \boldsymbol{l}_{it-1} + u_{it}$

the fixed effect estimator is not efficient, because of lagged dependent variable bias, which biases the OLS estimator of ë downwards. It is, however, consistent in the limit when the number of time periods goes to infinity, and for samples of the size used here the bias is small. If the parameters differ over groups there is a further heterogeneity bias, which can be dealt with by estimating each equation individually and taking an average of the individual estimates (Pesaran and Smith, 1995).

6. Empirical Results: Feder-Ram Approach

The data are for 28 countries over the period 1960-1997 for GDP, GDP per-capita, and gross domestic fixed capital formation as a measure of investment. These are measured in constant price US dollar values at 1990 exchange rates and price levels (Source: World Bank). In addition, there are data on military expenditure as a share of GDP from SIPRI. The sample consists of two groups: 17 OECD countries (Germany, France, Italy, Netherland, Belgium, UK, Denmark, Spain, Greece, Portugal, USA, Canada, Japan, Australia, Norway, Sweden, Turkey) and 9 other countries (Argentina, Brazil, Chile, Venezuela, South Africa, Malaysia, Phillipines, India, Israel, Pakistan, and South Korea).

To operationalise the model for empirical application the instantaneous rates of change of the variables in (5') are replaced by their discrete equivalents giving

$$(15) \qquad \Delta Y_t/Y_{t-1} = \alpha_0 + \alpha_1 \Delta L_t/L_{t-1} + \alpha_2 I_t/Y_{t-1} + \alpha_3 \Delta M_t/M_{t-1} (M_t/Y_{t-1}) + \alpha_4 \Delta M_t/M_{t-1} .$$

Estimating this equation for the 28 countries give the results reported in Table 1 for the one and two-way fixed effects and the Swamy random coefficient estimator.

Table 1: Feder-Ram Model

	Expect	Fixed Effects		RCM
		One	Two	
$\Delta L_t/L_{t-1}$	+	0.074 (0.8)	0.147 (1.7)	0.149 (0.3)
I_t/Y_{t-1}	+	0.002 (1.1)	0.003 (2.2)	0.471 (2.7)
$\Delta M_t/M_{t-1} (M_t/Y_{t-1})$	-/+	-0.072 (-0.7)	-0.008 (-1.5)	11.150 (0.1)

$\Delta M_t/M_{t-1}$	-/+	0.016 (1.8)	0.025 (2.9)	-0.161 (0.0)
t	+	-0.001 (-8.2)		-0.0005 (-0.8)
θ Size effect		0.016	0.025	-0.161
μ Externality		-1.112	0.017	

The one-way fixed effects model provides poor results for a growth equation with the labour and capital variables insignificant and the trend term significant but negative. The military spending terms are also insignificant. Moving to a two-way fixed effects model improves the significance of the variables and gives both size and externality effects as positive. The random coefficient estimates differ with only the capital term significant and significantly larger in magnitude. Neither of the military expenditure terms is significant.

These are very disappointing results and might lead us to consider expanding the model to introduce more sectors, as in Nikolaidou (2000) or to attempt to improve the dynamics, as in Birdi and Dunne (2001). In this paper, however, our concerns over the nature of the model lead us to search for an alternative approach.

7. Empirical Results: Modified Solow Growth Model

The alternative model developed in section e suggests the dynamic panel data specification

(11) $$\ln y_{i,t} = \mathbf{g} \ln y_{i,t-1} + \sum_{j=1}^{4} \mathbf{b}_j \ln x_{j,i,t} + \mathbf{h}_t + \mathbf{m}_i + \mathbf{n}_{i,t}$$

where x_1= s = (I+dK)/Y, x_2 = n+g+d = ÄL/L + 0.05, x_3 = m = M/Y , x_4 = m_{t-1}.

From the development of the theory we have a number of expectations for the signs and magnitudes of the coefficients: $\gamma = e^z$ should be in the range 0<ã<1 and should be close to unity for the empirically relevant range of z = (á-1)(n+g+d)<0; $\beta_1 = (1-e^z)\alpha/(1-\alpha) > 0$, and the value for á jointly identified by ã and $â_1$ should be within the typical range for the capital share in GDP of around 0.3 to 0.5; $\beta_2 = -\beta_1 < 0$; $\beta_3 = \theta$

measures the elasticity of long-run per-capita income with respect to the military expenditure share, and $\beta_4 = - e^z \theta = - \gamma\beta_3$.

Estimating the model using the same data set as in section 6 gives the results in Table 2 below, for one and two-way fixed effects and the random coefficient models.

