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Defence expenditure and economic growth in Latin American countries: evidence from linear and nonlinear causality tests

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Abstract Using SIPRI's new consistent database on military expenditures, the paper examines the economic effects of such spending in the case of the 13 Latin American countries. Employing both linear and nonlinear tests, the nexus between defence spending, economic growth, and investment is investigated for the period 1961–2014. Findings reported herein are not uniformed across all countries included in the sample. However, as a broad tentative generalization, they seem to be pointing to the absence of a strong and robust nexus between the variables examined.

1 Introduction

The empirical assessment of the economic effects of military spending is a contentious theme that has attracted considerable attention and debate without, however, the emergence of a robust and unequivocal consensus (*inter alia*: Alptekin and Levine 2012; Dunne and Tian 2013; Dunne and Smith 2010; Heo and Ye 2016). Essentially, the effects of such government outlays can be summarized into three broad categories: the opportunity cost of the resources allocated to national defence, encapsulated by the guns vs butter dilemma; demand stimulation; and supply side effects (*inter alia*: Drèze 2006; Dunne and Tian 2016; Dunne and Uye 2010; Hou

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and Chen 2013; Desli et al. 2016). The growth enhancing effects include increased employment of idle or underemployed resources, positive externalities, such as technological advances, that spillover to other sectors of the economy thus increasing productivity, infrastructure creation, and human capital formation. On the other hand, such spending can prove to be growth retarding through the crowding-out of other more productive forms of public spending as well as investment. Both cross-country and specific country case studies have empirically probed into this question with mixed findings, as noted above, although the scales do seem to tilt in favor of a negative net impact on growth (*inter alia*: Compton and Paterson 2016; Malizard 2015, 2016; Dunne and Tian 2015, 2016; Kollias and Paleologou 2016).

The issue of the economic impact of military spending has also been addressed for Latin American countries. Ramos (2004) finds a positive effect on growth in the case of Mexico. For Guatemala, Reitschuler and Loening (2005) report findings that point to a positive and significant externality effect of defence spending at low levels of such expenditure but not so for higher levels. Using a sample of Asian and Latin American countries, Murdoch et al. (1997) find that defence is growth promoting but generates an opportunity cost in the form of displacing other public expenditures that also boost growth. Stroup and Heckelman (2001) for a group of African and Latin American countries establish a nonlinear relationship between defence and growth, with the findings indicating that low levels of such expenditure increase economic growth, whereas high levels decrease it. Scheetz (1991), in the case of Argentina, Chile, Paraguay, and Peru, reports a negative effect on macroeconomic variables, such as growth, investment, and the current account balance. Klein (2004) also reports a negative net effect in the case of Peru over the period 1970–1996.

Hoping to contribute to the existing body of literature for Latin America by extending both the time period as well as the sample of countries, this paper (re)addresses the issue of the economic effects of defence expenditure using SIPRI's[1] new database (Perlo-Freeman and Sköns 2016; Smith 2016). SIPRI has recently extended its military expenditure data set that until now provided consistent data only from 1988 onwards. The new data set[2] has consistent defence spending estimates across countries that in a number of cases date back to 1949. Hence, it presents researchers with the opportunity to readdress the perennial question of the economic effects of military expenditure, since it allows to empirically probe into this issue for an appreciably longer time period compared to the previous studies. In the case of the Latin American countries, this implies the addition of more than 20 years in the sample period. There are obvious advantages associated with the availability of consistent and reliable time series with observations that cover longer periods. They offer the opportunity for researchers to reach more robust and reliable inferences over a longer time horizon that, in this case, spans both the bipolar and post-bipolar periods. Hence, better insights may be gained when it comes to the empirical appraisal of the economic effects of military spending. This paper, using

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[2] Before its official public release, this dataset was made available to a number of researchers to use and evaluate.

both linear and nonlinear causality tests, examines the economic effects of defence spending in the case of the 13 Latin American countries. The tests cover the period 1961–2014. The structure of the paper is as follows. The next section contains a descriptive comparative presentation of the data used, while Section 3 epigrammatically addresses the role of the military in Latin America from a comparative perspective in terms of defence burdens and economic performance. In Section 4, the methodology employed is briefly outlined and the findings are presented and discussed in Section 5. Finally, Section 6 concludes the paper.

2 Sample and data snapshots

Dictated solely by data availability, the 13 Latin American countries are included in the sample: Dominican Republic, El Salvador, Guatemala, Mexico, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, and Venezuela. As already pointed out, the military expenditure data is drawn from SIPRI's new consistent database. In line with the standard practice in the relevant literature, the defence burden, i.e., defence spending expressed as a share of GDP, is used in the empirical analysis that follows. The GDP growth rates and gross capital formation expressed as a share of GDP are drawn from the World Bank's World Development Indicators' database. The time period covered is 1961–2014.[3] In Table 1, the mean values of the three variables are presented for each country in the sample both for the entire period (1961–2014) as well as for sub-periods. Starting from the overall growth performance, it is the Dominican Republic that exhibits the highest average growth rate for the entire period (5.29%) followed by Paraguay (4.89%). Noteworthy is the fact that the mean growth rates of a number of other countries are above 4% for the whole period—Mexico (4.08%), Brazil (4.39%), Chile (4.3%), and Ecuador (4.07%)—with El Salvador, Venezuela, and Argentina having the lowest averages of the group: 2.38, 2.8, and 2.9%, respectively. Not surprisingly, significant variations in terms of growth performance are recorded from one decade to the other for all the 13 countries. Worth mentioning, however, is that compared to the world economy, all the 13 countries have over-performed in terms of growth rates. The global average growth rate for the entire period was around 1.9% according to the World Bank data. The 13 Latin American countries of the sample had mean growth rates that in cases were higher by more than 2% points compared to the world's average and 3% points in the case of Paraguay and the Dominican Republic (Fig. 1). In terms of gross capital formation expressed as a percentage of GDP, Guatemala, El Salvador, and Bolivia are the three with the lowest averages for the entire period—15.3, 15.9, and 15.9%, respectively, followed by Paraguay with an average of 17.5% (Table 1).

We now turn to present briefly the defence burdens of the 13 Latin American countries both in terms of the averages recorded over the period in question, as well as in terms of how this variable has fluctuated in the sub-periods, as presented in

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[3] With the exception of El Salvador where the tests are conducted for 1965–2014 and Bolivia with the estimations covering the period 1968–2014 due to data availability constraints.

