A Linear and Non-Linear Causality Analysis between Military Expenditures and External Debt in NATO Member Countries

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Abstract

This paper deploys the linear and non-linear Granger causality methods in order to determine the causal relationship between military expenditures and external debt in NATO countries for the time period 1960-2015. Its innovative feature lies in the empirical application of the Francis et al. (2010) nonlinear causality test. To our knowledge, this is the first study to employ the specific test in order to explore the existence of potential nonlinear links between military spending and debt. The empirical results indicate the existence of linearity in the cases of Greece, Italy, UK and USA and the existence of nonlinearity in the cases of Turkey and USA. The paper aims to provide valuable input to the regulators and decision makers.

Keywords: military expenditures, external debt, NATO countries

1. Introduction

The relationship between military expenditures and external debt has attracted the interest of many economists and policy makers. The significance of the topic lays to the impact of military expenditures on the indebtedness of both developed and developing countries. Especially, nowadays, with the advent of the economic crisis and the need for shrinking public spending, the issue has become more relevant than ever. Military expenditures burden the level of external debt in a threefold manner (Shahbaz et al. 2013; Günlük-Senesen, 2004; Wolde-Rufael, 2009); they cause pressure for borrowing (internal and especially external), increase imports of defence equipment or technologically advanced intermediate goods - to internally produce defence equipment. In all previous cases, countries resort either to foreign borrowing or to the reduction of their foreign exchange reserves.

The causal relationship between military expenditures and debt can be classified into four categories: a unidirectional causality running from military spending to debt, a unidirectional causality running from debt to military spending, a bidirectional causality between military spending and debt and the complete absence of causality. Since the late '80s, researchers have conducted causality tests to explore the presence and direction of causality between military spending and external debt either in country groups or in individual countries. The empirical investigation has yielded mixed results on the direction of causality, which are mainly attributed to differences in data sets, leading to different policy implications.

The aim of the present paper is to investigate the relationship between military expenditures and external debt by employing linear and non-linear causality methodologies in the NATO member countries during the time period 1960-2015. The innovative contribution of the study is the implementation of one of the most advanced econometric methods, the nonlinear Granger causality test developed by Francis et al. (2010). The potential existence of nonlinearity will reveal a far more complex relationship between these two variables that has never previously been recognised and it will push economic and defense policy makers to revise their military spending decisions for internal and external security purposes.

The remainder of the paper is organized as follows: Section 2 reviews the literature on the military expenditures-external debt nexus, Section 3 provides an overview of the empirical methodology, Section 4 presents the data and the empirical results of the study and section 5 provides the concluding remarks and suggestions for future research.

2. Literature Review

The topic of a potential causal relationship between the military expenditures and external debt was initially introduced by Brzoska (1983), who primarily acknowledged the significance of military spending to the external debt of many indebted developing countries. Subsequently, Looney and Frederiksen (1986) explored the relationship in resource-constrained and resource-unconstrained countries. Since then, many researchers examined different countries or groups of countries, in

different time periods, using different explanatory variables and different empirical methodologies in order to determine the causality flow of the relationship.

Among the multi-country studies, Alexander (2013) was the one that applied a dynamic panel model in a sample of high-income OECD/NATO countries, over the period 1988-2009 and found that the defence burden is a statistically significant and economically important determinant of public debt. There is a number of other multi-country studies that employed panel data analysis and investigated the military spending-debt nexus in EU or OECD countries. Zhang et al. (2016) examined a panel of 11 OECD countries and found a unidirectional flow running from military spending to external debt for the US and the opposite flow for Canada and the UK. Caruso and Di Domizio (2017) explored 13 EU countries and US and validated the fact that US military spending affects European sovereign debt. Similarly, Paleologou (2013) concluded to a large positive impact on the share of general government debt in the 25 EU countries.

Our analysis, though, focuses individually on each country, shaping more with the country-specific studies. Kollias et al. (2004) found that military expenditure adversely affects central government debt and external debt in the case of Greece. In the same spirit lays the study of Dimitraki and Kartsaklas (2017), that determined military spending as a primary cause of debt growth in Greece. Karagol (2005, 2006) acknowledged a unidirectional causal flow from defence expenditure to external debt for Turkey, whereas Sezgin (2004) found no clear evidence of the defense–debt relationship for the same country. Norrlof and Wohlforth (2016) ended up with the fact that military spending is not a significant determinant of public debt in the US.