Table 2: Modified Solow-Type Model

	Fixed Effects		
	One	Two	RCM
$\gamma = e^z > 0$	0.96 (149)	0.96 (151)	0.96 (9.1)
$\beta_1 = (1-e^z)\alpha / (1- \alpha) > 0$	0.04 (8.8)	0.04 (9.2)	0.11 (2.7)
$\beta_2 = - \beta_1 < 0$	-0.05 (-4.9)	-0.04 (-4.8)	-0.14 (-1.2)
$\beta_3 = \theta$	-0.04 (-5.3)	-0.03 (-3.5)	-0.06 (-1.0)
$\beta_4 = - e^z \theta = - \gamma\beta_3$	0.03 (3.7)	0.02 (2.9)	0.06 (1.2)
$\eta_t = g (t – (t-1) e^z)$	0.27 (1.5)	-	0.01 (2.4)

These results provide estimates that are entirely consistent with the expectations developed from the theory. The coefficient on lagged log output γ is positive and close to unity as we would expect, and the coefficient on the investment share, β_1, has likewise the expected sign. The value for the capital-output elasticity á implied by the estimated coefficients for ã and â1 is 0.5 for the fixed effects models and thus broadly in line with observable capital share figures, while the implied á of 0.73 for the ECM regression is rather high. The coefficient on the labour force growth term, β_2, is both negative and close in absolute value to β_1 and significant for the fixed effects models. The coefficient on the log of the military share β_3 is negative and significant for the fixed effects models, suggesting that a permanent one percent increase in m reduces long-run per-capita income permanently by 0.03 to 0.04 percent.[or: ... suggesting that a permanent increase in m lowers the steady-state growth path of per-capita income permanently by 0.03 to 0.04 percent]. As expected, β_4 has the opposite sign to β_3 and is of similar magnitude with significant estimates for the fixed effects models. The trend parameter η_t represents the impact of the rate of technical progress, which is assumed to be the same across all countries. This is significant and positive for the RCM model and while positive for the one way fixed effects model is not significant.

Clearly both the size and the significance of the coefficients vary between the fixed and the random coefficient models. The existence of heterogeneity will bias γ towards one, and so we might expect a decrease in the coefficient with the RCM, but in fact the estimate is the same for all models.

8. Conclusions

This paper has considered the theoretical and empirical issues involved in estimating growth models to investigate the impact of military spending. It suggests that the commonly used Feder-Ram model has a number of weaknesses and misinterpretations and should not really be the main tool of such analyses. A useful alternative approach is found to be to take a simple neoclassical growth model and introduce an impact of military expenditure through its effect on technology. Another issue considered is use of panel data, rather than simple cross-sections on averages. Estimates were made of both the Feder-Ram and the new growth model using one- and two-way fixed effects models and a Swamy random coefficient estimator. This produced poor results for the Feder-Ram model, but much more promising results for the new growth model. The use of this model and of panel data methods for the relatively long time series available have been shown to be a potentially important new development for research in the area.

REFERENCES

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.

Barro, Robert J. and Xavier Sala-i-Martin [1995] *Economic Growth*. New York: McGraw-Hill.

Barro, Robert J. and Jong-Wha Lee [2000] International Data on Educational Attainment: Updates and Implications. *CID Working Paper* No.42. Harvard University.

Bassanini, Andrea, Stefano Scarpetta, and Philip Hemmings [2001] Economic Growth: The Role of Policies and Institutions. Panel Data Evidence from OECD Countries. *OECD Economics Department Working Paper* No.283.

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.

Carr, Jack L. [1989] Government Size and Economic Growth: A New Framework and Some Evidence from Cross-Section and Time-Series Data: Comment. *American Economic Review* 79, 267-71.

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: Nils Petter Gleditsch, Adne Cappelen, Olav Bjerkholt, Ron Smith and Paul Dunne (eds) *The Peace Dividend*. (Contributions to Economic Analysis Series). Amsterdam: North Holland, 439-464.

Durlauf, Steven N. and Danny T. Quah [1999] The New Empirics of Economic Growth. In John B. Taylor / Michael Woodford (eds) *Handbook of Macroeconomics* Vol. 1A. Amsterdam: Elsevier, 235-308.

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.

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

Islam, Nazrel [1995] Growth Empirics: A Panel Data Approach. *Quarterly Journal of Economics* 110, 1127-70.

Knight, Malcolm, Norman Loayza and Delano Villanueva [1993] Testing the Neoclassical Theory of Economic Growth: A Panel Data Approach. *IMF Staff Papers* 40, 512-41.

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

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.

Nikolaidou, Eftychia [1999] Military Spending and Economic Growth in Greece: A Multi-Sector Analysis, 1961-1996. *Middlesex University Business School Economics Discussion Paper* No.72.

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

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

Temple, Jonathan R.W.[2001] Generalizations that aren't? Evidence on Education and Growth. *European Economic Review* 45, 905-18.

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