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The Military Expenditures and Economic Growth Nexus: Panel Bootstrap Granger Causality Evidence from NATO Countries

Summary: The purpose of this study is to examine the causal linkage between military expenditures and economic growth in 27 North Atlantic Treaty Organization (NATO) member countries. Different periods are studied due to the unavailability of data for the common period for all countries. Both the symmetric and the asymmetric causality between military expenditures and economic growth are investigated under cross-sectional dependence and panel heterogeneity by using the bootstrap panel Granger causality testing approach. The results indicate that there is both symmetric and asymmetric Granger-causality between military expenditures and economic growth, which vary from one country to another. The robust empirical findings support the military expenditures and economic growth nexus in 12 of the 27 NATO member countries. Moreover, the findings show that more empirical evidence between military expenditures and economic growth can be obtained when the asymmetric causality is considered, in addition to the symmetric causality.

Keywords: Defense economics, Military expenditures, Economic growth, Asymmetric bootstrap Granger causality.

JEL: C33, H50, H56, O47.

The military expenditures of a country, which are related to its political independence and deterrence, are an important factor in the capital budget because of their economic effects in the public and private sectors. Therefore, such expenditures have long been a subject of interest for both researchers and policy makers.

In addition, whereas understanding how military expenditures affect economic growth has been a main focus in the defense literature, the contribution of the previous literature on the relationship between the variables is to quantify the symmetric or asymmetric causality. In this sense, although many studies have aimed to examine the symmetric causality between these two variables, fewer works have explored the asymmetric causality between them. For example, previous analyses of this relationship have focused particularly on the symmetric causality (see, for example, Alper Ozun and Erman Erbaykal 2014; Jakub Odehnal and Jiri Neubauer 2016); in contrast Abdalnasser Hatemi-J et al. (2018) investigated the asymmetric causality in six

countries. The existing empirical literature, which includes intensive investigations of the relationship between military expenditures and economic growth, does not provide a consensus on the direction and characteristic of this relationship, especially in NATO member countries. Therefore, the present study analyzes the causal relationship between military expenditures and economic growth by applying both panel symmetric and asymmetric causality testing on data from 27 NATO member states.

This research generally focuses on two important contributions to the literature. The first is the investigation of the causality relationship between military expenditures and economic growth in 27 NATO members in terms of theoretical hypotheses, including Keynesian growth, conservative, feedback, and neutrality hypotheses. In the existing literature, studies on the causality relations between military expenditures and economic growth in NATO countries are limited. From the perspective of economic theory, this work presents findings that are consistent with four theoretical hypotheses. In addition, to the best of our knowledge, this is the first study explaining the relationship between the above-mentioned variables in NATO members within the asymmetric causality approach. The second contribution is the application of more robust empirical analyses to obtain consistent findings. In this regard, the relationship between military expenditures and economic growth in NATO members is examined by using panel heterogeneity, cross-sectional dependency, and symmetric causality approaches. Asymmetric causality analysis is also included in the models to obtain more robust results because symmetric causality analyses may not yield findings consistent with those in the empirical literature. Thus, if significant causality relationships are found in both symmetric and asymmetric analyses, the findings would provide more robust contributions to the defense literature. Therefore, this work may also provide an important empirical contribution to the literature on military expenditures and economic growth by showing the difference between symmetric and asymmetric causality in NATO countries.

The remainder of this report is organized as follows: Section 1 discusses the theoretical and empirical framework of the relationship between military expenditures and economic growth, Section 2 explains the data and econometric methodology applied, Section 3 presents the findings, and Section 4 provides the conclusions.

1. Theoretical and Empirical Literature

The military expenditure-economic growth nexus is one of the most important theoretical and empirical relationships analyzed in the defense economics literature. However, the results of theoretical and empirical analyses have apparently supported various explanations for controversial findings. Previous studies on the relationship between military expenditures and economic growth have focused mainly on two controversial areas in the impact of military expenditures on economic growth in terms of three different theoretical models of schools of economic thought, and the direction of causality between the two variables (for more details, see A. Henry Dakurah, Stephen P. Davies, and Rajan K. Sampath 2001, p. 652).

In this regard, the first controversial topic in the defense literature is whether the defense expenditure can either promote or hinder economic growth. From the theoretical perspective, there are different channels by which military expenditures can

have various impacts on economic growth based on different schools of economic thought. For example, the Keynesian aggregate demand approach holds that military expenditures lead to an increase in economic growth. Under this approach, increasing military expenditures stimulate economic growth by increasing employment, capital stock, and profits, thus leading to greater investments in a country (Pei-Fen Chen, Chien-Chiang Lee, and Yi-Bin Chiu 2014, p. 476). Therefore, there is a Keynesian multiplier mechanism in which military expenditures positively affect economic growth. For example, an increase in capital stock utilization through higher military expenditures results in increased profit rates and may therefore lead to higher investment levels, which may then generate higher economic growth rates with a short-run multiplier coefficient (Christos Kollias, George Manolas, and Suzanna-Maria Paleologou 2004, p. 556). In contrast, the classical approach has been used to examine the negative effects of military expenditures on economic growth; this has provided support to the defense literature by including the crowding-out effect of military expenditures. Under this approach, the negative effect of defense expenditures in the long-run will depend on two different financial management choices. First, if governments prefer to decrease other important public investments, such as education, public health, and infrastructure, in favor of increasing military expenditures, the defense spending may decrease economic growth in the long-run. Second, if governments finance military expenditures through borrowing or increased taxation, military expenditures may cause a decrease in private investments, known as the crowding-out effect of the public sector (Jonathan Lipow and Camille M. Antinori 1995, p. 581). The role of military expenditures and arms import in a debt crisis is also an important factor for investment and economic growth (see, for example, Eftychia Nikolaidou 2016). In this regard, borrowing to finance for military expenditures will lower the consumption level in a country and, thus, hamper the economic growth potential (Ourania Dimitraki and Aris Kartsaklas 2018, p. 716). According to the neoliberal approach, the supply channel means that national defense is a public good that causes opportunity costs. Under this channel, those costs are considered to be associated with certain economic problems, such as inflation, imbalances in the international financial structure, and excessive public debt. On the other hand, if the economic profits are greater than those costs in the supply channel, the military expenditures may contribute to the long-run economic growth (Grzegorz Waszkiewicz 2018, pp. 1-2).