3. Methodology

In this section, the definitions of the linear and the non-linear Granger causality tests are discussed. In the first part, we briefly describe the traditional linear Granger causality approach and in the second part, we present the statistical technique for non-linear Granger causality, developed by Baek and Brock (1992), modified by Hiemstra and Jones (1994) and revised by Francis et al. (2010).

3.1 The Linear Granger Causality Test

A time series X_t causes another time series Y_t in the Granger sense (Granger, 1969) if present Y can be predicted better by using past values of X than by not doing so, considering also other relevant information, including past values of Y. If this exists, X_t is said to linearly Granger cause Y_t. Bidirectional causality exists if Granger causality runs in both directions.

The test for linear Granger causality between military expenditures and external debt involves the estimation of the following equations in a vector autoregression (VAR) framework:

$$R_{1,t} = \sum_{i=1}^{\theta_1} \alpha_i R_{1,t-i} + \sum_{j=1}^{\theta_2} \beta_j R_{2,t-j} + \varepsilon_{1,t} \quad (1)$$

$$R_{2,t} = \sum_{i=1}^{\theta_3} \delta_i R_{2,t-i} + \sum_{j=1}^{\theta_4} \phi_j R_{1,t-j} + \varepsilon_{2,t} \quad (2)$$

$R_{1,t}$ and $R_{2,t}$ indicate, respectively, the military expenditures to GDP and external debt to GDP in the year t; α, β, δ, and ϕ indicate the parameters to be estimated; (ε_1, ε_2) are zero-mean error terms with a constant variance–covariance matrix. With the use of the Bayesian information criterion (BIC), we determine the optimal lag lengths.

Equations (1) and (2) identify the linear causal relationships. By examining the statistical significance of the individual β and ϕ coefficient estimates, we test for linear Granger non-causality at specific lags. By testing the null hypothesis that $\Sigma\beta_j=0$ in Equation (1) or $\Sigma\phi_j=0$ in Equation (2) using a T-statistic, we check for cumulative linear Granger non-causality (Francis et al., 2010).

3.2 The Non-Linear Granger Causality Test

Baek and Brock (1992) propose a non-parametric statistical method for detecting non-linear causal relations that cannot be uncovered by equivalent linear tests. Their approach employs the correlation integral, which provides an estimate of

spatial dependence across time. Consider two stationary and weakly dependent time series $R_{1,t}$, that stands for military expenditures to GDP and $R_{2,t}$ that stands for external debt to GDP. Let the *m*-length lead vector of $R_{1,t}$ be designated by $R_{1,t}^{m}$, and the *Lr1* and the *Lr2* be the lag vectors of $R_{1,t-Lr1}^{Lr1}$ and $R_{2,t-Lr2}^{Lr2}$ of $R_{1,t}$ and $R_{2,t}$, respectively.

For given values of *m, Lr1,* and *Lr2* ≥ 1 and for *d* > 0, $R_{2,t}$ does not strictly Granger cause $R_{1,t}$ if:

$$\Pr\left(\left\| R_{1,t}^{m} - R_{1,s}^{m} \right\| < e \,\middle|\, \left\| R_{1,t-Lr1}^{Lr1} - R_{1,s-Lr1}^{Lr1} \right\| < d \,,\, \left\| R_{2,t-Lr2}^{Lr2} - R_{2,s-Lr2}^{Lr2} \right\| < d\right)$$

$$= \Pr\left(\left\| R_{1,t}^{m} - R_{1,s}^{m} \right\| < d \,\middle|\, \left\| R_{1,t-Lr1}^{Lr1} - R_{1,s-Lr1}^{Lr1} \right\| < d\right), \qquad (3)$$

where Pr(.) denotes probability and $\|\ .\ \|$ denotes the maximum norm for vector X≡ (X_1, X_2, …, X_K) and *s, t* = max (*Lr1, Lr2*) + 1, …, *T* – *m* + 1.