Table 1 Mean values of growth rates (GDP), gross capital formation as a share of GDP (Inv/GDP) and defence spending as a share of GDP (M/GDP)

	1961–1969	1970–1979	1980–1989	1990–1999	2000–2009	2010–2014	1961–2014
Dominican Republic							
M/GDP	3.8	2.0	1.3	0.7	0.8	0.6	1.6
GDP	4.83	8.20	3.79	4.99	4.68	5.17	5.29
Inv/GDP	14.42	22.00	22.57	19.80	21.28	23.63	20.45
El Salvador							
M/GDP	0.7	0.9	4.1	1.7	0.9	0.9	1.7
GDP	4.83	3.90	−1.95	4.89	1.98	1.85	2.38
Inv/GDP	14.24	19.32	12.93	17.04	16.10	14.07	15.91
Guatemala							
M/GDP	1.2	1.2	1.9	1.1	0.6	0.4	1.1
GDP	5.50	5.86	0.97	4.07	3.42	3.59	3.90
Inv/GDP	11.63	16.95	13.26	15.53	19.00	14.33	15.26
Mexico							
M/GDP	0.6	0.5	0.6	0.6	0.5	0.6	0.6
GDP	6.84	6.43	2.29	3.62	1.84	3.36	4.08
Inv/GDP	18.91	22.62	22.25	20.73	22.45	22.16	21.51
Argentina							
M/GDP	1.7	2.8	2.5	1.3	1.0	1.0	1.8
GDP	4.11	2.93	−0.73	4.52	3.05	4.40	2.90
Inv/GDP	22.12	26.04	19.93	17.77	17.51	18.79	20.47
Bolivia							
M/GDP	1.3	2.0	2.4	2.3	1.9	1.8	2.0
GDP	3.20	4.03	−0.44	3.99	3.69	5.34	3.12
Inv/GDP	10.71	19.52	15.33	16.92	15.08	18.91	15.92
Brazil							
M/GDP	2.6	2.1	1.5	1.8	1.6	1.5	1.9

Table 1 continued

|	1961–1969	1970–1979	1980–1989	1990–1999	2000–2009	2010–2014	1961–2014
GDP	5.90	8.47	2.99	1.88	3.39	3.29	4.39
Inv/GDP	19.66	22.92	21.02	19.25	18.51	21.52	20.40
Chile							
M/GDP	2.8	6.4	6.4	2.7	2.5	2.1	4.0
GDP	4.37	2.48	4.39	6.38	3.74	4.63	4.30
Inv/GDP	17.96	17.85	18.47	25.26	22.08	23.45	20.66
Colombia							
M/GDP	2.9	1.9	2.0	2.8	3.4	3.3	2.7
GDP	5.08	5.81	3.40	2.86	4.14	4.82	4.29
Inv/GDP	19.09	18.68	19.43	19.95	19.79	24.00	19.82
Ecuador							
M/GDP	2.0	2.1	1.8	1.9	2.2	3.0	2.1
GDP	3.71	7.28	2.63	2.32	3.89	5.05	4.07
Inv/GDP	17.60	22.59	23.35	21.34	22.59	28.28	22.20
Paraguay							
M/GDP	2.7	3.0	3.2	2.1	1.1	1.3	2.3
GDP	5.07	8.32	4.92	3.09	2.00	6.99	4.89
Inv/GDP	–	–	–	20.63	16.04	15.99	17.75
Peru							
M/GDP	3.0	4.7	3.7	2.4	1.4	1.3	2.9
GDP	5.25	3.94	0.41	3.20	5.04	5.79	3.74
Inv/GDP	34.46	20.17	23.65	19.01	19.41	26.21	23.40
Venezuela							
M/GDP	2.5	2.3	2.0	1.6	1.4	1.1	1.9
GDP	4.81	3.97	−0.16	2.46	3.98	1.13	2.80
Inv/GDP	24.45	34.45	21.46	20.50	24.28	24.73	25.01
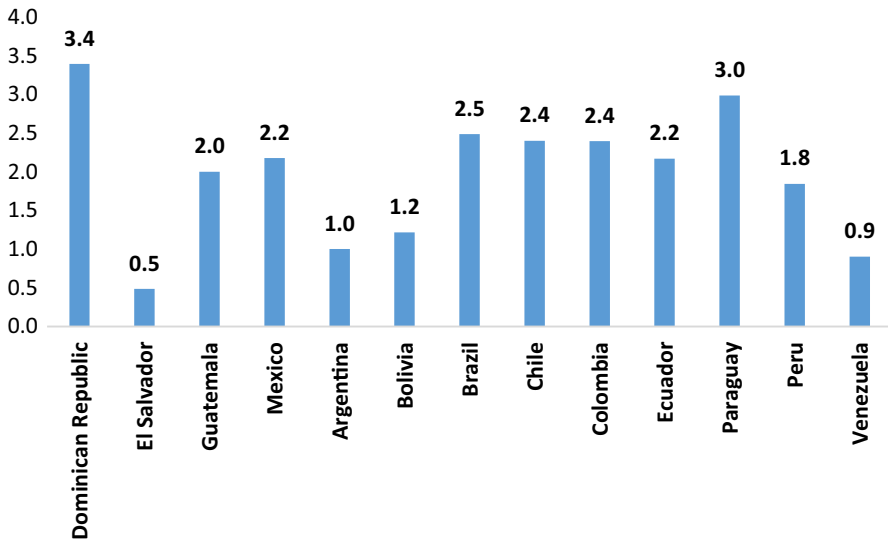
Fig. 1 Growth over-performance vis-à-vis the world average 1961–2014 (Growth rate of the *i*th country minus the world average)

Table 1. The annual defence budget is the monetary quantification of the resources allocated to national defence and denotes the costs of the inputs that go into the production of military capabilities. As suggested in the relevant literature, cohort of factors determines the level of the resources allocated to the military including external as well as domestic security considerations, economic constraints, strategic aspirations, and the ideological and political orientation of the incumbent government (*inter alia*: Bove and Brauner 2016; Wang 2013; Dunne et al. 2008). Expressed as a share of GDP, military expenditure reflects the defence burden of a country in terms of the inputs that the implementation of national defence policy absorbs. As a first broad observation in terms of the 1961–2014 averages, it can be seen that Mexico has the lowest mean value in terms of military spending as a share of GDP over the entire period (0.6%). Noteworthy, is that the value of Mexican defence burden has more or less remained constant over the sub-period presented in the table. The country with the highest average is Chile (4%). Interesting to observe is that the Chilean defence burden was as high as 6.4% during 1970–1989 and this probably can be associated with the Chilean junta (1973–1990). For example, in 1982, military spending as a share of GDP in Chile reached 8.9%. Following the collapse of the regime, it dropped appreciably in the next decades (Table 1). Peru and Colombia are the next two countries with the highest defence burden: 2.9 and 2.7%, respectively. Although the empirical investigation of the determinants of such expenditures falls outside the scope of this paper, in the case of Peru, the long-running territorial disputes with Ecuador as well as domestic security issues associated with terrorist activity by *Sendero Luminoso* and the *Tupac Amaru Revolutionary Movement* (Klein 2004). Similarly, internal strife and conflict in
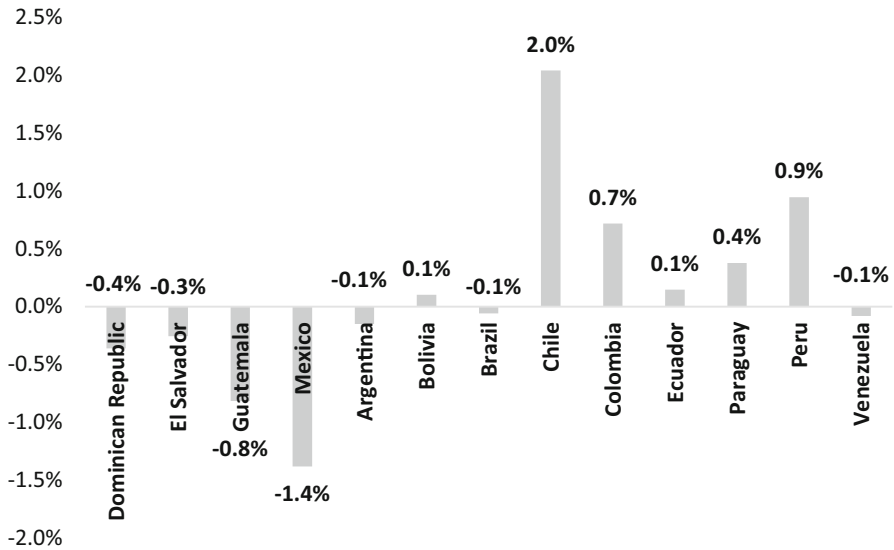
Fig. 2 Defence burden of Latin American countries compared to the world average 1961–2014 (Defence burden of the *i*th country minus the world average)