The second controversial topic in the existing empirical literature, which includes intensive investigations of the relationship between military expenditures and economic growth, is the absence of a consensus on the direction and characteristics of such relationship, especially in NATO countries. Although a number of studies have examined the causal relationship between military expenditures and economic growth, there is no general consensus on the direction and magnitude of this relationship. In this context, a subject of intense discussion has been whether or not there is a causal linkage between the variables previously studied in the defense literature. For instance, Dakurah, Davies, and Sampath (2001) analyzed the causal relationship between defense expenditures and economic growth in 62 economies. Their findings showed a unidirectional causality running from defense expenditures to economic growth in 23 countries, and a bidirectional causality existing in 7 countries (see also Nikolaos

Dritsakis 2004; Korhan K. Gokmenoglu, Nigar Taspinar, and Mohammedsmaeil Sadeghieh 2015; Melike Bildirici 2016).

The implications of the relationship between military expenditures and economic growth have also been discussed intensively in the empirical literature on the defense-growth nexus. Previous empirical studies have presented different methods of determining the causality between military expenditures and economic growth. Some works have applied time-series techniques for individual countries, whereas several studies have used other types of analysis, such as cross-section, panel data, or spatial data analysis, in different country groups. The empirical research on the causal relationship between military expenditures and economic growth indicates that the findings differ according to the period studied and the econometric method applied in each model, as well as the development level of each country or country group. In this regard, it also seems that the empirical discussions associated with the military expenditures-economic growth nexus have recently continued to grow as such in theoretical discussions (see Table 3 in the Appendix). The general opinion emerging from these discussions is that the theoretical and the empirical literature provide conflicting results and that there is no consensus on the existence and direction of the causality between military expenditures and economic growth. For example, some studies failed to find any significant relationship between military expenditures and economic growth (see, for example, Uk Heo 2010; Hsin-Chen Chang, Bwo-Nung Huang, and Chin Wei Yang 2011; Gregory T. Papanikos 2015; Waszkiewicz 2018; John Paul Dunne and Ron P. Smith 2019), whereas other works reported a significant positive relationship between the two variables (Emile Benoit 1973; Julide Yıldırım, Selami Sezgin, and Nadir Öcal 2005; Masoud Ali Khalid and Zaleha Mohd Noor 2015; Yıldırım and Öcal 2016). On the other hand, the main findings in the literature on defense economics mainly indicate that military expenditures have a strong negative association with economic growth (Hannah Galvin 2003; Johavannes Aikaeli and Bonaventura Mlamka 2011; Dunne and Nikolaidou 2012; Serkan Küñü, Sertaç Hopođlu, and Gürkan Bozma 2016; Nusrate Aziz and M. Niaz Asadullah 2017).

There seems to be no consensus on the military expenditures and economic growth nexus, according to empirical research on the role of military expenditures in promoting economic growth based on country income groups. In the least developed and developing countries, for instance (see, for example, Ömür Candar 2003; Yıldırım, Sezgin, and Öcal 2005; Khalid and Noor 2015), several works have shown that military expenditures have a strong positive impact on economic growth, whereas a number of studies (Galvin 2003; Chang, Huang, and Yang 2011; Küñü, Hopođlu, and Bozma 2016; Aziz and Asadullah 2017) have reported a negative effect of military expenditures on economic growth. Some researches that examined this relationship in developed countries (for example, Odehnal and Neubauer 2016) have found that military expenditures positively affect economic growth in higher-income countries. However, increasing military expenditures has been found to have a nonsignificant effect on economic growth, as reported in Heo (2010) and Chang, Huang, and Yang (2011). Duygu Yolcu-Karadam, Yıldırım, and Öcal (2017) considered the volume of military expenditures to be an important factor in explaining a positive relationship between military expenditures and economic growth. The former seems to strengthen the latter in

economies with a strong defense industry and low military expenditures. From another point of view, however, it should be emphasized that the empirical literature generally applies linear-symmetric and traditional estimation methods in analyzing the military expenditures and economic growth nexus. In addition to the symmetric estimation method, some studies have discussed the relationship between military expenditures and economic growth in recent years. The related literature shows that different types of economic methods have been applied. For example, Yolcu-Karadam, Yıldırım, and Öcal (2017) used nonlinear estimation methods, such as panel smooth transition regression (PSTR) and the BDS tests of William A. Brock et al. (1996). Aside from these nonlinear tests, some empirical research on the relationship between military expenditures and economic growth have applied second-generation estimation methods, such as bootstrap Granger causality (Hsien-Hung Kung and Jeniffer C. H. Min 2013; Mehmet Destek and Ilyas Okumuş 2016), bootstrap cointegration (Destek and Okumuş 2016), and spatial data analysis (Yıldırım and Öcal 2016). Nevertheless, to our knowledge, most works have not applied the asymmetric causality method as a second-generation estimation method in their models, except for Hüseyin A. Özer, Özge F. Yağcıbaşı, and Sadık Karaoğlan (2017), Hatemi-J et al. (2018), and Ekrem Gül and Mustafa Torusdağ (2019).