The probability on the left hand side of Equation (3) is the conditional probability that the two arbitrary *m*-length lead vectors $R_{1,t}$ are within a distance *d* of each other, given that the corresponding *Lr1*-length lag vectors of $R_{1,t}$ and two *Lr2*-length lag vectors of $R_{2,t}$ are within *d* of each other. The probability on the right hand side of Equation (3) is the conditional probability that two arbitrary *m*-length lead vectors of $R_{1,t}$ are within a distance *d* of each other, given that their corresponding *Lr1*-length lag vectors are within a distance *d* of each other.

If we express the conditional probability in terms of the ratios of joint and conditioning probabilities, the test in Equation (3) takes the form of Equation (4):

$$\frac{CI(\boldsymbol{m}+\boldsymbol{Lr1},\boldsymbol{Lr2},d)}{CI(\boldsymbol{Lr1},\boldsymbol{Lr2},d)} = \frac{CI(\boldsymbol{m}+\boldsymbol{Lr1},d)}{CI(\boldsymbol{Lr1},d)} \qquad (4)$$

The correlation-integral estimators of the joint probabilities, which are discussed in detail by Hiemstra and Jones (1994), are given in Equation (5):

$$CI(\boldsymbol{m}+\boldsymbol{Lr1},\boldsymbol{Lr2},d) \equiv \Pr(\|\boldsymbol{R}_{1t-Lr1}^{\boldsymbol{m}+\boldsymbol{Lr1}} - \boldsymbol{R}_{1s-Lr1}^{\boldsymbol{m}+\boldsymbol{Lr1}}\| < d, \|\boldsymbol{R}_{2t-Lr2}^{\boldsymbol{Lr2}} - \boldsymbol{R}_{2s-Lr2}^{\boldsymbol{Lr2}}\| < d),$$

$$CI(\boldsymbol{Lr1},\boldsymbol{Lr2},d) \equiv \Pr(\|\boldsymbol{R}_{1t-Lr1}^{\boldsymbol{Lr1}} - \boldsymbol{R}_{1s-Lr1}^{\boldsymbol{Lr1}}\| < d, \|\boldsymbol{R}_{2t-Lr2}^{\boldsymbol{Lr2}} - \boldsymbol{R}_{2s-Lr2}^{\boldsymbol{Lr2}}\| < d),$$

$$CI(\boldsymbol{m}+\boldsymbol{Lr1},d) \equiv \Pr(\|\boldsymbol{R}_{1t-Lr1}^{\boldsymbol{m}+\boldsymbol{Lr1}} - \boldsymbol{R}_{1s-Lr1}^{\boldsymbol{m}+\boldsymbol{Lr1}}\| < d),$$

$$CI(\boldsymbol{Lr1},d) \equiv \Pr(\|\boldsymbol{R}_{1t-Lr1}^{\boldsymbol{Lr1}} - \boldsymbol{R}_{1s-Lr1}^{\boldsymbol{Lr1}}\| < d).$$

(5)

In order to test the condition in Equation (4), we use the correlation-integral estimators of Equation (5). Supposing that $R_{1,t}$ and $R_{2,t}$ are strictly stationary, weakly dependent and satisfy the mixing conditions of Denker and Keller (1983), under the null hypothesis that $R_{2,t}$ does not strictly Granger cause $R_{1,t}$, the test statistic T is asymptotically normally distributed and it is determined by Equation (6):

$$T = \left[\frac{CI(\boldsymbol{m}+\boldsymbol{Lr1},\boldsymbol{Lr2},d,n)}{CI(\boldsymbol{Lr1},\boldsymbol{Lr2},d,n)} - \frac{CI(\boldsymbol{m}+\boldsymbol{Lr1},d,n)}{CI(\boldsymbol{Lr1},d,n)}\right] \sim N\left(0, \frac{1}{\sqrt{n}}\sigma^2(\boldsymbol{m},\boldsymbol{Lr1},\boldsymbol{Lr2},d)\right) \qquad (6)$$

where, *n* = *T* + *1* − *m* − max (*Lr1, Lr2*) and *σ2(·)* is the asymptotic variance of the modified Baek and Brock test statistic. The test statistic in Equation (6) is applied to the two estimated residual series from the VAR model in Equations (1) and (2), $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$, respectively. Therefore, if the null hypothesis of Granger non-causality is rejected, the detected causal relationship between the two variables must necessarily be nonlinear.