Colombia between government forces, paramilitaries, insurgents, such as *FARC*, and crime syndicates, can be cited as explanatory factors of comparatively higher defence spending (Vargas 2012). However, the overall assessment of the 13 Latin American countries included in our sample is that in comparative terms, their defence burden in most cases has been lower than the world average during the period in question (Fig. 2).

3 The military in Latin America: a bird's eye view of defence burdens and growth

A particular feature of Latin American countries is the role that the armed forces have played in domestic politics (*inter alia*: Catoggio 2011; Frantz and Geddes 2016; Biglaiser 2002). For reasons of brevity, we focus exclusively on the time period of our sample and the countries included in it. During 1961–2014, out of the 13 countries of the sample less than a handful—Mexico,[4] Colombia, Venezuela, and the Dominican Republic[5]—were not directly ruled by a military government. In fact, the direct or indirect involvement of the military in the political scene of almost all Latin American countries was for decades an endemic feature of the region and its legacy has left an indelible imprint in Latin American history. However, as many have pointed out, the dominant presence and central role of the military in Latin

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[4] The only country out of the thirteen contained in the sample that has enjoyed uninterrupted parliamentary rule since the early twentieth century.

[5] The Trujillo Era in the Dominican Republic ended with his assassination in 1961.

Table 2 GDP growth rates and defence spending as a share of GDP during military rule in selected Latin American countries

	M/GDP%	GDP%
Brazil 1964–1985	2	6.2
Sample's average 1964–1985	2.5	4.1
Country's average 1961–2014	1.9	4.4
Chile 1973–1990	6.3	3.4
Sample's average 1973–1990	2.5	3.1
Country's average 1961–2014	4	4.3
Argentina 1966–1973	1.7	3.8
Sample's average 1966–1973	2.2	5.5
Argentina 1976–1983	3.6	1
Sample's average 1976–1983	2.6	2.7
Country's average 1961–2014	1.8	2.9
Peru 1968–1980	4.4	3.8
Sample's average 1968–1980	2.4	5.2
Country's average 1961–2014	2.9	3.7
Bolivia 1970–1982	2.3	2.7
Sample's average 1970–1982	2.5	4.5
Country's average 1961–2014	2	3.1

American politics, either in the form of direct military rule or military coups, rapidly withered away towards the late 1980s (*inter alia*: Norden 1996; Dix 1994). Even though a plethora of themes related to the role of the military in Latin American countries could be addressed, we opt to focus onto two of the key variables examined herein: the defence burden and GDP growth rate in the case of six periods of direct military rule in five selected countries: Brazil, Chile, Argentina, Peru, and Bolivia. All five have experienced direct military rule during the period examined here. Following the 1964 coup, Brazil was ruled by a military government until 1985. Chile between 1973 and 1990 following the overthrow of Salvador Allende's government, Peru 1968–1980, and Bolivia when between 1970 and 1982 were also ruled by successive military juntas. With the exception of a brief spell, Argentina was also under direct military rule between 1966–1973 and 1976–1983 when the military government collapsed following the 1982 military defeat by the United Kingdom.

In Table 2, we present the following statistics for comparison purposes: the average defence burden (M/GDP) and GDP growth rate during the period of military rule in the aforementioned countries; the corresponding averages of these variables for the entire sample of the 13 countries during the same period and the country's average defence burden and growth rate for the entire sample period, i.e., 1961–2014. Thus, we allow for comparisons on two levels. First, on how the country faired in terms of these two variables vis-à-vis the entire sample during each period of direct military rule, and second, how the military rule period compares with the country's averages over the entire period. Starting from the defence burden level, it appears that in most cases, spending on defence expressed as a share of

GDP was higher during military rule compared to the country's average for the entire period. This is the case for Chile (1973–1990), Argentina (1976–1983), and Peru (1968–1980) but less so for Brazil (1964–1985), Argentina (1966–1973), and Bolivia (1970–1982) in which cases, the defence burden during military government is not appreciably higher than the average of the entire period examined here. To put things into perspective, a comparison with the sample's average defence burden during each period of military rule yields a similar picture. In the cases of Chile (1973–1990), Argentina (1976–1983), and Peru (1968–1980), military spending expressed as a percentage of GDP is noticeably higher than the sample's average during the same period: 6.3% vs a sample average of 2.5% in the case of Chile (1973–1990), 3.6 vs 2.6% in the case of Argentina (1976–1983), and 4.4% vs a sample average of 2.5% in the case of Peru (1968–1980). Noteworthy is the fact that in the case of Brazil (1964–1985), Argentina (1966–1973), and Bolivia (1970–1982), their defence burdens during military rule were lower than the sample's average for the same periods (2 vs 2.5%, 1.7 vs 2.2%, and 2.3 vs 2.5%, respectively). Although such descriptive analysis falls short from offering robust inferences than a more systematic empirical investigation would, it nevertheless coincides with the findings of other studies that have addressed the determinants of defence budgets in Latin America (*inter alia*: Looney and Frederiksen 2000, 1988; Peláez 2007). A similarly mixed picture emerges if we compare growth performance during military rule (Table 2). For example, Brazil's growth rate under military government was noticeably higher than the sample's average during the same period (1964–1985)—6.2 vs 4.1%—as well as higher than its average (4.4%) over the entire period examined here. Exactly the reverse is the case for Argentina (1976–1983). The sample's average growth rate during the same period was more than double (2.7 vs 1%) and so was its average over the whole sample period (2.9 vs 1%). A more diverse picture emerges for the other cases presented in Table 2. For example, Argentina (1966–1973) significantly underperforms vis-à-vis the sample's average for the same period (3.8 vs 5.5%) but has a higher growth rate compared to the one of the entire period. A considerable underperformance compared to the sample's average growth rate for the same period is also the case for Peru (1968–1980)—3.8 vs 5.2%—and also for Bolivia (1970–1982)—2.7 vs 4.5%. Chile's growth rate during the dictatorship (1973–1990) was roughly the same to that of the sample for the same period (3.4 vs 3.1%). On balance, it appears that for most of the selected countries shown in Table 2, growth underperformance vis-à-vis the sample for the same period is the case during military rule.

