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"Guns or Butter?" Revisited: Robustness and Nonlinearity Issues in the Defense-Growth Nexus*

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Abstract

The relationship between military expenditure and growth is studied taking into account potential nonlinearities and robustness issues in the specification of the econometric models used. Using cross-country growth regressions and the widely used Feder-Ram model, the partial correlation between defense spending and economic growth appears robust and significantly negative only for countries with a relatively low military expenditure ratio. While the externality effect appears positive in this subgroup of countries, the overall effect turns negative due to the size effect of the military sector.

JEL classification: E12, E13, C22

Keywords: Defense Expenditures, Economic Growth, Externality Effect, Robustness Test, Threshold Models.

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1 Introduction

The relation between economic well-being and resources absorbed by the military[1] has been widely debated among defense economists during the last decades. The discussion has been centered on the question whether the losses through crowding out of resources invested in the military sector exceed the potential positive externalities that the defense sector may have for the civil sector.

A number of channels by which the military spending can influence the civil economy have been identified in the literature. The defense sector can take away skilled labor from civilian production, but can also train workers through provision of education, particularly in developing economies. It could crowd out resources for consumption and investment, but it may also provide positive externalities for the civilian sector, like public infrastructure development, technology spillovers and human capital formation. It can lead to damaging wars and stipulate civil strife, but may also maintain peace and provide a secure climate for investment.

The traditional "guns-versus-butter" argument deemed the impact of military expenditure on output growth to be negative, even though no empirical evidence was presented in this respect until the seminal contribution by Benoit (1973). This first extensive empirical investigation of the defense-growth nexus found a growth-inducing effect of defense expenditure and shed new light on the empirical "black spot" in this field, resulting in a large number of studies that consequently tried to assess empirically the growth effect of the military.

Deger and Sen (1995), Ram (1995) and Dunne (1996) provide extensive reviews of the empirical literature, where the diversity as a result of sample selection (cross-country versus single-country estimates) and methodology are illustrated. Empirical evidence usually tends to vary across countries and over time and is sensitive to the theoretical framework. At first sight, the results tend to show no positive impact of military spending on economic growth, even if a supply-side framework (where the potential crowding out effect of defense is usually disregarded) is used. As Ram (1995) notes, it is nevertheless also difficult to claim that defense outlays have an overall negative effect on growth, since those demand-side studies that indicate an adverse effect of defense on investment only display a partial view as potential

[1] The terms *defense* and *military* will be used as synonyms throughout the paper.

(positive) externality effects of the military are not explicitly modelled.

Recently, several authors have postulated the existence of a nonlinear relationship between defense expenditures and economic growth (see for example Shieh *et al*, 2002). The notion that government expenditures in general could affect growth in a nonlinear way has already been formalized in contributions by Barro (1990) for example. Theoretical results predict a negative growth effect in countries where government expenditures exceed a certain threshold, resulting in an inverse U-shaped relationship between these two variables. In defense economics the idea that defense expenditures could have a nonlinear growth effect has recently also become more popular. The contributions of Kinsella (1990), Hooker and Knetter (1997), Heo (1998), Stroup and Heckelman (2001) Aizenman and Glick (2003) and Crespo Cuaresma and Reitschuler (2003) are examples of this branch of literature.

This piece of research contributes to the empirical literature on the defense-growth nexus in several aspects. For a sample of 105 developed and developing countries, the robustness of the relationship between GDP per capita growth and defense expenditure is assessed using a generalization of the procedure proposed by Sala-i-Martin (1997a, 1997b) that allows for nonlinearity in the underlying econometric specification. Given that the results support the existence of a level-dependent effect of defense spending on growth, a nonlinear version of the Feder-Ram model is implemented empirically in order to assess the nature of the growth effect of military expenditure.

The remainder of the paper is organized as follows: Section 2 evaluates the robustness of the defense-growth nexus taking account of potential nonlinearities. Section 3 applies a similar nonlinear modelling strategy to the widely used Feder-Ram model. Section 4 concludes.

2 The defense-growth nexus: Robustness and nonlinearity in cross-country growth regressions

This section studies the robustness of military expenditures as a determinant of economic growth in cross-country growth regressions, taking into account the potential nonlinearity that may exist between defense spending and growth. The methodology used in order to tackle the issue of robustness is based on Sala-i-Martin (1997a, 1997b), and has been applied to the determinants of economic growth in a more general setting by Crespo Cuaresma (2002).

2.1 Defense expenditure in cross-country growth regressions

Since the seminal contributions of Kormendi and Meguire (1985) and Barro (1991), cross-country growth regressions have been widely used in order to identify variables with a robust (partial) correlation with GDP per capita growth. The general setting provided by the Solow-Swan model of economic growth has given rise to the investigation of a vast amount of economic, social, political and demographic variables to find robust correlates of GDP per capita growth.[2] Defense expenditure has been used as an explanatory variable for economic growth in cross-country growth regressions on many occasions, with mixed results concerning the size and direction of its effect.

A stereotyped cross-country growth regression that nests practically all the specifications aimed at studying the effect of defense expenditure on growth is of the type

$$y_i = \vec{\beta}\mathbf{x}_i + \gamma D_i + \vec{\phi}\mathbf{z}_i + \varepsilon_i, \tag{1}$$

where y_i is the growth rate of GDP per capita for country i in the period considered, $\mathbf{x}_i$ is a set of variables that are almost unanimously used in most cross country growth regressions (usually those implied by the classical Solow-Swan model: initial GDP per-capita, the investment share and some measure of educational attainment), D_i is a measure of defense expenditure (usually the ratio of defense spending to GDP), whose effect the scientist is interested in, and $\mathbf{z}_i$ is a set of extra conditioning variables. The effect of defense spending on GDP growth will thus be embodied in $\hat{\gamma}$, the estimate of γ.