4. DATA AND EMPIRICAL RESULTS

4.1 Data

The present analysis has been carried out using annual data for NATO member countries[1] for the time period 1960-2015. The data concerning debt to Gross Domestic Product (GDP) ratio is obtained from the *Historical Public Debt Database* published by the International Monetary Fund (IMF, 2019). Military expenditures as percentage of GDP data are obtained from the *SIPRI Military Expenditure Database* (SIPRI, 2018). All data used are expressed as percentage of GDP and in current prices. The implementation of non-linear causality tests requires the use of current prices, in order to avoid the filtering caused by the transformation of time-series in constant prices.

4.2 Results of the Linear Granger Causality Test

Before we proceed to the implementation of the linear Granger causality test, stationarity tests should be performed for each of the relevant variables. Unit roots need to be removed, in order to obtain stationary series. For this purpose, in the present study, the augmented Dickey-Fuller (ADF) test procedure (Dickey and Fuller, 1979) was employed. The findings from the ADF test suggest that the series have been proved to be stationary in the first differences at 10% significance level. The Schwartz Info criterion rule has been employed for the selection of the lag parameters. Subsequently, we carry out the linear Granger causality test. The null hypothesis suggests that no Granger causality exists between military expenditures and debt. The alternative hypothesis declares that a linear Granger causality exists. If the probability is greater than the critical value, the null hypothesis is considered as significant and we accept it as the true case. If the critical value is greater than the probability, the null hypothesis is not considered to be significant and we accept the alternative hypothesis. Table 1 provides a view of the linear Granger causality results.

The findings indicate the existence of a unidirectional causality running from military expenditures to external debt in the UK and the USA as well as a unidirectional flow running from debt to military expenditures in the cases of Greece and Italy. No causality is observed in all other cases. Overall, the results indicate that, in some countries, as military expenditure grows there is a tendency for external debt to grow and vice versa. The results of the study are comparable to the study of Sezgin (2004), that found no signs of linear causality for Turkey, but contradictory to the study of Karagol (2005, 2006), that determined defence burden as a statistically significant and economically important determinant of external debt. Our findings also contradict to the findings of Kollias et al. (2004) and Dimitraki and Kartsaklas (2017) for Greece, that indicated a positive effect of military spending on sovereign debt in Greece. Additionally, Norrlof, and Wohlforth (2016) found that military spending is not a significant determinant of debt in the USA, in contrast with our conclusions that declare the existence of a unidirectional flow from military expenditures to debt. These opposing results could be attributed to the fact that different studies have focused on different time periods, proxy variables and alternative econometric methodologies to elaborate the external debt and defense spending relationship.

Table 1: Linear Granger causality test results

Countries	Null Hypothesis	Probability	Results
Belgium	DEBT does not Granger Cause ME	0.6545	
	ME does not Granger Cause DEBT	0.3362	
Canada	DEBT does not Granger Cause ME	0.0965	
	ME does not Granger Cause DEBT	0.7400	
Denmark	DEBT does not Granger Cause ME	0.6720	
	ME does not Granger Cause DEBT	0.8216	
France	DEBT does not Granger Cause ME	0.6518	
	ME does not Granger Cause DEBT	0.6826	
Germany	DEBT does not Granger Cause ME	0.1400	
	ME does not Granger Cause DEBT	0.8845	
Greece	DEBT does not Granger Cause ME	0.0140	DEBT → ME
	ME does not Granger Cause DEBT	0.8407	
Italy	DEBT does not Granger Cause ME	0.0420	DEBT → ME
	ME does not Granger Cause DEBT	0.3838	
Netherlands	DEBT does not Granger Cause ME	0.0947	

[1] NATO consists of 29 independent member countries. In our study, we have included 14 of the NATO member countries (namely, Belgium, Canada, Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Spain, Turkey, UK and USA), since for the rest of the countries, the data was incomplete and the time series required for the implementation of the specific methodology were limited.