4 Methodology: a brief outline

As noted earlier, to examine the economic effects of defence spending in the case of the 13 Latin American countries of our sample, both linear and nonlinear causality tests will be employed. For the linear causality, we apply the Granger-causality test following the Toda and Yamamoto (1995) (hereafter TY). Following Granger's (1969) development of the causality test, two shortcomings were identified. One relates to the specification bias and the other to the presence of spurious regression. As

explained by Engel and Granger (1987), two series are regarded to be cointegrated if the linear combination of these two series is stationary, however, every variable is not. As a result, they stressed that when these two series are non-stationary and cointegrated, the Granger-causal inference will be biased. In addition, in the asymptotic distribution framework, Sims et al. (1990) have produced evidence that when applying the vector autoregressive (VAR) model, we cannot test for the causality of integrated variables in level form regardless if these variables are cointegrated. However, the TY applied in this study overcomes those problems, since it is based on augmented VAR modeling having a modified Wald test statistic (MWALD), which asymptotically as a Chi-square distribution. Moreover, since the test used here (i.e., TY) does not require any pre-tests for cointegration, it presents a better alternative over the traditional Granger-causality test. As Toda and Yamamoto (1995) explain, their test can be applied regardless of whether a series is I(0), I(1), or I(2), non-cointegrated or cointegrated of an arbitrary order producing valid estimates. This is quite suitable in our case, since the economies examined herein reveal several structural breaks[6] in the macroeconomic variables used. Finally, as Kuzozumi and Yamamoto (2000) suggest, the TY test should be preferred when sample sizes are small, since the distortions of the small sample properties remain in low levels, given the potential bias related to the asymptotic distribution of the applied test.

The approach developed by TY employs a modified Wald test for restriction on the parameters of the VAR (k), where k is the lag length of the model. The TY test is to artificially augment the correct order, k, by the maximal order of integration, say d_{max}. Once this is done, a $(k + d_{max})$th order of VAR is measured and the coefficients of the last lagged d_{max} vectors are ignored (Menyah and Wolde-Rufael 2010).[7] Following this approach, the military expenditure (MGDP) and economic growth (GDP) model is given in the following VAR system:

$$\ln \text{MGDP}_t = a_o + \sum_{i=1}^{k} a_{1i} \ln \text{MGDP}_{t-i} + \sum_{j=k+1}^{dmax} a_{2i} \ln \text{MGDP}_{t-j} + \sum_{i=1}^{k} \beta_{1i} \ln \text{GDP}_{t-i} +$$

$$\times \sum_{j=k+1}^{dmax} \beta_{2i} \ln \text{GDP}_{t-j} + \sum_{i=1}^{k} \gamma_{1i} \ln \text{INV}_{t-i} + \sum_{j=k+1}^{dmax} \gamma_{2i} \ln \text{INV}_{t-j} + \varepsilon_{1t},$$

$$(1)$$

$$\ln \text{GDP}_t = \vartheta_o + \sum_{i=1}^{k} \vartheta_{1i} \ln \text{MGDP}_{t-i} + \sum_{j=k+1}^{dmax} \vartheta_{2i} \ln \text{MGDP}_{t-j} + \sum_{i=1}^{k} \lambda_{1i} \ln \text{GDP}_{t-i}$$

$$+ \sum_{j=k+1}^{dmax} \lambda_{2i} \ln \text{GDP}_{t-j} + \sum_{i=1}^{k} v_{1i} \ln \text{INV}_{t-i} + \sum_{j=k+1}^{dmax} v_{2i} \ln \text{INV}_{t-j} + \varepsilon_{2t},$$

$$(2)$$

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[6] For the identification of multiple breaks see Kapetanios (Kapetanios 2005).

[7] For more details see Toda and Yamamoto (1995) or for shortcoming see, Caporale and Pittis (1999) and Wolde-Rufael (2004, 2005, 2006).

where $\ln \mathrm{MGDP}_t$ represents countries' military spending as a share of GDP, $\ln \mathrm{GDP}_t$ countries' annual growth rate of GDP, and $\ln \mathrm{INV}_t$ countries' gross fixed capital formation as of GDP.[8] Support of the growth-enchasing hypothesis suggests a unidirectional Granger causality running from military expenditure (MGDP) measure to the annual growth rate of GDP ($\vartheta_{1i} \neq 0 \forall_i$). When we have the presence of unidirectional Granger causality running from the annual growth rate of GDP to the military expenditure ($\beta_{1i} \neq 0 \forall_i$), it is evident that the conservation hypothesis holds. On the other hand, when the feedback hypothesis is true, it suggests the existence of a bidirectional Granger causality between both variables, i.e., military expenditure and the annual growth rate ($\beta_{1i} \neq 0 \forall_i$) and ($\vartheta_{1i} \neq 0 \forall_i$). Finally, the absence of Granger causality between the MGDP and the growth rate ($\beta_{1i} = 0 \forall_i$) and ($\vartheta_{1i} = 0 \forall_i$) implies the existence of the impartiality hypothesis. Moreover, to overcome the bias of the omitted variable in growth models, a multivariate framework is applied by incorporating the measures of gross fixed capital formation in addition to military expenditure and GDP.[9] Before we estimate our model and proceed with the TY test, we apply several diagnostic tests (normality, serial correlation, heteroscedasticity, and the CUSUM and CUSUM of square tests) and we resort to the use of four unit roots tests to explore the degree of integration of the variables used in the empirical analysis. Namely, we apply the Augmented Dickey and Fuller (1979) (ADF) test, the Phillips and Perron (1988) (PP) test, the Kwiatkowski et al. (1992) (KPSS) test, and the Zivot and Andrews (1992) test. Finally, although tTY suggest that cointegration is not required in order for the estimates to be valid, we apply the Johansen and Juselius (1990) test as robustness check.[10]

As Brock (1991) illustrates, linear Granger-causality tests can have low power uncovering nonlinear causal relations, which could also exist among variables. In addition, the assumption of linear causality may act as a limiting factor when the true relationship could be nonlinear. Furthermore, since linear methods depend on testing the significance of suitable parameters only in a mean equation, causality in any higher order structure cannot be explored Diks and DeGoede (2001). For that reasons, we examine the nonlinear non-Granger causality. Baek and Brock (1992), to emphasize the limitations of the linear assumption, suggest a nonparametric statistical method for detecting nonlinear Granger causality. Whereas, Hiemstra and Jones (1994) extended their work by introducing a modified test statistic for the nonlinear causality. In addition, Diks and Panchenko (2006) (hereafter DP) develop a new nonparametric test statistic for Granger causality which enable us to avoid the problem of over-rejection observed in the frequently used test proposed by Hiemstra and Jones. As a result, in our paper, we apply the nonlinear causality test proposed by Diks and Panchenko (2006) which can be used to detect possible nonlinear causality relationship between two time series. Following the representation by Diks and Panchenko (2006, p. 1649–1657), let a strictly bivariate process $\{(X_t, Y_t)\}$, and $\{X_{t,}\}$ Granger causes $\{Y_{t,}\}$ if current and past values of variable X contain information on

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[8] All variables are in logarithmic form.