However, the size, sign and significance of the estimate of γ in (1) has been found to depend strongly on the conditioning set $\mathbf{z}_i$. As a robustness test to changes in the set of conditioning variables in growth regressions, Levine and Renelt (1992) applied Leamer's extreme bound analysis (Leamer, 1983) to the determinants of growth in cross-country growth regressions such as (1), among them the ratio of defense expenditure to GDP. Their conclusion is that defense expenditures are not robustly related to economic growth.

[2]In their survey of the empirics of economic growth, Durlauf and Quah (1999) name more than eighty variables that have been used at least once in a cross country growth regression.

An alternative robustness study is provided by Sala-i-Martin (1997a, 1997b). The methodology proposed by Sala-i-Martin (1997a, 1997b) drifts away from the labelling of variables as 'robust' or 'not robust', and instead attaches to each variable a level of robustness (in terms of probability) based on the entire distribution of its parameter estimate for different conditioning sets. The group of (95%) robust variables found in Sala-i-Martin (1997a, 1997b), however, does not include the defense expenditure ratio. Nevertheless, as we will argue below, this result seems to be affected by omitted nonlinearities when modelling the growth-defense relationship in specifications such as (1).

2.2 Nonlinearity and robustness in the defense-growth nexus

We will perform a robustness analysis of the defense-growth nexus in cross-country growth regressions using a generalization of Sala-i-Martin's (1997a, 1997b) procedure, and the same dataset. The methodology used in Sala-i-Martin (1997a, 1997b) evaluates the robustness of D_i as an explanatory variable in cross country growth regressions of the type given in (1) as follows. For a given set of fixed variables $\mathbf{x}_i$ (initial level of GDP per capita, life expectancy and primary school enrollment, and a constant) and a conditioning set $\mathbf{z}_i$, an OLS estimate of γ, $\hat{\gamma}_1$, and the variance of the estimate, $\hat{\sigma}^2_{\gamma,1}$ is obtained. This is repeated for all possible combinations of conditioning variables (in the basic setting, Sala-i-Martin, 1997a, 1997b, uses 58 conditioning variables in groups of three for $\mathbf{z}_i$, which leads to 30,856 estimates of γ and σ^2_γ). The robustness level of D_i is then calculated for positive estimates of $\bar{\bar{\gamma}} = 1/30,856 \sum_j \hat{\gamma}_j$ as the probability mass above zero (below zero for negative estimates of $\bar{\bar{\gamma}}$) in a normal distribution with mean $\bar{\bar{\gamma}}$ and variance $\bar{\bar{\sigma}}^2_\gamma = 1/30,856 \sum_j \hat{\sigma}^2_{\gamma,j}$. Alternative robustness levels can be obtained by weighting the individual estimates of γ and σ^2_γ using the relative goodness of fit of the model used to obtained them. Sala-i-Martin (1997a, 1997b) proposes using the ratio of the likelihood of model j over the sum of the likelihood of all estimated models as a weight for $\hat{\gamma}_j$and $\bar{\bar{\sigma}}^2_{\gamma,j}$ in the computation of $\bar{\bar{\gamma}}$ and $\bar{\bar{\sigma}}^2_\gamma$. The empirical distribution of the estimates of γ may also used instead of the normal distribution.

Independently of the method used to calculate the robustness measure, the variable 'Defense Spending Ratio' does not appear (95%) robust in the results presented in Sala-i-Martin (1997a, 1997b), although it is very close to robustness if the investment share is included as a fixed variable in $\mathbf{x}_i$. The resulting $\bar{\bar{\gamma}}$ is negative both for the weighted and unweighted averages.

We will generalize this procedure in order to allow for a level-dependent effect of military expenditure on economic growth. Our methodology will concentrate on the alternative piecewise-linear cross-country regression

$$y_i = \vec{\beta}_{n,i}\mathbf{x}_i + \gamma_n D_i + \vec{\phi}_{n,i}\mathbf{z}_i + \varepsilon_i, \tag{2}$$

where

$$n = \begin{cases} 1 \ if \ D_i \leq \mu \\ 2 \ if \ D_i > \mu \end{cases} \tag{3}$$

that is, the specification is piecewise-linear, and the regime n depends upon the level of defense expenditure. Notice that the linear model (1) is nested in (2)-(3) and can be obtained just by setting $(\vec{\beta}_1 \ \ \gamma_1 \ \ \vec{\phi}_1) = (\vec{\beta}_2 \ \ \gamma_2 \ \ \vec{\phi}_2)$.

In order to evaluate the robustness of military expenditure as a determinant of economic growth, equation (1) and its nonlinear counterpart, (2)-(3) are estimated for a given set of fixed variables, $\mathbf{x}_i$ and a combination of variables $\mathbf{z}_i$. The estimator of μ in (2)-(3) is given by

$$\widehat{\mu} = \text{argmin}_{\{D_k\}} \sum_i \widehat{\varepsilon}_i(D_z)^2$$

that is, the value of D_i that minimizes the sum of squared residuals in the nonlinear regression (2)-(3). The estimator $\widehat{\mu}$ is sought among the actually realized values of D_i, after trimming the extremes of the distribution for obvious identification reasons.[3] Once an estimator for μ has been found, the rest of the parameters in (2)-(3) can be estimated by OLS in a straightforward manner.