	ME does not Granger Cause DEBT	0.1332	
Norway	DEBT does not Granger Cause ME	0.5097	
	ME does not Granger Cause DEBT	0.3449	
Portugal	DEBT does not Granger Cause ME	0.1832	
	ME does not Granger Cause DEBT	0.2623	
Spain	DEBT does not Granger Cause ME	0.7213	
	ME does not Granger Cause DEBT	0.6027	
Turkey	DEBT does not Granger Cause ME	0.7821	
	ME does not Granger Cause DEBT	0.8109	
UK	DEBT does not Granger Cause ME	0.0592	
	ME does not Granger Cause DEBT	0.0003	ME → DEBT
USA	DEBT does not Granger Cause ME	0.6583	
	ME does not Granger Cause DEBT	0.0345	ME → DEBT

Notes: 1) Debt stands for external debt as percentage to GDP and ME for military expenditures as percentage to GDP. 2) The critical value is 0.05

4.3 Results of the Non-Linear Granger Causality Test

Given that the existence of linearity does not rule out the existence of nonlinearity (Kyrtsou and Labys, 2006), our study goes one step further and applies the nonlinear causality test developed by Francis et al. (2010). To begin with, we remove any potential linear dependence by applying a Vector Autoregression (VAR) model. We, then, use the estimated residual series as inputs to the nonlinear test. The test has been applied in both directions and a common lag length of 1 to 5 lags has been used (*Lx*=*Ly*=1, …, 5 and lead length *m*=1). The study also uses common scale parameter of *e*=1.5σ, where σ denotes the standard deviation of the standardized time series. The analytical results of the *p*-values of the nonlinear test are reported in Table 2.

Table 2: NonLinear causality test results

Countries	Lx=Ly	p-value		Results
		ME → DEBT	DEBT → ME	
Belgium	1	0.41	0.02*	
	2	0.08*	0.07*	
	3	0.11	0.42	
	4	0.18	0.61	
	5	0.36	0.44	
Canada	1	0.55	0.47	
	2	0.61	0.43	
	3	0.48	0.47	
	4	0.12	0.22	
	5	0.28	0.26	
Denmark	1	0.36	0.48	
	2	0.05*	0.65	
	3	0.05*	0.46	
	4	0.24	0.07*	
	5	0.45	0.23	
France	1	0.03*	0.98	
	2	0.28	0.82	
	3	0.30	0.69	
	4	0.09*	0.55	
	5	0.45	0.67	
Germany	1	0.46	0.09*	
	2	0.59	0.09*	
	3	0.26	0.15	
	4	0.23	0.49	

	5	0.60	0.45	
Greece	1	0.43	0.35	
	2	0.32	0.17	
	3	0.56	0.50	
	4	0.30	0.58	
	5	0.49	0.72	
Italy	1	0.06*	0.50	
	2	0.04*	0.51	
	3	0.29	0.28	
	4	0.50	0.08*	
	5	0.74	0.37	
Netherlands	1	0.88	0.15	
	2	0.94	0.45	
	3	0.47	0.42	
	4	0.59	0.88	
	5	0.46	0.49	
Norway	1	0.46	0.14	
	2	0.03*	0.30	
	3	0.04*	0.17	
	4	0.13	0.58	
	5	0.26	0.40	
Portugal	1	0.54	0.27	
	2	0.60	0.19	
	3	0.51	0.31	
	4	0.44	0.45	
	5	0.48	0.31	
Spain	1	0.33	0.67	
	2	0.34	0.38	
	3	0.19	0.60	
	4	0.10*	0.60	
	5	0.07*	0.66	
Turkey	1	0.69	0.25	
	2	0.08*	0.24	
	3	0.03*	0.35	ME → DEBT
	4	0.05*	0.25	
	5	0.12	0.81	
UK	1	0.08*	0.17	
	2	0.21	0.10*	
	3	0.38	0.30	
	4	0.39	0.30	
	5	0.20	0.17	
USA	1	0.30	0.01*	
	2	0.21	0.05*	
	3	0.43	0.02*	DEBT → ME
	4	0.59	0.18	
	5	0.23	0.18	

Notes:

The null hypothesis suggests that ME does not cause DEBT and DEBT does not cause ME, respectively.