[9] See Stern (1993, 2000) and Apergis and Payne (2009)

[10] However, it must be noted that the TY test can suffer some loss of power since intentionally over-fits VAR models.

future values of Y which is not contained in Y and $Y_{t,}$. In addition, suppose that $F_{X,t}$ and $F_{Y,t}$ represent for time t the information sets of past observations of $X_{t,}$ and $Y_{t,}$, respectively. Then, for a stationary bivariate time series process $\{(X_t, Y_t)\}, t \in \mathbb{Z}, \,$, we can represent formally that $\{X_t\}$ does not Granger causes $\{Y_t\}$ as

$$\left(Y_{t+1,\ldots,}Y_{t+k}\right)\big|\left(F_{X,t}, F_{Y,t}\right) \sim \left(Y_{t+1,\ldots,}Y_{t+k}\right)\big|F_{Y,t}. \tag{3}$$

Equation (3) represents the nonlinear Granger-causality test, where '$\sim$' indicates equality in distributions and $k \geq 1$.[11] Then, by following Hiemstra and Jones (1994), we can define the null hypothesis of Granger non-causality as: $H_0 : \{X_{t,}\}$ is not Granger causing $\{Y_{t,}\}$. Under the null hypothesis, Y_{t+1} is conditionally independent of $X_t, X_{t-1}, \ldots$, given $Y_t, Y_{t-1}, \ldots$ For finite lags l_X and l_Y, the conditional independence can be tested as

$$Y_{t+1}\big|\left(X_t^{l_x}, Y_t^{l_y}\right) \sim Y_{t+1}\big|Y_t^{l_y} \tag{4}$$

where $X_t^{l_x} = \left(X_{t-l_x+1}, \ldots, X_t\right)$ and $Y_t^{l_y} = \left(Y_{t-l_y+1}, \ldots, Y_t\right)$. According to Diks and Panchenko (2006), Eq. (4) represents a statement about the invariant distribution of the $l_X + l_Y + 1$-dimensional vector $W_t = \left(X_t^{l_x}, Y_t^{l_y}, Z_t\right)$, where $Z_t = Y_{t+1}$. By dropping the time index and assume that $l_X = l_Y = 1$, we can write $W = (X, Y, Z)$ as a random vector with invariant distribution of $\left(X_t^{l_x}, Y_t^{l_y}, Y_{t+1}\right)$. Under the null the conditional distribution of Z given, $(X, Y) = (x, y)$ is the same as Z given $Y = y$. Therefore, we can restructure (4) by taking into account the joint probability density functions $f_{X,Y,Z}(x, y, z)$, where its marginals should satisfy the following relationship:

$$\frac{f_{X,Y,Z}(x, y, z)}{f_y(y)} = \frac{f_{X,Y}(x, y)}{f_Y(y)}\frac{f_{Y,Z}(y, z)}{f_Y(y)} \tag{5}$$

suggesting that X and Z are independent when $Y = y$ for each fixed value of y. Diks and Panchenko (2006) proved that the restated null hypothesis suggests that

$$q = E\big[f_{X,Y,Z}(X, Y, Z)f_Y(Y) - f_{X,Y}(X, Y)f_{Y,Z}(Y, Z)\big]. \tag{6}$$

By denoting the local density estimators of a d_w variate random vector W as $\hat{f}_W(W_i) = \frac{(2_\varepsilon)^{-d_w}}{n-1} \sum_{j,j\neq 1} I_{ij}^W I_{ij}^W = I\left(W_i - W_j < \varepsilon\right).,$[12] the test statistic can be presented as

$$T_n(\varepsilon) = \frac{(n-1)}{n(n-2)} \sum_i \left(\hat{f}_{X,Y,Z}(X_i, Y_i, Z_i)\hat{f}_Y(Y_i) - \hat{f}_{X,Y}(X_i, Y_i)\hat{f}_{Y,Z}(Y_i, Z_i)\right). \tag{7}$$

For a sequence of bandwidths $\varepsilon_n = Cn^{-\beta}$ with $C > 0$ and $\beta \in \left(\frac{1}{4}, \frac{1}{3}\right)$, the statistic in (7) satisfies

$$\sqrt{n}\frac{(T_n(\varepsilon_n) - q)}{S_n} \xrightarrow{d} N(0, 1) \tag{8}$$

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[11] Most of the times k is equal to 1.

[12] where $I_{ij}^W = I\left(\|W_i - W_j\| < \varepsilon\right)$

where $\xrightarrow{d}$ denotes convergence in distribution and S_n is an estimator of the asymptotic variance of $T_n(\cdot)$. Finally, the test statistic in Eq. (7) for nonlinear causality is asymptotically distributed as standard normal and diverges to positive infinity under the alternative hypothesis.[13] Before we estimate the nonlinear model, we must check if the nonlinearity assumption holds, and therefore, we utilize the BDS test (Brock et al. 1987). Under the null hypothesis, the BDS test implies that the variables under examination are identically and independently distributed (i.i.d.). However, under the alternative hypothesis, the test implies that they have linear or nonlinear dependency.

5 The findings

Examining for linear causality, the ADF and PP unit root and the KPSS stationary tests were employed to the intercept and trend (Table 3). The results from the ADF, PP, and KPSS statistics suggest that the variables are integrated of order one $I(1)$. Furthermore, we apply the Zivot and Andrews test (Table 4) for structural breaks. The result of that test also indicate that all the series are $I(1)$. Accordingly, all variables are integrated of order one $I(1)$.

The Jarque–Bera (JB) tests indicate that all residuals are normal distributed, whereas the Portmanteau test show that there is no serial correlation. Furthermore, the Arch tests show that there is no heteroscedasticity for all equations in our analysis. Finally, the CUSUM and CUSUMS of square tests could not verify a stability violation.[14] In addition, the results of the Johansen cointegration test for the countries are reported in Table 5. The findings suggest that there is a cointegration vector among the variables. The null hypotheses of zero cointegrating vector $r = 0$ as well as less than or equal to one cointegrating vector $r \leq 1$ is rejected at the 5% significance level for the trace and the maximum eigenvalue statistics. For robustness check, Table 5 also presents the results for $r \leq 2$. The findings suggest that the null hypothesis for $r \leq 2$ is rejected at the 1 and 5 significance level for the trace and the maximum eigenvalue statistics (except for the cases of Paraguay and Peru). The above empirical findings suggest that there is a stable long-run equilibrium relationship among the variables. To determine the optimal lag length, the Schwarz Bayesian information criterion (SBIC) used to select the lag length for our models with the initial lag length set at $k = 1$ ($k = 4$ for two countries).