The problem of testing for threshold-nonlinearity of the type presented above has been widely discussed recently in the econometric literature. The intuition of the test for linearity is extremely simple: just test the null hypothesis of parameter equality across regimes against the alternative that at least one of the parameters differs between regime 1 and regime 2. The technical difficulty is posed by the fact that, given that the parameter μ is only identified under the alternative hypothesis of nonlinearity, standard probability distributions cannot be used in order to evaluate the corresponding likelihood ratio test statistic. In the spirit of Andrews and Ploberger (1994), Hansen (1996, 2000) proposes a bootstrap

[3] For the properties of this estimator, see e.g. Chan (1993).

procedure for testing the null of linearity against piecewise-linearity of the threshold type. The procedure can be summarized as follows: using the estimated linear relationship (1), artificial data on the dependent variable (real GDP per-capita growth) is simulated and both a linear and a piecewise linear model with the estimated threshold are fitted to the simulated sample. The corresponding likelihood ratio test statistic for the test of parameter equality across regimes is computed and the procedure is repeated a large number of times, leading to an approximate distribution of the test statistic under the null of linearity. The percentage of replicated test statistics that exceed the original value of the test statistic computed with real data is thus the p-value of the linearity test.

The threshold estimation and linearity testing procedure described above will be used in the modelling exercise in order to quantify the significance of the potential deviation from linearity of the data given the postulated linear relationship (1). The exercise is carried out in the following steps: For a given set of conditioning variables $\mathbf{z}_i = (z_1 \ldots z_m)'$, specification (1) is estimated, as well as the nonlinear specification (2)-(3). The estimated parameters corresponding to defense spending in the linear specification ($\widehat{\gamma}$) and in the nonlinear specification ($\widehat{\gamma}_i, i = 1, 2$) are stored, together with their estimated variances ($\widehat{\sigma}^2_{\gamma}, \widehat{\sigma}^2_{\gamma_1}$ and $\widehat{\sigma}^2_{\gamma_2}$, respectively) and the estimated threshold ($\widehat{\mu}$). For this specification of the cross-country growth regression the bootstrap testing procedure for linearity is carried out, and the resulting p-value is stored. The procedure is then repeated for another combination of conditioning variables, until all possible combinations are tried out. The resulting estimate of γ is the weighted average value of $\widehat{\gamma}$ across all replications of the experiment, and the estimate of σ^2_{γ} is the weighted average value of $\widehat{\sigma}^2_{\gamma}$. The estimate of the parameter of D_i in each regression is weighted using the likelihood of the estimated model over the sum of the likelihoods of all estimated cross-country regressions.[4]

2.3 Robustness results

The same dataset as in Sala-i-Martin (1997a, 1997b) was used for the analysis of the robustness of military expenditures as an explanatory factor of economic growth. The dataset includes information on average GDP per capita growth and 63 other economic, political and

[4]The weighting scheme, similar to the one used in Sala-i-Martin (1997a, 1997b), aims at giving more importance to those models that fit the data better in terms of sum of squared residuals. Doppelhofer, Miller and Sala-i-Martin (2000) show that this weighting scheme results as a limiting case of Bayesian model averaging with diffuse priors.

demographic variables for 105 countries[5] in the period 1960-1990. Information on country coverage and variables is given in Table 1 and Table 2.

Tables 1 and 2 around here

The variable of interest for the robustness analysis is the military spending share, defined as 'Public expenditures in defense as a fraction of GDP'. For the study, the three variables that will be used as fixed regressors, apart from the intercept, are the initial (logged) level of GDP per capita, initial primary school enrollment and initial life expectancy.[6] The vector of conditioning variables, $\mathbf{z}_i$, was constrained to contain two variables in each replication, and 25% of the distribution of D_i was trimmed in each extreme prior to the search of the threshold estimate. 500 replications were used in the computation of the p-value for the linearity tests in each round of the robustness experiment.

Table 3 around here

The results of the robustness analysis described above are presented in Table 3. The first two columns of Table 3 present the estimates of $\bar{\hat{\gamma}}$ and $\bar{\hat{\sigma}}$ for the linear and nonlinear specifications, and the third column presents the probability mass to the left of zero in a normal distribution centered around the estimate of γ with the corresponding standard deviation. The (weighted) average estimate of the parameter associated to defense expenditure in the linear setting appears negative and not robust, with an average estimate of its standard deviation which is more than four times bigger in absolute value. The value of the defense expenditure ratio corresponding to the (weighted) average estimate of the threshold is approximately 2%, which divides the sample of countries into two groups of roughly the same size (of the 105 countries with available defense expenditure data, 54 are in the 'low' regime, and 51 are in the 'high' regime). The average p-value for the linearity test rejects the null hypothesis of linearity at the usual 5% significance level. The picture arising from the nonlinear model is very different from that of the linear setting: the average estimate of the parameter in the low regime is extremely robust, negative and more than 75 times

[5] The dataset is comprised of 138 countries, but only 105 have available data for defense expenditures.

[6] These variables are also used as fixed regressors for the analysis in Sala-i-Martin (1997a, 1997b). In a variation of the procedure, Sala-i-Martin (1997a, 1997b) also uses the investment share as a fixed regressor. Due to the potential endogeneity of this variable, we decided not to use it as part of $\mathbf{x}_i$.

higher in absolute value than the average estimate in the linear model. Defense expenditure does not appear robustly related to growth in the high regime. Notice that these results do not support the inverse U-shaped relationship between military spending and growth, and actually contradict the results that Stroup and Heckelman (2001) obtain for Africa and Latin America.

The results point towards a level-dependent effect of defense expenditure on economic growth: while there is evidence of a robust negative partial correlation between military expenditure and growth for countries with a low level of defense expenditure over GDP (relative to the endogenously estimated threshold), the defense-growth nexus is not robust for countries with higher levels of defense spending. The next section will aim at analyzing the nature of this asymmetric effect of defense expenditure on growth by estimating a piecewise-linear version of the widely used Feder-Ram model.