A more systematic analysis of the studies in the literature would therefore indicate three main areas of contention, namely, different theoretical models of schools of economic thought, differences in the income levels of countries, and the direction of causality between the variables. First, from the perspective of different theoretical models of schools of economic thought, it may be emphasized that despite the numerous studies carried out in this area, the literature shows that there is a lack of consensus on the positive or negative impact of military expenditures on economic growth. These previous studies have indicated that military expenditures may influence the economy, especially its growth, through different channels. In this regard, there are generally two theses regarding the impact of military expenditures on economic growth: the demand side and the supply side. The supply side mostly, but not entirely, focuses on the negative effect, whereas the demand side argues a positive effect of this relationship (Michael P. Gerace 2002, p. 2). For example, from the positive effect or demand perspective, military expenditures are theorized to be capable of influencing economic growth through the expansion of total demand, generally called the Keynesian effect. This view holds that an increase in total demand leads to increased utilization of unproductive capital, a lower underemployment level, higher profits, and, therefore, higher economic growth (Suleiman Abu-Bader and Aamer Abu-Qarn 2003, p. 571). On the other hand, from the negative effect or supply perspective, the theoretical statements assert that military expenditure is a factor that inhibits economic growth. According to this negative perspective, military expenditures can slow down economic growth through some channels, such as the crowding out effect in investments, inflationary pressures, and decreases in publicly available funds for use in productive areas (Kollias, Manolas, and Paleologou 2004, p. 556). In addition to the above-mentioned theoretical relationships, many empirical studies have also shown different results regarding the direction of the effect of those relationships. For instance, Ådne Cappelen, Nills Peter Gleditsch, and Olav Bjerkholt (1984), Alex Mintz and Randolph T. Stevenson (1995), and

Yıldırım, Sezgin, and Öcal (2005) provided support for a direct or indirect positive effect of military expenditures on economic growth. In contrast, Mintz and Chi Huang (1990), Jeffrey Kentor and Edward Kick (2008) and Luca Pieroni (2009) found a negative relationship between the variables.

Second, in light of differences in the income levels of countries, many studies have analyzed whether military expenditures affect economic growth in less developed countries (see, for example, Saadet Deger and Ron Smith 1983; Basudeb Biswas and Rati Ram 1986), developing countries (Na Hou and Bo Chen 2013), and advanced countries (Aynur Alptekin and Paul Levine 2012). More specifically, the theoretical arguments presented in the literature vary across country groups classified by income levels. For example, in examining the relationship between military expenditures and economic growth in less developed countries, it is important to recognize the existence of four channels: resource allocation and mobilization, production organization, sociopolitical structure, and external relations (Deger and Smith 1983, p. 337). On the other hand, economists assume that, compared with less developed countries, defense expenditures decrease economic growth in developed countries because these expenses use up current resources available for investment (Benoit 1973, p. 271). In addition, some economists believe that military expenditures increase economic growth in less developed countries. Therefore, poor countries prefer to cut back on expenditures providing high-growth development in favor of larger defense expenditures, whereas richer countries tend to increase development expenditures while maintaining a constant level of military expenditures. Thus, according to this perspective, a negative relationship between military expenditures and economic growth can be expected in poorer countries, and a positive relationship in richer countries (Peter C. Frederiksen and Robert E. Looney 1983, p. 633).

Finally, from the theoretical and methodological perspective, the literature provides four approaches in considering the direction of the causal relationship between military expenditures and economic growth. The first approach is the growth hypothesis, which focuses on the impact of military expenditures on economic growth. According to this hypothesis, military expenditures positively affect economic growth by increasing the total demand; this is called the Keynesian effect. The literature can be said to support the existence of unidirectional causality from military expenditures to economic growth (see, for example, Dunne, Nikolaidou, and Dimitrios Vougas 2001; Erdal Karagol and Serap Palaz 2004; Chang, Huang, and Yang 2011). The second approach is the conservation hypothesis. In this regard, the conservative argument of Wayne Joerding (1986) claims that, theoretically, an economically growing country may strengthen itself against internal and external threats by increasing its military expenditures. Thus, the literature holds that there is unidirectional causality from economic growth to military expenditures (see, for example, Dritsakis 2004). The third approach is the feedback hypothesis, which asserts the existence of bidirectional causality between military expenditures and economic growth, as indicated in the literature (see, for example, Tsanyao Chang et al. 2001). The last approach is the neutrality hypothesis, which is supported by literature reports indicating the absence of a causal link between military expenditures and economic growth (see, for example, Kollias 1997; Kollias, Manolas, and Paleologou 2004; Chang, Huang, and Yang 2011).

However, the differences in the results are mainly caused by the various methods used in the studies.