On the other hand, before we estimate the testing for nonlinear causality, we must check if the nonlinearity assumption holds, and therefore, we utilize the BDS test. Two are the main parameters to estimate when applying the BDS test, namely, the embedding dimension m and the distance ε. To obtain reliable results, we use a range of dimensions from 2 to 5. Table 6 presents the results of BDS test. It is clear from the statistics in Table 6 that the BDS test and the null of i.i.d is rejected for all

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[13] For more details please see Diks and Panchenko (2006).

[14] Due to length limitations and the quantity of the results/tests performed, the results of the above diagnostic test cannot be presented. However, all the results are available upon request.

Table 3 Results from the unit root tests

	ADF test		Perron test		KPSS test	
	Level	1st diff.	Level	1st diff.	Level	1st diff.
Argentina						
lnGDP	−3.44**	−6.29***	−49.94***	−61.99***	0.09*	0.03*
lnMGDP	−1.99	−4.04***	−9.21	−56.21***	1.61***	0.09*
lnINV	−2.83	−4.59***	−14.57	−41.87***	1.17***	0.04*
Bolivia						
lnGDP	−2.67	−5.22***	−39.87***	−54.57***	0.27*	0.05*
lnMGDP	−3.73**	−4.26***	−12.6	−57.69***	0.36*	0.14*
lnINV	−2.90	−4.16***	−22.48**	−51.28***	0.19*	0.04*
Brazil						
lnGDP	−3.40*	−5.53***	−47.26***	−61.69***	0.88***	0.04*
lnMGDP	−2.20	−4.09***	−12.88	−52.19***	0.67***	0.04*
lnINV	−2.51	−4.44***	−19.53**	−50.67***	0.33*	0.03*
Chile						
lnGDP	−2.42	−5.85***	−57.49***	−73.27***	0.25*	0.03*
lnMGDP	−0.77	−3.59**	−3.36	−58.90***	1.52***	0.32*
lnINV	−2.91	−4.44***	−28.94***	−58.07***	1.14***	0.02*
Colombia						
lnGDP	−3.53**	−5.56***	−43.34***	−69.29***	0.31*	0.02*
lnMGDP	−2.13	−3.68**	−9.49	−45.49***	0.96***	0.05*
lnINV	−3.50**	−4.66***	−20.15***	−52.56***	0.43*	0.07*
Dominican Republic						
lnGDP	−4.32***	−5.55***	−43.48***	−58.19***	0.18*	0.02*
lnMGDP	−1.55	−3.22*	−15.60	−48.56***	2.27***	0.04*
lnINV	−2.72	−4.47***	−18.24*	−57.87***	0.80***	0.05*
Ecuador						
lnGDP	−2.94	−6.18***	−51.06***	−69.33***	0.12*	0.02*
lnMGDP	−2.42	−4.54***	−22.25**	−62.01***	0.40*	0.07*
lnINV	−4.01**	−4.44***	−16.47	−60.26***	0.94***	0.07*
El Salvador						
lnGDP	−3.44*	−3.72**	−26.04***	−61.39***	0.43*	0.03*
lnMGDP	−1.52	−3.15*	−3.43	−42.69***	0.53**	0.25*
lnINV	−3.00	−3.28*	−13.28	−45.24***	0.10*	0.05*
Guatemala						
lnGDP	−2.45	−3.80**	−13.72	−55.08***	0.41*	0.14*
lnMGDP	−3.94**	−3.97**	−11.06	−50.77***	0.36*	0.06*
lnINV	−2.46	−4.01**	−16.80*	−55.61***	0.25*	0.03*
Mexico						
lnGDP	−4.18***	−6.02***	−35.30***	−55.06***	0.78***	0.01*
lnMGDP	−3.59**	−3.74**	−20.25**	−69.49***	0.25*	0.10*
lnINV	−2.89	−4.14***	−15.64	−53.71***	0.44*	0.05*

Table 3 continued

	ADF test		Perron test		KPSS test	
	Level	1st diff.	Level	1st diff.	Level	1st diff.
Paraguay						
lnGDP	−1.90	−4.10**	−44.72***	−66.01***	0.51**	0.02*
lnMGDP	−2.40	−3.76**	−9.36	−81.82***	1.88***	0.12*
Peru						
lnGDP	−3.81**	−5.75***	−42.69***	−60.86***	0.07*	0.02*
lnMGDP	−2.01	−3.61**	−12.68	−55.21***	1.98***	0.09*
lnINV	−2.39	−5.42***	−11.35	−50.83***	0.81***	0.15*
Venezuela						
lnGDP	−2.86	−4.18***	−62.20***	−77.58***	0.15*	0.02*
lnMGDP	−3.88**	−5.63***	−38.15***	−54.49***	1.98***	0.01*
lnINV	−2.39	−4.79***	−19.42*	−47.04***	0.32*	0.03*

***, **, and * Significant at the 1, 5, and 10 levels, respectively

data. However, the results suggest that all countries are nonlinearly dependent, as well as that nonlinear causality testing is appropriate.

In the next step of the empirical investigation, we proceed to the estimation of nonlinear causality test (DP test), for our model following Bekiros and Diks (2008a, b). First, we apply the DP test in the raw data (pre-filtering step) to distinguish the nonlinear interrelationships, and second, we reapply it to the filtered VAR residuals to examine whether there is a strict nonlinear causality in nature or not. The value of bandwidth is set to one.[15] Finally, the number of lags used for the nonlinear causality test is $lX = lY = 1$. The full results from both the linear and nonlinear causality tests are presented in Table 9 in the appendix. However, given the BDS results presented previously, we choose to summarize the findings from Table 9 only for those obtained when applying the nonlinear test. Specifically, Table 7 presents the findings on the nexus between military spending and growth rates when we applied the nonlinear causality tests for the raw data and for the residuals from the VAR specification. Similarly, Table 8 presents the findings on the relationship governing defence spending and gross capital formation. As a broad, general observation based on Table 7, it would appear that the dominant picture is that there is not any bidirectional relationship between military spending and the countries' growth rates. Furthermore, the nonlinear findings indicate unidirectional causality from the growth rates to military spending for the case of El Salvador and Paraguay. This tentatively can be interpreted that the growth of the economy allows more resources to be allocate to defence. The effective demand stimulative effect channel from defence spending to the economy seems to be indicating the majority of the causality findings for Argentina, Bolivia, Brazil,

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[15] Bandwidth values smaller (larger) than 1 result in larger (smaller) p values (Bekiros and Diks 2008a, b).