3 Evidence from a nonlinear Feder-Ram model

Given the results of the robustness exercise, this section establishes empirically the relationship between defense expenditures and growth using the Feder-Ram model (Feder, 1983; Biswas and Ram, 1986), taking account of potential nonlinearities in the defense-growth nexus. The popularity of this theoretical setting in defense economics may be explained because of its ability to explicitly treat externality effects of the defense on the civil sector.[7] The model is a two-sector neoclassical growth model with an economy composed of a civilian and a defense sector, and it allows the defense sector to be treated as one sector in the economy and the size effect of the sector and its differential productivity effect to be distinguished. The model will be presented and the theoretical relationship between GDP growth and defense spending will then be estimated, allowing for level dependence in the effects of military spending on growth.

3.1 The Feder-Ram model: A piecewise-linear specification

Assume that the economy is composed of two sectors, the defense and the civilian sector. Let real output in the defense sector at time t be $D(t)$, and that in the civilian sector be $C(t)$. Furthermore, let us assume that labor ($L(t)$) and capital ($K(t)$) are the only inputs

[7] For a critique of the Feder-Ram model, see Dunne, Smith and Willenboeckel (2001).

in each sector, that the relative marginal products of labor and capital may differ across the two sectors and that the size of the defense sector output ($D(t)$) may act as an externality factor for the civilian sector

Consider the production functions of the two sectors,

$$C(t) = C(L_c(t), K_c(t), D(t))$$

and

$$D(t) = D(L_d(t), K_d(t))$$

where the lower case subscripts c and d denote sectoral inputs ($L(t) = L_c(t) + L_d(t)$ and $K(t) = K_c(t) + K_d(t)$), and total output in the economy ($Y(t)$) is the sum of output in both sectors. The marginal productivities of the factors of production – labor and capital – in the defense sector may not be the same as in the civilian sector.[8] Allowance is made for this by assuming that the marginal productivity of factors used in the defense sector is equal to $(1 + \delta)$ times the corresponding marginal factor productivity in the civilian sector, i.e.,

$$\frac{D_l}{C_l} = \frac{D_k}{C_k} = (1 + \delta)\,, \qquad \delta > -1$$

where the subscripts l and k refer to marginal products (assumed constant). If δ is positive, factors of production have a larger marginal productivity in the defense sector and vice versa if δ is negative. If δ is zero, marginal productivities are equal across the two sectors.

Differentiating total output with respect to time and substituting $dK(t)/dt$ by investment, $I(t)$, yields

$$\frac{dY(t)/dt}{Y(t)} = \alpha\frac{I(t)}{Y(t)} + \phi\frac{dL(t)/dt}{L(t)} + \psi\frac{dD(t)/dt}{D(t)}\frac{D(t)}{Y(t)} \tag{4}$$

[8] Defense production is not completely physically separate from civilian production because a large portion of defense supplies and equipment is used for defense purposes. The distinction between defense and civilian sectors is a theoretical difference. Empirically, civilian output or spending is just the difference between real output and defense spending, $C(t) = Y(t) - D(t)$.

where $\alpha = C_K, \phi = C_L$ and $\varphi = (\delta/(1+\delta) + C_d)$. However, this specification only allows us to test empirically whether both C_d and δ are zero at the same time. In order to be able to test independently the significance of each parameter, the further assumption that the effect of defense expenditure on the civilian sector has constant elasticity needs to be made. This implies a production function in the civil sector such as

$$C(t) = D(t)^{\theta} \Psi(L_c(t), K_c(t)),$$

for $\theta \in I\!R$. The resulting econometric specification if this assumption is made is

$$\frac{dY(t)/dt}{Y(t)} = \alpha \frac{I(t)}{Y(t)} + \phi \frac{dL(t)/dt}{L(t)} + \varpi \frac{dD(t)/dt}{D(t)} \frac{D(t)}{Y(t)} + \theta \frac{dD(t)/dt}{D(t)} \tag{5}$$

where $\varpi = \delta/(1+\delta) - \theta$ can be interpreted as the *size* effect of military expenditure on economic growth. This parametrization allows us to identify the structural parameters, θ (the externality parameter) and δ (the productivity differential parameter).

The empirical application will imply estimating the linear specification of the Feder-Ram model, both in the form of (4) and (5), and its nonlinear alternative, where both the externality and the productivity differential effect are allowed to differ depending on the overall level of defense expenditure,

$$\frac{dY(t)/dt}{Y(t)} = \alpha \frac{I(t)}{Y(t)} + \phi \frac{dL(t)/dt}{L(t)} + \psi_n \frac{dD(t)/dt}{D(t)} \frac{D(t)}{Y(t)} \tag{6}$$

and

$$\frac{dY(t)/dt}{Y(t)} = \alpha \frac{I(t)}{Y(t)} + \phi \frac{dL(t)/dt}{L(t)} + \varpi_n \frac{dD(t)/dt}{D(t)} \frac{D(t)}{Y(t)} + \theta_n \frac{dD(t)/dt}{D(t)} \tag{7}$$

with n defined in a similar fashion as in (3), that is,

$$n = \begin{cases} 1 \; if \; \frac{D(t)}{Y(t)} \leq \mu \\ 2 \; if \; \frac{D(t)}{Y(t)} > \mu \end{cases} \tag{8}$$

The specification assumes that the level of military expenditure determines the size (and, eventually, the existence) of both the inter-sectoral externality effect and the productivity differential between the military and civil sector.[9]

[9] A more general specification would allow the potential breakpoint to differ across structural parameters.