2. Data and Econometric Methodology

The present study analyzes the causal relationship between military expenditures and economic growth by using data from 27 NATO member states. The variables used in this study include the *per capita* real military expenditure (*MilEx*) and the *per capita* real gross domestic product (*Y*), both of which are measured in constant 2010 US dollars¹. *Y* is obtained from the World Development Indicators (World Bank 2017)², whereas *MilEx* is from the Stockholm International Peace Research Institute (SIPRI 2017)³. Due the data on military expenditures are not available for the common period, the 27 NATO countries are divided into two panels and periods for the panel data analyses. Panel A includes data for the period between 1960 and 2019 for 15 NATO member countries: Belgium, Canada, Denmark, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Turkey, the United Kingdom, and the United States. Panel B considers data for the period 1996 to 2019 for 12 NATO countries: Albania, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia.

After the data collection, the Granger causal linkage between military expenditures and economic growth is examined by applying symmetric and asymmetric bootstrap Granger causality analysis. In the first point, we use the symmetric bootstrap panel causality test developed by László Kónya (2006) for the relationship between military expenditures and economic growth. This test has some advantages. First, the level values of the variables show the initial values even if the variables are not stationary because the model does not require preliminary testing, such as unit root and cointegration tests. Second, this test considers the correlation between countries because it allows cross-sectional dependence. Third, the approach enables a comparison of the relationship between two variables across countries, providing separate results for each country. The bootstrap panel Granger causality test is carried out through a two-step process. In the first step, the cross-sectional dependence and panel heterogeneity are tested. In the second step, the causality between the variables is estimated with seemingly unrelated regression (SUR) system estimation. In this regard, the asymmetric approach proposed by Hatemi-J (2012) is applied to the bootstrap Granger causality test developed by Kónya (2006) to investigate the causal relationship between military expenditures and economic growth. The following sections first discuss how the asymmetric approach obtains positive and negative series from the original

¹ SIPRI presents the *per capita* military expenditure in constant prices in 2018 US dollars. Because the real GDP is presented in constant prices in 2010 US dollars, the *MilEx* data were deflated to the 2010 constant prices.

² **World Bank**. 2017. World Development Indicators. <https://databank.worldbank.org/source/world-development-indicators> (accessed July 20, 2017).

³ **Stockholm International Peace Research Institute (SIPRI)**. 2017. <https://www.sipri.org/databases> (accessed July 15, 2017).

SIPRI provides the *per capita* military expenditures up to 1989. The data on total population from the WDI were used to generate the *per capita* military expenditures up to 1960.

forms of the variables and then explain the essential processes for the application of the bootstrap Granger causality test developed by Kónya (2006).

2.1 Asymmetry

According to the theoretical literature, economic agents in the cycles of economic growth and recession are generally accepted to favor different strategies, and this behavior is particularly true in the real and monetary sectors. Policymakers and domestic institutions face difficulties in these times because they are under pressure to determine how to respond to economic growth or decline. Because the asymmetry approach is incapable of providing full details on the situation of economic growth or recession, these difficulties are neglected in the calculation of symmetric estimation methods when the relationship between economic variables and symmetric estimation methods are evaluated. On the other hand, this approach, which presents a non-linear relationship between two variables, is believed to provide a more complete picture of the causality relationship between the variables as a more general tool because it provides more insights on the situation under both economic growth and recession. Thus, in terms of model specification, the asymmetric approach is said to be more successful than the symmetric approach. Furthermore, bootstrap simulations are more effective in generating critical values because economic series are typically non-normal with time-varying volatility. Otherwise, in such situations, asymptotic critical values will not be accurate. In this sense, Kónya's (2006) panel Granger causality test establishes bootstrap critical values and provides the cross-sectional dependency and heterogeneity. In the present work, the asymmetric approach proposed by Hatemi-J (2012) is adapted to the symmetric panel Granger causality approach developed by Kónya (2006). If both symmetric and asymmetric approaches indicate the causal relationship between military expenditures and economic growth, then the variables are strongly causal. In certain situations, even if the symmetric causality is insignificant, the asymmetric causality findings may indicate a significant causal relationship between the economic variables. In this case, ignoring the asymmetric relationship in the analysis could lead to a tendency to neglect the possibility of a causality relationship.

The fundamental asymmetric approach of Hatemi-J (2012) mainly derives positive and negative cumulative sum series from the original forms of the series and then explores the causal relationship between these cumulative sums (Veli Yılcı and Mücahit Aydın 2017, p. 12). To explain this approach, first, suppose that two series, such as X_{it} and Y_{it} , follow the random walk processes in Equations (1) and (2), where:

$$X_{it} = X_{it-1} + \varepsilon_{it} = X_{it,0} + \sum_{i=1, j=1}^{t,n} \varepsilon_{it}, \quad (1)$$

$$Y_{it} = Y_{it-1} + e_{it} = Y_{it,0} + \sum_{i=1, j=1}^{t,n} e_{it}. \quad (2)$$