Table 4 Results from the ZA unit root tests with a structural break

	Variable	Level	Break	1st diff.	Break
Argentina	lnGDP	−7.67***	2009	−11.19***	1975
	lnMGDP	−7.67***	2009	−11.19***	1975
	lnINV	−3.70	1981	−6.81***	1963
Bolivia	lnGDP	−7.02***	1978	−11.05***	1970
	lnMGDP	−5.99***	1975	−C10.61***	1976
	lnINV	−4.36	2003	−8.69***	2004
Brazil	lnGDP	−6.57***	1977	−10.64***	2013
	lnMGDP	−5.03*	1987	−8.88***	1981
	lnINV	−4.21	1995	−8.12***	1989
Chile	lnGDP	−8.94***	1998	−14.02***	1965
	lnMGDP	−5.36**	1970	−9.56***	1969
	lnINV	−5.54**	1987	−9.90***	1983
Colombia	lnGDP	−6.50***	1981	−11.72***	1998
	lnMGDP	−5.03*	1972	−8.37***	1977
	lnINV	−5.29**	1999	−7.58***	1995
Dominican Republic	lnGDP	−6.69***	2003	−10.24***	1970
	lnMGDP	−4.60	1987	−9.31***	1991
	lnINV	−4.75	1981	−9.36***	1964
Ecuador	lnGDP	−8.16***	1982	−12.68***	1983
	lnMGDP	−5.04*	1980	−9.64***	1984
	lnINV	−6.49***	1965	−9.63***	1966
El Salvador	lnGDP	−4.82*	1990	−10.54***	1986
	lnMGDP	−3.41	1979	−7.41***	1985
	lnINV	−4.38	1979	−7.07***	1978
Guatemala	lnGDP	−9.82***	1992	−9.24***	1993
	lnMGDP	−5.39**	1992	−8.18***	1995
	lnINV	−4.49	2006	−8.49***	1975
Mexico	lnGDP	−6.05***	2001	−9.50***	2002
	lnMGDP	−4.83*	2004	−9.90***	2006
	lnINV	−5.16***	1982	−8.16***	1995
Paraguay	lnGDP	−8.34***	1998	−12.44***	2002
	lnMGDP	−3.45	2002	−13.59***	2005
Peru	lnGDP	−6.56***	1979	−10.62***	1978
	lnMGDP	−5.37**	1975	−10.64***	2008
	lnINV	−3.54	1968	−7.42***	1982
Venezuela	lnGDP	−8.28***	2002	−14.41***	1985
	lnMGDP	−7.52***	2010	−10.66***	2011
	lnINV	−5.19**	1983	−8.26***	1990

Break denotes the time of the structure change

***, **, and * Significant at the 1, 5, and 10 levels, respectively

Table 5 Results of Johansen's cointegration tests

	Trace statistic (λ_{trace})			Maximum eigenvalue statistics (λ_{max})		
	$r = 0$	$r \leq 1$	$r \leq 2$	$r = 0$	$r \leq 1$	$r \leq 2$
Argentina	47.93***	18.42**	5.17*	32.51***	15.25**	4.95*
Bolivia	48.61***	27.30***	11.11**	21.31**	16.19**	8.31*
Brazil	36.08**	18.19**	5.30*	22.90**	14.89**	4.10*
Chile	33.55**	17.71**	6.60*	21.83**	14.91**	5.02*
Colombia	36.06**	22.28**	4.83*	23.78**	18.45**	3.15*
Dominican Republic	49.15***	19.46**	4.13*	29.69***	15.33**	4.00*
Ecuador	41.79***	17.84**	5.41*	23.95**	14.43**	3.95*
El Salvador	34.64**	19.69**	5.66*	24.94**	17.09**	4.91*
Guatemala	72.53***	18.44**	5.98*	56.09***	15.46**	4.51*
Mexico	38.76***	20.78**	6.77**	22.98**	15.01**	5.20*
Paraguay	19.02***	9.02**	3.40*	18.01**	9.02**	2.10
Peru	34.19**	18.81**	3.78*	23.38**	15.02**	2.01
Venezuela	31.86**	18.63**	5.04*	22.23**	14.59**	4.15*

***, **, and * Significant at the 1, 5, and 10 levels, respectively, and r is cointegration rank

Chile, Dominican Republic, and El Salvador, and Brazil, Mexico, and Venezuela and the nonlinear for Bolivia, Chile, and the Dominican Republic.

In broad generalization terms, the results on the bidirectional causality relationship between gross capital formation and military spending are also overall indicating the absence of strong nexus between the two variables. An exception can be observed only for the cases of Brazil and Peru in which a bidirectional nonlinear relationship is observed. A nonlinear causality running from gross capital formation to military spending is observed for the cases of Argentina, Brazil and Peru, whereas a nonlinear causality relationship from defence spending to gross capital formation in the cases of Brazil, Chile, Colombia, Peru, and Venezuela, respectively, may be tentatively interpreted as indicating effects from dual use infrastructure and technological spillovers.

6 Concluding remarks

A steadily growing body of empirical studies has addressed the subject of the economic effects of military spending with no unequivocal consensus emerging. SIPRI's new consistent database on defence expenditures, which extends the available time series covering in some cases the entire postwar period, presents the opportunity to (re)address the issue. This paper set out to examine via linear and nonlinear causality tests the nexus between defence spending, economic growth, and investment in the 13 Latin American countries for the period 1961–2014. The findings reported herein are not uniformed across all countries included in the sample. Both bidirectional, unidirectional and non-causality were empirically

Table 6 BDS results

	Length in SD ($\sigma^{2)}$)	Emdedding dimension (m)	W statistic of variables		
			lnGDP	lnMGDP	lnINV
Argentina	0.5	2	26.85***	49.77***	10.76***
	0.5	3	40.16***	65.44***	9.93***
	0.5	4	64.09***	61.97***	8.96***
	0.5	5	69.38***	32.30***	8.28***
Bolivia	0.5	2	3.51***	6.67***	2.80***
	0.5	3	4.61***	7.32***	2.77***
	0.5	4	6.41***	8.38***	2.38***
	0.5	5	7.73***	8.63***	2.40***
Brazil	0.5	2	5.59***	33.99***	21.48***
	0.5	3	7.03***	22.98***	23.03***
	0.5	4	4.09***	14.11***	30.89***
	0.5	5	2.72***	16.47***	21.02***
Chile	0.5	2	2.61***	28.13***	9.03***
	0.5	3	0.34	45.92***	8.97***
	0.5	4	4.89***	2.66***	5.25***
	0.5	5	3.26***	1.74**	3.51***
Colombia	0.5	2	17.28***	24.51***	8.64***
	0.5	3	21.33***	10.42***	1.96**
	0.5	4	20.53***	6.34***	5.40***
	0.5	5	13.95***	4.41***	3.61***
Dominican Republic	0.5	2	9.41***	16.30***	38.12***
	0.5	3	77.17***	15.80***	31.57***
	0.5	4	46.01***	1.19	7.26***
	0.5	5	31.35***	0.74	4.88***
Ecuador	0.5	2	5.29***	2.21***	10.36***
	0.5	3	6.16***	4.53***	6.51***
	0.5	4	12.26***	2.60***	15.14***
	0.5	5	2.93***	1.70*	10.26***
El Salvador	0.5	2	17.01***	21.37***	16.77***
	0.5	3	11.88***	58.81***	56.65***
	0.5	4	59.44***	58.27***	62.91***
	0.5	5	10.93***	22.77***	59.56***
Guatemala	0.5	2	36.04***	25.84***	14.63***
	0.5	3	37.88***	37.45***	19.21***
	0.5	4	68.29***	60.27***	26.28***
	0.5	5	85.52***	72.97***	38.56***