3.2 Empirical results

The linear (4) and (5) and nonlinear models (6) and (7) are estimated using data for 108 countries in the period 1985–1997.[10] The sample includes both developed and developing countries. The variables are averages in the period considered, as we are interested in potential effects of defense expenditures on long run growth. Table 4 presents the results of the OLS estimation of model (4) and its nonlinear counterpart (6).[11] In principle, it could be suspected that some of the right hand side variables are endogenous in the specification given by (4). Instrumental variable estimation of (4) was carried out using initial levels of investment, openness, military expenditure and GDP per capita as instruments. Although the Sargan test could not reject the validity of these instruments, the Durbin-Wu-Hausman test statistic gave evidence in favour of OLS estimation.[12]

Tables 4 and 5 around here

The estimates corresponding to α and ϕ are highly significant and positive for both models, and in the range of values usually reported in the literature. The estimate of the effect of military expenditure on GDP growth in the linear model is positive and not significant. The residuals of the linear model present significant deviations from normality and homoskedasticity according, respectively, to the Jarque-Bera and White test. The likelihood ratio test proposed by Hansen (1996) rejects the null of linearity at all reasonable significance levels, and the parameter estimates associated to defense spending in the nonlinear model offer a very different picture of the defense-growth nexus. The threshold level in the nonlinear model is estimated to be around 3.25%, which divides the sample into a 'low regime' subsample, formed by 72 countries (those with a level of military expenditure over GDP below the estimated threshold level) and a 'high regime' subsample of 36 countries. Table 5 presents the identity of the countries in each group. In the lower regime, the parameter

Given that the estimated thresholds for this specification using the data available were not distinguishable from each other (in the sense of overlapping 95% confidence intervals calculated following the method proposed in Hansen, 1996), we assume them to be located at the same value.

[10] The source of the data used for the estimations in this section is the World Development Indicators Database (World Bank) for the military expenditure ratio, investment share and population growth, and the Penn World Tables, Mark 5 (Summers and Heston, 2002) for GDP growth. The reason for not using the same data as in the previous section is that there is no data available for the growth of military expenditures in the Sala-i-Martin dataset.

[11] All estimations include a constant, which is not reported.

[12] The results from the estimation using instrumental variables are available from the authors upon request.

corresponding to the effect of military expenditures on GDP growth is negative, significant and much higher in absolute value than the estimate of the linear model. The positive parameter associated to military expenditure for the subsample of countries with a defense spending ratio higher than 3.25% is positive and only marginally significant (the p-value corresponding to the t-statistic from ψ_2 is 0.099). There is, thus, evidence of a negative effect of military expenditure on growth for countries with low levels of military expenditure (with respect to the endogenously estimated ratio of 3.25%). The evidence concerning the existence of a (positive) effect for countries with higher levels of military expenditure is very limited. We thus estimate the extended Feder-Ram model given by equation (7) in order to be able to distinguish a size and a growth effect. Notice as well that both the null hypothesis of normal distribution and homoskedasticity in the residuals cannot be rejected at the 5% significance level in the nonlinear model. This can be seen as evidence that the failure of the model given by (5) in rendering 'white' residuals is due to the omission of level-dependent nonlinearity in the relationship between defense spending and growth.

Table 6 around here

In order to investigate the nature of this asymmetric growth effect of military expenditure on growth, equations (5) and (7) were estimated. The threshold was estimated again for specification (7), yielding a similar value as for (6). The division of countries in regimes is, thus, the same as given in Table 5. The parameter estimates and other test statistics of the regression are shown in Table 6.[13]

The estimates corresponding to α and ϕ are, again, highly significant and positive for both models. The estimate of the size and the growth effect of military expenditure on GDP growth in the linear model are both not significant. The likelihood ratio test proposed by Hansen (1996) rejects the null of linearity at all reasonable significance levels. The threshold level in the nonlinear model is also estimated to be around 3.25%, leading to the same subsamples presented in Table 5. Notice that the residuals of the nonlinear model cannot reject the null of homoskedasticity using White's test, while there is evidence of heteroskedasticity

[13]A double threshold model, where the data was divided into three regimes according to the level of the military expenditure share, was also tried. The values of the defense spending share that jointly minimized the sum of squared residuals for the two-threshold model where 1.04% and 3.25%, but Hansen (1996)'s test could not reject at the usual 5% significance level that the proper specification is the one with a single threshold. The results of the three-regime model are available from the authors upon request.

in the linear model. This offers extra statistical evidence concerning the superiority of the nonlinear model over the linear setting.

In the lower regime, the parameter corresponding to the size effect of military expenditures on GDP growth is negative and highly significant. The point estimate of δ based on the results for the low regime is approximately -0.91, indicating that factors of production have a larger marginal productivity (on average) in the civil sector for the corresponding subsample. The externality effect (reflected in the parameters θ_1 and θ_2) is significantly positive only for the low regime, and not significant for the high regime. This result can be reconciled with a concave functional form for the indirect effects of defense on growth such as the one behind the model by Stroup and Heckelman (2001), but the productivity effect renders the net effect for those countries below the estimated threshold negative. No significant productivity differential or externality effect is found for the group of countries in the high regime.

Surprisingly, in the subset of countries where the basic externalities provided by the military sector seem to have a significantly positive effect on output growth, the productivity differential between the defense and civilian sector renders the average net effect of increases in defense production on growth negative. It is thus the size effect of military expenditure that accounts for the results found in the robustness exercise in the previous section of this paper.

4 Conclusions

This piece of research presents evidence concerning the effect of defense expenditures on economic growth for two datasets including more than a hundred developing and developed countries. A robustness analysis allowing for nonlinear effects of military expenditure on GDP per capita growth for the period 1960-1990 finds evidence of a robust negative partial correlation between military expenditures and growth for countries with relatively low levels of defense expenditure share with respect to an endogenously estimated threshold. Using a dataset that includes more recent observations, we found additional evidence for a level-dependent effect of defense spending on growth and were also able to shed light on the sources of the negative growth effect of military expenditures on growth for the subsample of countries with a low military burden.