$X_{it,0}$ and $Y_{it,0}$ are the initial values for the series in the equations, and $\varepsilon_{it} \sim N(0, \sigma_{\varepsilon_{it}}^2)$ and $e_{it} \sim N(0, \sigma_{e_{it}}^2)$ are disturbance terms with a white noise distribution characteristic. In this regard, the empirical representation of the positive and negative shocks of the series is defined as:

$$\varepsilon_{it}^+ = \max(\varepsilon_{it}, 0), \varepsilon_{it}^- = \min(\varepsilon_{it}, 0), \tag{3}$$

$$e_{it}^+ = \max(e_{it}, 0), \varepsilon_{it}^- = \min(e_{it}, 0). \tag{4}$$

Due to the disturbance terms identified in the form of $\varepsilon_{it} = \varepsilon_{it}^+ + \varepsilon_{it}^-$ and $e_{it} = e_{it}^+ + e_{it}^-$, Equations (1) and (2) can be written as Equations (5) and (6):

$$X_{it} = X_{it-1} + \varepsilon_{it} = X_{it,0} + \sum_{i=1, j=1}^{t,n} \varepsilon_{it}^+ + \sum_{i=1, j=1}^{t,n} \varepsilon_{it}^-, \tag{5}$$

$$Y_{it} = Y_{it-1} + e_{it} = Y_{it,0} + \sum_{i=1, j=1}^{t,n} e_{it}^+ + \sum_{i=1, j=1}^{t,n} e_{it}^-. \tag{6}$$

With the help of Equations (5) and (6), the positive and negative shocks in each variable can be expressed as Equations (7) and (8):

$$X_{it}^+ = \sum_{i=1, j=1}^{t,n} \varepsilon_{it}^+, \text{ and } X_{it}^- = \sum_{i=1, j=1}^{t,n} \varepsilon_{it}^-, \tag{7}$$

$$Y_{it}^+ = \sum_{i=1, j=1}^{t,n} e_{it}^+, \text{ and } Y_{it}^- = \sum_{i=1, j=1}^{t,n} e_{it}^-. \tag{8}$$

2.2 Testing Cross-Sectional Dependence

The first step in the Kónya bootstrap Granger causality test is to examine the cross-sectional dependency for the series. In the application of cross-sectional dependence, it is often useful to test whether there is a connection between cross-sectional units and whether these units are equally affected by shocks to related series (Yusuf Ekrem Akbas, Mehmet Senturk, and Canan Sancar 2013, p. 796). Given the expansion of globalization and the increased interdependence among countries today, any analyses that do not consider cross-sectional dependence would provide biased and inconsistent results (M. Hashem Pesaran 2004). In the case of cross-sectional dependence, first generation tests lead to spurious results because of size distortion. Trevor S. Breusch and Adrian R. Pagan (1980) proposed the Lagrange multiplier (LM) test in Equation (9) to examine cross-sectional dependence.

$$CD_{LM1} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}^2. \tag{9}$$

In the LM test, the null hypothesis that there is no cross-sectional dependence is $H_0 = cov(u_{it}, u_{jt}) = 0$ for all t and $i \neq t$, whereas the alternative hypothesis that there is cross-sectional dependence for at least one pair is $H_1 = cov(u_{it}, u_{jt}) \neq 0$ for at least one pair of $i \neq t$. $\hat{\rho}_{ij}$ indicates a pair-wise Pearson correlation coefficient among residuals acquired through OLS estimation for each i . The LM statistic is used to test for cross-sectional dependence when $T \rightarrow \infty$ and N is constant, that is, when $T > N$. In addition, under these conditions, the statistics has an asymptotic chi-squared distribution with $N(N-1)/2$ degrees of freedom. Thus, the power of the LM statistic decreases when N increases. To solve this problem, Pesaran (2004) suggested two different cross-sectional dependence test methods with an asymptotic standard normal distribution. According to Pesaran, these methods are under $T \rightarrow \infty$ and $N \rightarrow \infty$, if $T > N$, the CD_{LM} test is used; if $N > T$, the CD test is used. Under the null hypothesis that there is no cross-sectional dependence, the empirical representations of the CD_{LM2} and CD tests are modeled, respectively, as follows:

$$CD_{LM2} = \left(\frac{1}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^N T \hat{\rho}_{ij}^2 - 1, \tag{10}$$

$$CD = \left(\frac{2T}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}. \tag{11}$$

However, in the stationary dynamic panel data models, the CD_{LM2} and CD tests do not have a tendency to reject the null hypothesis if the group means are zero but the individual means are different from zero. To solve this problem, Pesaran, Aman Ullah, and Takashi Yamagata (2008) suggested a bias-adjusted modified LM statistic that uses the mean and variance of the LM statistic. The bias-adjusted LM equation is expressed as:

$$LM_{adj} = \sqrt{\left(\frac{2T}{N(N-1)}\right) \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}^2}}}. \tag{12}$$

In Equation (12), the terms μ_{Tij} and v_{Tij}^2 , respectively, are the mean and variance of $(T - k)\hat{\rho}_{ij}^2$ derived by Pesaran, Ullah, and Yamagata (2008). LM_{adj} has an asymptotically standard normal distribution when $T \rightarrow \infty$ and $N \rightarrow \infty$ under the null hypothesis that there is no cross-sectional dependence.