Table 6 continued

	Length in SD ($\sigma^{2)}$	Emdedding dimension (m)	W statistic of variables		
			lnGDP	lnMGDP	lnINV
Mexico	0.5	2	1.82**	19.44***	13.25***
	0.5	3	1.42*	17.56***	4.52***
	0.5	4	5.20***	17.75***	10.42***
	0.5	5	3.47***	16.61***	3.74***
Paraguay	0.5	2	10.24***	59.00***	
	0.5	3	6.61***	22.74***	
	0.5	4	40.09***	13.70***	
	0.5	5	3.08***	9.44***	
Peru	0.5	2	5.11***	32.95***	32.70***
	0.5	3	16.79***	10.05***	44.60***
	0.5	4	22.65***	6.12***	26.54***
	0.5	5	15.55***	4.26***	18.05***
Venezuela	0.5	2	33.59***	13.22***	20.55***
	0.5	3	92.57***	8.82***	14.91***
	0.5	4	66.42***	5.16***	13.80***
	0.5	5	45.29***	3.45***	9.35***

k represents five dimensions; SD equals 0.5

***, **, and * Significant at the 1, 5, and 10% levels, respectively

Table 7 Summary of the nonlinear findings on the nexus between military expenditures and growth

	MGDP ↔ GDP		GDP → MGDP		MGDP → GDP	
	Raw Data	Resid. VAR	Raw Data	Resid. VAR	Raw Data	Resid. VAR
Argentina						+
Bolivia					+	
Brazil						+
Chile					+	
Colombia						
Dominican Republic					+	
Ecuador						
El Salvador	+		+		+	
Guatemala						
Mexico						
Paraguay			+			
Peru						
Venezuela						

Table 8 Summary of the nonlinear findings on the nexus between military expenditures and gross capital formation

	MGDP ↔ INV		INV → MGDP		MGDP → INV	
	Raw Data	Resid. VAR	Raw Data	Resid. VAR	Raw Data	Resid. VAR
Argentina			+			
Bolivia						
Brazil		+		+		+
Chile					+	
Colombia					+	
Dominican Republic						
Ecuador						
El Salvador						
Guatemala						
Mexico						
Paraguay						
Peru		+		+		+
Venezuela					+	

established. Yet, as a broad tentative generalization, the prevailing picture is that of a weak causal relationship. In most cases, no nexus could be statistically traced albeit, as noted, this is not a universally applicable inference. Clearly, the results presented above should be treated as a first reassessment of the issue at hand using the new consistent database constructed by SIPRI. Further empirical investigation is needed to examine both the determinants of such expenditures in Latin American countries as well as in order to probe further and in a more detailed manner into the economic effects of such government outlays.

Appendix

See Table 9.

Table 9 Linear and nonlinear causality results

	lnMGDP to lnGDP			lnINV to lnGDP			lnGDP to lnMGDP		
	Linear[a]	Non Linear[b]		Linear[a]	Non Linear[b]		Linear[a]	Non Linear[b]	
	Raw data	Raw data	Resid. VAR	Raw data	Raw data	Resid. VAR	Raw data	Raw data	Resid. VAR
Argentina	7.8*	−0.44	1.98**	12.2***	0.50	−1.13	24.3***	1.14	0.81
Bolivia	0.49	2.03**	−0.37	0.9	0.63	0.43	0.81	0.44	−0.57
Brazil	13.2***	−0.43	1.75**	47.9***	−0.62	1.26*	3.3	−0.30	0.99
Chile	58.2***	1.65**	1.03	78.0***	−0.23	0.31	97.4***	−1.12	−0.02
Colombia	3.9	−0.33	0.67	2.5	0.31	−0.33	3.4	−0.80	−0.57
Dominican Republic	4.9	1.37*	0.65	11.5**	1.67**	−0.47	0.72	−0.29	0.72
Ecuador	1.6	0.21	0.24	0.27	−0.72	0.36	1.0	−0.43	0.18
El Salvador	2.0	1.74**	0.51	3.0	1.50*	1.03	2.1	1.27*	1.10
Guatemala	17.0***	−0.77	−0.19	18.3***	1.32*	−1.24	11.4***	1.14	0.05
Mexico	11.7***	−0.28	0.62	19.5***	−0.39	−0.01	0.91	0.21	−0.02
Paraguay	0.78	0.85	−2.11	–	–	–	6.0**	1.87**	0.26
Peru	0.00	−0.06	0.89	0.00	−1.14	0.36	0.00	−0.09	−0.68
Venezuela	2.5*	−1.28	−1.10	1.8	0.05	−0.40	0.00	−0.39	−0.55

	lnINV to lnMGDP			lnGDP to lnINV			lnMGDP to lnINV		
	Linear[a]	Non Linear[b]		Linear[a]	Non Linear[b]		Linear[a]	Non Linear[b]	
	Raw data	Raw data	Resid. VAR	Raw data	Raw data	Resid. VAR	Raw data	Raw data	Resid. VAR
Argentina	30.9***	1.26*	−.019	1.6	−0.00	−0.62	1.1	−0.09	−0.68
Bolivia	3.9	0.56	0.63	1.3	1.46*	−1.24	1.2	1.01	0.05
Brazil	2.9	0.87	1.77**	57.4***	−0.00	1.97**	59.7***	0.05	1.34*
Chile	59.3***	0.60	−0.40	2.7	0.68	0.31	5.6	1.35*	1.05

Table 9 continued

	lnINV to lnMGDP			lnGDP to lnINV			lnMGDP to lnINV		
	Linear[a]	Non Linear[b]		Linear[a]	Non Linear[b]		Linear[a]	Non Linear[b]	
	Raw data	Raw data	Resid. VAR	Raw data	Raw data	Resid. VAR	Raw data	Raw data	Resid. VAR
Colombia	4.6	0.35	0.20	1.2	–0.67	0.32	1.0	1.25*	0.89
Dominician Republic	0.69	0.18	–0.68	30.5***	0.22	0.78	66.0***	–0.04	1.02
Ecuador	0.06	0.56	0.06	0.79	–0.30	–1.41	6.6***	–0.04	–0.08
El Salvador	1.1	–0.14	–0.57	7.2*	1.76**	1.35*	3.0	1.09	–0.14
Guatemala	12.9***	–0.12	0.67	10.8***	0.12	–0.47	25.9***	0.39	0.06
Mexico	0.52	0.52	–0.41	25.2***	0.04	0.46	12.6***	0.57	0.77
Paraguay	–	–	–	–	–	–	–	–	–
Peru	0.05	1.40*	0.70	0.42	1.42*	–0.87	1.2	1.10	1.24*
Venezuela	0.01	0.52	–0.04	0.00	–0.25	0.95	1.9	1.45*	–0.13

[a] Modified Wald Chi-square statistics

[b] T statistics

***, **, and * Significant at the 1, 5, and 10 levels, respectively

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