The results indicate that the negative productivity differential between the military and civilian sector in the subsample of "low military spending" countries accounts for the negative partial correlation between the share of defense expenditures and economic growth. However, it is only in these countries where the potential externality effect of the military sector seems to play a role in terms of contribution to GDP growth, although the (average) net effect is negative due to the size effect. Given the lower productivity of the defense sector and given that downsizing the defense sector, the logic implication of our empirical finding, may be unrealistic due to political reasons, one feasible alternative may be to raise productivity in the defense sector. This could, at least partly, allow to reap some benefits for the civil sector.

Both the robustness exercise and the estimation results of the Feder-Ram model present overwhelming statistical evidence that the use of linear models can lead to a distorted picture of the defense-growth nexus. Hence nonlinear models are bound to replicate better the stylized facts underlying the relationship between defense spending and economic growth. Although the simple Feder-Ram model that was estimated in this piece of research gives a clear indication of the nature of the negative effect of military expenditures on growth, other theoretical frameworks concentrating on institutional or political variables may as well serve to give complementary explanations of the asymmetry .

References

[1] Aizenman, J., Glick, R., 2003. Military expenditure, threats, and growth. NBER Working Paper 9618.

[2] Andrews, D., Ploberger, W., 1994. Optimal tests when a nuisance parameter is present only under the alternative. Econometrica 62, 1383-1414.

[3] Barro, R. J., 1990. Government spending in a simple model of endogenous growth. Journal of Political Economy 98, S103–S125.

[4] Barro, R. J., 1991. Economic growth in a cross section of countries. Quarterly Journal of Economics 106, 407-443.

[5] Barro, R. J., 1996. Democracy and growth. Journal of Economic Growth 1, 1-27.

[6] Barro, R. J., Lee, J., 1993. International comparisons of educational attainment. Journal of Monetary Economics 32, 363-394.

[7] Benoit, E., 1973. Defense and Economic Growth in Developing Countries. Lexington, MA, Lexington Books.

[8] Biswas, B., Ram, R., 1986. Military expenditures and economic growth in LDCs: An augmented model and further evidence. Economic Development and Cultural Change 34, 361-372.

[9] Chan, K. S., 1993. Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model. Annals of Statistics 21, 520-533.

[10] Crespo Cuaresma, J., Reitschuler, G., 2003. A nonlinear defense-growth nexus? Evidence from the US economy. Defense and Peace Economics, forthcoming.

[11] Deger, S., Sen, S., 1995. Military Expenditures and Developing Countries, in: Hartley, K., Sandler, T. (Eds.), Handbook of Defense Economics Vol. 1. Elsevier, Amsterdam, pp. 275-307.

[12] DeLong, J. B., Summers, L. H., 1991. Equipment investment and economic growth. Quarterly Journal of Economics 106, 445-502.

[13] Doppelhofer, G., Miller, R. I., Sala-i-Martin, X. X., 2000. Determinants of long-term growth: A bayesian averaging of classical estimates (BACE) approach. NBER Working Paper 7750. Forthcoming in American Economic Review.

[14] Dunne, J. P., 1996. Economic Effects of Military Expenditure in Developing Countries: A Survey, in: Gleditsch N.P. et al. (Eds.), The Peace Dividend. North Holland, Amsterdam, pp. 439-464.

[15] Dunne, J. P., Smith, R., Willenbockel, D., 2001. Theoretical and econometric issues in analyzing the military expenditure-growth nexus. Paper presented at the sixth annual conference on econometric modelling for africa, University of Pretoria, July 2001.

[16] Easterly, W., Levine, R., 1997. Africa's growth tragedy: Policies and ethnic divisions. Quarterly Journal of Economics 112, 1203-1250.

[17] Feder, G., 1983. On exports and economic growth. Journal of Development Economics 12, 59-73.

[18] Durlauf, S. N., Quah, D. T., 1999. The New Empirics of Economic Growth, in: Taylor, J. B., Woodford, M. (Eds.), Handbook of Macroeconomics, Vol. IA. North-Holland, Amsterdam, pp. 231-304.

[19] Hall, R., Jones, C., 1996. The productivity of nations. NBER Working Paper 5812.

[20] Hansen, B., 1996. Inference when a nuisance parameter is not identified under the null hypothesis. Econometrica 64, 413-30.

[21] Hansen, B., 2000. Sample splitting and threshold estimation. Econometrica 68, 575-603.

[22] Heo, U., 1998. Modeling the defense-growth relationship around the globe. Journal of Conflict Resolution 42, 637-657.

[23] Summers, R., Heston, A., 1991. Penn world table (Mark 5): An expanded set of international comparisons, 1950-1988. Quarterly Journal of Economics 106, 327-369.

[24] Hooker, M. A., Knetter, M. M., 1997. The effects of military spending on economic activity: Evidence from state procurement spending. Journal of Money, Credit, and Banking 29, 400-21.

[25] King, R. G., Levine, R., 1993. Finance, entrepeneurship and growth: Theory and evidence. Journal of Monetary Economics 32, 513-542.

[26] Kinsella, D., 1990. Defense spending and economic performance in the United States: A causal analysis. Defence Economics 1, 295-309.

[27] Knack, S., Keefer, P., 1995. Institutions and economic performance: Cross-country tests using alternative institutional measures. Economics and Politics 7, 207-227.

[28] Kormendi, R., Meguire, P., 1985. Macroeconomic determinants of growth, cross-country evidence. Journal of Monetary Economics 16, 141-163.

[29] Leamer, E. E., 1983. Let's take the con out of econometrics. American Economic Review 73, 31-43.

[30] Levine, R., Renelt, D., 1992. A sensitivity analysis of cross-country growth regressions. American Economic Review 82, 942-963.

[31] Ram, R., 1995. Defense Expenditure and Economic Growth, in: Hartley, K., Sandler, T. (Eds.), Handbook of Defense Economics, Vol. 1. Elsevier, Amsterdam, pp. 251-273.