2.3 Testing Slope Homogeneity

The second step in the Kónya bootstrap Granger causality test is to determine whether the slope coefficients are homogenous. The traditional method used to determine whether there is evidence of homogeneity of slope coefficients is the standard F test. However, the F test is acceptable only when the number of cross sections (N) is small or the time period is large and when the explanatory variables are strictly exogenous or the error variances are homoscedastic. Paravastu A. V. B. Swamy (1970) developed a test to minimize the lack of homoscedasticity assumption in the F test. However, this test, similarly to the F test, is valid only under $T > N$. Pesaran and Yamagata (2008) recently proposed a standardized version of the Swamy’s test, called the $\tilde{\Delta}$ test, which is valid for larger panels. The first step in this test is to calculate the revised version of Swamy statistic. The test is formulated as defined in Equation (13):

$$\tilde{S} = \sum_{i=1}^N (\hat{\beta}_i - \hat{\beta}_{WFE})' \frac{x_i' M_\tau x_i}{\tilde{\sigma}_i^2} (\hat{\beta}_i - \hat{\beta}_{WFE}). \tag{13}$$

In Equation (13), $\hat{\beta}_i$ denotes the pooled OLS estimator, $\hat{\beta}_{WFE}$ is the weighted fixed effect pooled estimator, M_τ is an identity matrix, and $\tilde{\sigma}_i^2$ is the estimator of σ_i^2 . Standardized dispersion statistics are later developed in Equation (14) as:

$$\tilde{\Delta} = \sqrt{N} \left(\frac{N^{-1} \tilde{S} - k}{\sqrt{2k}} \right). \tag{14}$$

On the other hand, the $\tilde{\Delta}$ test has an asymptotically normal distribution. We test the null hypothesis, $H_0: \beta_i = \beta$ for all i which states that the slope coefficient is homogeneous, against the alternative hypothesis, $H_1: \beta_i = \beta_j$ for $i \neq j$, which holds that the slope coefficient is heterogeneous under $(N, T) \rightarrow \infty$, provided that $\sqrt{N}/T \rightarrow \infty$.

The bias-adjusted $\tilde{\Delta}$ test, which is used for small samples and indicates a normal distributive property in the disturbance term, is defined in Equation (15) as:

$$\tilde{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1} \tilde{S} - E(\tilde{z}_{it})}{\sqrt{\text{var}(\tilde{z}_{it})}} \right). \tag{15}$$

In Equation (15), $E(\tilde{z}_{it}) = k$ is the mean, and $\text{var}(\tilde{z}_{it}) = 2k(T - k - 1)/(T + 1)$ is the variance.

2.4 Bootstrap Panel Granger Causality

When the existence of cross-sectional dependence and heterogeneity across the NATO countries has been determined, a bootstrap panel Granger causality test that should account for these dynamics is applied. The bootstrap panel causality test proposed by Kónya (2006) can account for both cross-sectional dependence and country-specific heterogeneity. This approach is based on the SUR estimation of the set of equations and on Wald tests with individual country-specific bootstrap critical values. The variables in the system do not need to be stationary when the critical values for the cross sections are derived from the bootstrap. Therefore, the level values of the variables can be used directly without applying preprocessing tests, such as unit root and cointegration tests, in the system estimation. The bootstrap Granger causality approach has two sets of equations: X_{it} , including X_{it}^+ and X_{it}^- for asymmetric causality; and Y_{it} , including Y_{it}^+ and Y_{it}^- for asymmetric causality. The two sets of equations to be estimated are expressed in Equations (16) and (17):

$$\begin{aligned} Y_{1,t} &= \alpha_{1,1} + \sum_{j=1}^{ly_1} \beta_{1,1,j} Y_{1,t-j} + \sum_{j=1}^{lx_1} \gamma_{1,1,j} X_{1,t-j} + \varepsilon_{1,1,t}, \\ Y_{2,t} &= \alpha_{1,2} + \sum_{j=1}^{ly_2} \beta_{1,2,j} Y_{2,t-j} + \sum_{j=1}^{lx_2} \gamma_{1,2,j} X_{2,t-j} + \varepsilon_{1,2,t}, \\ &\vdots \\ Y_{N,t} &= \alpha_{1,N} + \sum_{j=1}^{ly_N} \beta_{1,N,j} Y_{N,t-j} + \sum_{j=1}^{lx_N} \gamma_{1,N,j} X_{N,t-j} + \varepsilon_{1,N,t}; \end{aligned} \tag{16}$$

and

$$\begin{aligned} X_{1,t} &= \alpha_{2,1} + \sum_{j=1}^{lx_1} \beta_{2,1,j} Y_{1,t-j} + \sum_{j=1}^{ly_1} \gamma_{2,1,j} X_{1,t-j} + \varepsilon_{2,1,t}, \\ X_{2,t} &= \alpha_{2,2} + \sum_{j=1}^{lx_2} \beta_{2,2,j} Y_{2,t-j} + \sum_{j=1}^{ly_2} \gamma_{2,2,j} X_{2,t-j} + \varepsilon_{2,2,t}, \\ &\vdots \\ X_{N,t} &= \alpha_{2,N} + \sum_{j=1}^{lx_N} \beta_{2,N,j} Y_{N,t-j} + \sum_{j=1}^{ly_N} \gamma_{2,N,j} X_{N,t-j} + \varepsilon_{2,N,t}; \end{aligned} \tag{17}$$

where $[Y]$ indicates economic growth or positive $[Y^+]$ and negative $[Y^-]$ components of economic growth. $[X]$ indicates military expenditures $[MilEx]$ or positive $[MilEx^+]$ and negative $[MilEx^-]$ components of military expenditures. N and t denote the number of countries for two panels (A and B) and the time period, respectively. More specifically, N is 13 for Panel A and 14 for Panel B; t is 55 for Panel A and 20 for Panel B. α , β , and γ are common factors, whereas ε and l refer to the disturbance and lag length, respectively. Changing of lag lengths in the equation systems is allowed; however, it is assumed that the individual lag length does not change according to the cross sections. The maximum lag length considered in this work is 4, which was determined based on the Akaike (AIC) and the Schwarz (SBC) information criterion for systems.