* denotes *p*-value statistical significance at 10% level.

The findings support the existence of a strong unidirectional nonlinear causality running from military expenditure to external debt in Turkey and the existence of the opposite nonlinear flow in the USA. The first finding denotes that a shock in military spending is expected to have disproportionate effects on external debt, due to the existence of nonlinear causality. This fact indicates that an abrupt change in military spending is expected to affect debt in a non-proportionate way and policy makers cannot ex ante detect the results of this shock in the state budget. The results also indicate the existence of a unidirectional nonlinear flow running from external debt towards military spending in the case of USA. This finding indicates that an abrupt change in debt is expected to disproportionately affect military expenditures and policy makers are unable to know ex ante the results of a shock they may cause in the economy. Although, the specific non-linear methodology cannot determine the magnitude of the engendered change, yet it reveals that the presence of nonlinearity decreases predictability in the co-movements of the variables and raises sensitivity of variables responses to economic shocks. In the rest of the countries, there are no signs of nonlinear causality either because non-linear flows cannot be detected or because such flows do not exist in these specific set of countries. The results of the non-linear test cannot be compared to any other studies, since the specific non-linear technique has never been applied before.

A summary view of the empirical findings from both linear and nonlinear tests is displayed on Table 3. Greece and Italy have a significantly strategic geographical position. The fact, though, that they are highly indebted countries, determines, to a large extent, the level of their military spending, which is predictable due to the existence of linearity. Turkey also occupies a strategic geographical position and its military spending may well be used for both internal and external security purposes. The existence of non-linear causality suggests that policy makers are unable to forecast the exact size of the debt change due to a modification in the military expenditure level. Therefore, military expenditures cannot be used as means of policy making, since their impact on external debt cannot be detected. UK is the third highest-spending NATO member, and its defence expenditure comes right behind Greece and the US. In the UK, military spending is a major contributor to the volume of external debt, but the magnitude of its change is predictable. USA is an exceptionally big defence spender and it could be characterized as one of the most militant countries with a strong presence in warfare all around the world. Its military spending affects its external debt in a predictable and proportional way, but simultaneously the level of its debt its policy makers are unable to forecast the exact size of the debt impact on the modification of the military expenditure level.

Table 3: Linear and NonLinear causality test results

Countries	linear		non-linear	
	ME⟶DEBT	DEBT⟶ME	ME⟶DEBT	DEBT⟶ME
Belgium	-	-	-	-
Canada	-	-	-	-
Denmark	-	-	-	-
France	-	-	-	-
Germany	-	-	-	-
Greece	-	√	-	-
Italy	-	√	-	-
Netherlands	-	-	-	-
Norway	-	-	-	-
Portugal	-	-	-	-
Spain	-	-	-	-
Turkey	-	-	√	-

UK	√	-	-	-
USA	√	-	-	√

5. Conclusions

In the present study, we investigate the nexus between military expenditure and external debt in the NATO member countries for the time period 1960-2015. The linear causal analysis has been conducted with the use of the traditional linear Granger causality test, whereas the non-linear with the implementation of the non-linear Granger causality technique, developed by Baek and Brock (1992), modified by Hiemstra and Jones (1994) and revised by Francis et al. (2010).

The findings of the linear causality test provide signs for the existence of a unidirectional causality running from military expenditures to external debt in the UK and the USA and a unidirectional causal flow running from external debt to military expenditures in Greece and Italy. The empirical results of the non-linear causality test indicate the presence of a strong unidirectional causality flow from military spending to external debt in Turkey and the existence of the nonlinear flow from external debt to military spending in the USA.

The presence of non-linearity should raise the concern of economic and defence policy makers regarding the expansive or restrictive policies they intend to apply in the field of defense spending, in conjunction with budgetary considerations. Future research can be pursued by determining the sign and the magnitude of the relationship between these two variables. Yet, this purpose escapes from the potential of this non-linear test.

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