[32] Sachs, J., Warner, A., 1996. Natural resource abundance and economic growth. Mimeo, Harvard Institute for International Development.

[33] Sala-i-Martin, X. X., 1997a. I just ran two million regressions. American Economic Review 87, 178-183.

[34] Sala-i-Martin, X. X., 1997b. I just ran four million regressions. NBER Working Paper 6252.

[35] Shieh, J., Lai, C., Chang, W., 2002. The impact of military burden on long-run growth and welfare. Journal of Development Economics 68, 443-454.

[36] Stroup, M. D., Heckelman, J. C., 2001. Size of the military sector and economic growth: A panel data analysis of Africa and Latin America. Journal of Applied Economics IV, 329-360.

Table 1: Country coverage for the robustness analysis

Algeria	Finland	Madagascar	Singapore
Argentina	France	Malawi	South africa
Australia	Gabon	Malaysia	Spain
Austria	Germany, West	Mali	Sri Lanka
Bangladesh	Ghana	Mauritania	Sudan
Belgium	Greece	Mauritius	Sweden
Benin	Guatemala	Mexico	Switzerland
Bolivia	Guinea	Morocco	Syria
Brazil	Guyana	Myanmar (Burma)	Taiwan
Burkina Faso	Haiti	Nepal	Tanzania
Burundi	Honduras	Netherlands	Thailand
Cameroon	Hong Kong	New Zealand	Togo
Canada	India	Nicaragua	Trinidad & Tobago
Cent'l Afr. Rep.	Indonesia	Niger	Tunisia
Chad	Iran, I.R. of	Nigeria	Turkey
Chile	Iraq	Norway	Uganda
Colombia	Ireland	Pakistan	United Kingdom
Congo	Israel	Panama	United States
Costa Rica	Italy	Papua New Guinea	Uruguay
Cote d'Ivoire	Jamaica	Paraguay	Venezuela
Cyprus	Japan	Peru	Yugoslavia
Denmark	Jordan	Philippines	Zaire
Dominican Rep.	Kenya	Portugal	Zambia
Ecuador	Korea	Rwanda	Zimbabwe
Egypt	Kuwait	Saudi Arabia	
El Salvador	Liberia	Senegal	
Ethiopia	Luxembourg	Sierra Leone	

Table 2: Variables used in the robustness analysis

Absolute Lattitude. Barro (1996)
Area (Scale Effect). Barro and Lee (1993). Total area of the country.
Average Inflation Rate 1960-90. Levine and Renelt (1992)
Average Years of Higher Schooling. Barro and Lee (1993)
Average Years of Primary Schooling in 1960. Barro and Lee (1993)
Average Years of Schooling. Barro and Lee (1993)
Average Years of Secondary Schooling. Barro and Lee (1993)
Black Market Premium. Barro and Lee (1993) [log (1+Black Market Premium)]
British Colony Dummy. Barro (1996)
Civil Liberties Index. Knack and Keefer (1995)
Defense Spending Share. Barro and Lee (1993)
Degree of Capitalism Index. Hall and Jones (1996)
Equipment Investment. Delong and Summers (1991)
Ethnolinguistic Fractionalization Index. Easterly and Levine (1997)
Exchange Rate Distortions. Levine and Renelt (1992)
Fraction of Buddhists. Barro (1996)
Fraction of Catholics. Barro (1996)
Fraction of Confucius. Barro (1996)
Fraction of GDP in Mining. Hall and Jones (1996)
Fraction of Hindu. Barro (1996)
Fraction of Jewish. Barro (1996)
Fraction of Muslims. Barro (1996)
Fraction of Population Able to Speak a Foreign Language. Sala-i-Martin (1997a, 1997b)
Fraction of Population Able to Speak English. Hall and Jones (1996)
Fraction of Protestants. Barro (1996)
Free Trade Openness. Barro and Lee (1993)
French Colony Dummy. Barro (1996)
Growth of Domestic Credit 1960-90. Levine and Renelt (1992)
Growth Rate of GDP per capita 1960-90. Penn World Tables, Summer and Heston (1991);
Growth Rate of Population 1960-90. Barro and Lee (1993)
Higher Education Enrollment, 1960. Barro and Lee (1993)
Index of Democracy as of 1965. Knack and Keefer (1995)
Latin American Dummy. Sala-i-Martin (1997a, 1997b)
Life Expectancy in 1960. Barro and Lee (1993)
Liquid Liabilities to GDP Ratio. King and Levine (1993)

Table 2 (continued): Variables used in the robustness analysis

Log(GDP per capita 1960). Barro and Lee (1993)
Non-Equipment Investment. Delong and Summers (1991)
Number of Years Open Economy. Sachs and Warner (1996)
Outward Orientation Index. Levine and Renelt (1992)
Political Assassinations. Barro and Lee (1993)
Political Instability Index. Knack and Keefer (1995)
Political Rights Index. Barro (1996)
Primary Exports Share in Total Exports. Sachs and Warner (1996)
Primary School Enrollment in 1960. Barro and Lee (1993)
Product of average years of schooling and GDP per capita in 1960. Barro and Lee (1993)
Public Consumption Share. Barro and Lee (1993)
Public Education Spending Share. Barro and Lee (1993)
Public Investment Share. Barro and Lee (1993)
Ratio of Workers to Population. Barro and Lee (1993)
Revolutions and Coups. Barro and Lee (1993)
Rule of Law Index. Barro (1996)
Secondary School Enrollment in 1960. Barro and Lee (1993)
Size Labor Force (Scale Effect). Barro and Lee (1993)
Spanish Colony Dummy. Barro (1996)
Standard Deviation of Domestic Credit 1960-90. King and Levine (1993)
Standard Deviation of Inflation 1960-90. Levine and Renelt (1992)
Standard Deviation of the Black Market Premium 1960-89. Levine & Renelt (1992)
Sub-Sahara African Dummy. Sala-i-Martin (1997a, 1997b)
Tariff Restrictions Degree. Barro and Lee (1993)
Terms of Trade Growth 1960-90. Barro and Lee (1993)
Urbanization Rate. Barro and Lee (1993)
War Dummy. Barro and Lee (1993)