The general functional forms for these information criteria may be written as in Equations (18) and (19):

$$AIC = \ln|W| + \frac{2N^2q}{T}, \quad (18)$$

$$SBC = \ln|W| + \frac{2N^2q}{T} \ln(T). \quad (19)$$

Here, W , N , q , and T are, respectively, the residuals covariance matrix, number of equations, number of coefficients per equation, and sample size.

Each equation of the system analysis has various predetermined variables and disturbance terms. The disturbance terms in the equations are assumed to be closely interrelated with each other, that is, to have cross-sectional dependence. Hence, each set of equations is a SUR system. On the other hand, the Wald test is used to analyze causality. Four types of Granger causality may occur in the system estimation (Kónya 2006, p. 981).

1. If $\beta_{2,i} = 0$ for all i when $\gamma_{1,i} \neq 0$ for each i , there is one-way Granger causality from *MilEx* (or positive and negative components of *MilEx*) to Y (or positive and negative components of Y).
2. If $\beta_{2,i} \neq 0$ for all i when $\gamma_{1,i} = 0$ for each i , there is one-way Granger causality from Y (or positive and negative components of Y) to X (or positive and negative components of *MilEx*).
3. If $\gamma_{1,i} \neq 0$ and $\beta_{2,i} \neq 0$ for all i , there is bidirectional Granger causality between X (or positive and negative components of *MilEx*) and Y (or positive and negative components of Y).
4. If $\gamma_{1,i} = 0$ and $\beta_{2,i} = 0$ for all i , there is no Granger causality between X (or positive and negative components of *MilEx*) and Y (or positive and negative components of Y).

3. Findings

Table 1 shows the results of the cross-sectional dependence (i.e. CD_{LM1} , CD_{LM2} , CD , and LM_{adj}) and slope homogeneity tests (i. e. $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$) applied to both panel groups. The results of the cross-sectional dependence test show that the null hypothesis of no cross-sectional dependence in the series is clearly rejected in both panel groups. Only the CD-test statistic for the negative cumulative shock series of Y in Panel A accepts the null hypothesis of no cross-sectional dependence. In contrast, the results of the three other tests of cross-sectional dependence indicate that the null hypothesis of no cross-sectional dependence for the negative cumulative shock series of Y is also clearly rejected. The results of the slope homogeneity test indicate that the null hypothesis claiming homogeneity is clearly rejected. Thus, the assumption of country-specific heterogeneity is valid because the economic relations of individual countries in a panel group may vary. In this regard, the bootstrap panel Granger causality approach can be applied under both cross-sectional dependence and slope heterogeneity.

Table 1 Cross-Sectional Dependence and Slope Homogeneity

Panel A (N = 15, T = 1960-2019)						
	<i>MilEx</i>	<i>Y</i>	<i>MilEx</i> *	<i>Y</i> *	<i>MilEx</i>	<i>Y</i> *
<i>Cross-sectional dependence test</i>						
CD _{LM1}	136.9 ^b	264.7 ^a	134.5 ^b	180.7 ^a	213.8 ^a	548.8 ^a
CD _{LM2}	2.20 ^b	11.0 ^a	2.03 ^b	5.22 ^a	7.50 ^a	30.6 ^a
CD	-3.85 ^a	-4.11 ^a	-4.03 ^a	-4.62 ^a	-3.62 ^a	-0.12
LM _{adj}	16.5 ^a	19.7 ^a	13.2 ^a	8.32 ^a	12.7 ^a	11.3 ^a
<i>Slope homogeneity test</i>						
$\bar{\Delta}$	3.415 ^b		13.181 ^a		7.832 ^a	
	(0.019)		(0.000)		(0.000)	
$\bar{\Delta}_{adj}$	3.451 ^b		13.517 ^a		8.031 ^a	
	(0.013)		(0.000)		(0.000)	
Panel B (N = 12, T = 1996-2019)						
	<i>MilEx</i>	<i>Y</i>	<i>MilEx</i> *	<i>Y</i> *	<i>MilEx</i>	<i>Y</i> *
<i>Cross-sectional dependence test</i>						
CD _{LM1}	107.2 ^a	139.9 ^a	115.9 ^a	135.1 ^a	151.0 ^a	132.7 ^a
CD _{LM2}	3.58 ^a	6.43 ^a	4.34 ^a	6.02 ^a	7.40 ^a	-2.11 ^b
CD	-3.14 ^a	-2.02 ^b	-2.87 ^a	-2.80 ^a	-2.99 ^a	-3.43 ^a
LM _{adj}	6.61 ^a	14.6 ^a	5.98 ^a	7.51 ^a	10.6 ^a	4.20 ^b
<i>Slope homogeneity test</i>						
$\bar{\Delta}$	3.975 ^a		3.203 ^a		-3.856 ^a	
	(0.000)		(0.001)		(0.000)	
$\bar{\Delta}_{adj}$	4.237 ^a		3.415 ^a		-3.913 ^a	
	(0.000)		(0.000)		(0.000)	

Notes: ^a and ^b indicate significance at the levels of 1%, and 5%, respectively. Numbers in parentheses (...) represents probability values of homogeneity test statistics.