Table 3: Robustness and nonlinearity analysis: Defense expenditure ratio

	Linear Specification		
	$\bar{\bar{\gamma}}$	$\bar{\bar{\sigma}}_\gamma$	$P(\gamma < 0 \mid \bar{\bar{\gamma}}, \bar{\bar{\sigma}}_\gamma)$
	-0.0115	0.0505	0.5898
	Nonlinear Specification		
	$\bar{\bar{\gamma}}_k$	$\bar{\bar{\sigma}}_{\gamma_k}$	$P(\gamma_k < 0 \mid \bar{\bar{\gamma}}_k, \bar{\bar{\sigma}}_{\gamma^k})$
$k = 1$	-0.8451	0.3718	0.9885
$k = 2$	-0.0467	0.0650	0.7639
$\overline{\widehat{\mu}}$	0.0197		
Average p-value	0.0205		

Table 4: Linear and nonlinear Feder-Ram models: estimates

	Linear Model	**Nonlinear Model**
Parameter	Estimate (s.e)	Estimate (s.e)
α	0.1433*** (0.0368)	0.1311*** (0.0356)
ϕ	0.6889*** (0.2376)	0.7806***(0.2299)
ψ	0.1299 (0.4837)	–
ψ_1	–	-2.8878*** (1.0639)
ψ_2	–	0.8653*(0.5195)
μ	–	0.0325
R^2_{adj}	0.1142	0.1842
J-B test stat.	6.1419	4.3984
White test stat.	27.2255	21.1355
Linearity test stat.	10.4180 (p-value: 0.004)	

***(**)[*] stands for 1% (5%) [10%] significant. An intercept was included in both specifications, but is not reported. The J-B test statistic refers to the Jarque-Bera test statistic for normality, $\chi^2(2)$ distributed under the null of normally distributed residuals. The White test statistic refers to White's TR^2 test for heteroskedasticity, $\chi^2(9)$ distributed under the null of homoskedasticity for the linear model and $\chi^2(14)$ distributed under the null of homoskedasticity for the nonlinear model. The p-value of the linearity test is computed using 500 bootstrap replications. The threshold estimate was sought in the central 50% of the empirical distribution of the defense expenditure ratio over GDP variable.

Table 5: **Subsamples in the Feder-Ram nonlinear model**

Countries in the 'low regime' ($D_i \leq \hat{\mu}$)		Countries in the 'high regime' ($D_i > \hat{\mu}$)
Albania	Japan	Botswana
Algeria	Kenya	Bulgaria
Argentina	Lithuania	Burundi
Australia	Luxembourg	Chile
Austria	Madagascar	Congo, Rep.
Azerbajan	Malawi	Croatia
Barbados	Malaysia	Cyprus
Belarus	Malta	Egypt
Belgium	Mauritius	Ethiopia
Bolivia	Mexico	France
Brazil	Moldava	Great Britain
Burkina Faso	Moldova	Greece
Cameroon	Namibia	Hungary
Canada	Nepal	Iran
Chad	Netherlands	Israel
China	New Zealand	Jordania
Colombia	Nigeria	Korea, Rep.
Congo, Dem. Rep.	Norway	Lebanon
Costa Rica	Panama	Lesotho
Cote d'Ivoire	Papua New Guinea	Morocco
Czech Rep.	Paraguay	Nicaragua
Denmark	Peru	Pakistan
Dominican Rep.	Phillipines	Poland
Ecuador	Portugal	Romania
Estonia	Sierra Leone	Russia
Fiji	Slovakia	Rwanda
Finland	Spain	Singapur
Gabon	Sweden	South Africa
Germany	Switzerland	Sri Lanka
Ghana	Thailand	Syria
Guinea	Togo	Turkey
Guinea-Bissau	Trinidad and Tobago	Uganda
India	Tunisia	United States
Indonesia	Uruguay	Vietnam
Ireland	Venezuela	Yemen
Italy	Zambia	Zimbawe

Table 6: Production Function Approach: Nonlinear Specification

	Linear Model	**Nonlinear Model**
Parameter	Estimate (s.e)	Estimate (s.e)
α	0.1375*** (0.0371)	0.1359*** (0.0390)
ϕ	0.7351*** (0.2409)	0.7931***(0.3140)
ω	1.3474 (1.1942)	–
θ	-0.0611 (0.0548)	–
ω_1	–	-9.9388***(3.053)
ω_2	–	-0.1841 (1.6437)
θ_1	–	0.2094**(0.0891)
θ_2	–	0.0631(0.0942)
μ	–	0.0325
R^2_{adj}	0.1162	0.1979
J-B test stat.	3.7107	5.5255
White test stat.	28.0248	28.4266
Linearity test stat.	13.350 (p-value: 0.002)	

***(**)[*] stands for 1% (5%) [10%] significant. An intercept was included in both specifications, but is not reported. The J-B test statistic refers to the Jarque-Bera test statistic for normality, $\chi^2(2)$ distributed under the null of normally distributed residuals. The White test statistic refers to White's TR^2 test for heteroskedasticity, $\chi^2(14)$ distributed under the null of homoskedasticity for the linear model and $\chi^2(23)$ distributed under the null of homoskedasticity for the nonlinear model. The p-value of the linearity test is computed using 500 bootstrap replications. The threshold estimate was sought in the central 50% of the empirical distribution of the defense expenditure ratio over GDP variable.