Source: Authors' calculation with GAUSS.

The results of the symmetric and asymmetric bootstrap panel Granger causality tests between military expenditures and economic growth are shown in Tables 4 and 5 in the Appendix; Table 2 presents a summary of the direction of Granger causality. The statistical significance of Granger causal relations at different confidence intervals is indicated by arrows. In considering the asymmetric relationships, the findings show more empirical evidence for the causal linkages between military expenditures and economic growth. There is Granger causality from the *MilEx* to *Y* in only 11 NATO countries when the asymmetric relationship between *MilEx* and *Y* is not taken into account; the number of countries increases from 11 to 21 when the asymmetric relationship between variables is considered. Additionally, there is Granger causality from *Y* to *MilEx* in only 7 NATO countries when the asymmetric relationship is not taken into account; the number of countries increases from 7 to 13 when the asymmetrical relationship is considered.

Although the significance levels vary from country to country, the findings of the bootstrap Granger causality test indicate that there is both symmetric and asymmetric causality between *MilEx* and *Y*, which vary from country to country. Specifically, there is no symmetric and asymmetric Granger causality between *MilEx* and *Y* in two NATO countries: Italy and the United States. In contrast, there is bidirectional Granger causality in 12 NATO countries: Belgium, Bulgaria, Canada, Germany, Greece, Latvia, Norway, Poland, Romania, Slovak Republic, Spain, and the United Kingdom. There is clear bidirectional Granger causality between *MilEx* and *Y*, especially in Germany, as both symmetric and asymmetric causal linkages are statistically significant. Further, according to the empirical findings there is only unidirectional Granger causality from *MilEx* to *Y* in 9 NATO countries: Albania, Czechia, Denmark,

France, Hungary, Lithuania, Luxembourg, Netherlands, and Portugal. In 7 NATO countries, namely, Belgium, Canada, Denmark, France, Germany, Netherlands, and Norway there is strong Granger causality from *MilEx* to *Y*. Thus, the Granger causality from *MilEx* to *Y* in these countries is both symmetric and asymmetric. The empirical findings also show that there is unidirectional Granger causality from *Y* to *MilEx* in Croatia, Estonia, Slovenia, and Turkey, whereas the findings for Estonia indicate that there is either symmetric or asymmetric Granger causality from *Y* to *MilEx*.

Table 2 Summary for Direction of Granger Causality

Countries	Symmetric		Asymmetric		Countries	Symmetric		Asymmetric	
	<i>MilEx</i>		<i>MilEx</i> ⁺	<i>MilEx</i> ⁻		<i>MilEx</i>		<i>MilEx</i> ⁺	<i>MilEx</i> ⁻
Direction: from military expenditures (<i>MilEx</i>) to economic growth (<i>Y</i>)									
Albania	→				Lithuania				→
Belgium	→		→		Luxembourg	→			→
Bulgaria			→		Netherlands	→		→	
Canada	→		→		Norway	→		→	
Croatia					Poland	→			
Czechia			→	→	Portugal			→	
Denmark	→		→	→	Romania				→
Estonia					Slovakia				→
France	→		→	→	Slovenia				
Germany	→		→		Spain	→			
Greece				→	Turkey				
Hungary			→	→	UK			→	→
Italy					USA				
Latvia				→					
Countries	Symmetric		Asymmetric		Countries	Symmetric		Asymmetric	
	<i>MilEx</i>		<i>MilEx</i> ⁺	<i>MilEx</i> ⁻		<i>MilEx</i>		<i>MilEx</i> ⁺	<i>MilEx</i> ⁻
Direction: from economic growth (<i>Y</i>) to military expenditures (<i>MilEx</i>)									
Albania					Lithuania				
Belgium	←				Luxembourg				
Bulgaria			←		Netherlands				
Canada				←	Norway	←			
Croatia			←		Poland	←			←
Czechia					Portugal				
Denmark					Romania			←	
Estonia	←			←	Slovakia				←
France					Slovenia				←
Germany	←		←		Spain				←
Greece			←		Turkey	←			
Hungary					UK				←
Italy					USA				
Latvia	←			←					

Source: Authors' calculation.

4. Conclusion

This research empirically examines the symmetric and asymmetric causal relationships between military expenditures and economic growth in 27 NATO member states by using the bootstrap panel Granger causality analysis. The advantage of this approach is that it allows testing for cross-sectional dependence and country-specific heterogeneity. Because data on military expenditures are not available for all countries for the common period, the 27 NATO countries are divided into two groups (i.e., Panels A and B). Panel A includes data for the period of 1960-2019 for 15 countries: Belgium, Canada, Denmark, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Turkey, the United Kingdom, and the United States. Panel B considers data for the period 1996-2019 for 12 countries: Albania, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. The empirical results indicate that there is both symmetric and asymmetric Granger causality between military expenditures and economic growth, which vary from country to country. Here, the results are presented in terms of four outcomes. First, considering the asymmetric relationships between military expenditures and economic growth, the results suggest more empirical evidence for the causal linkages between military expenditures and economic growth. Second, there is no symmetric and asymmetric causality between military expenditures and economic growth only in Italy and the United States. Third, there is unidirectional and strong symmetric and asymmetric causality from military expenditures to economic growth in Denmark, France, and Netherlands and from economic growth to military expenditures in Latvia. Finally, the results of the causality tests indicate that there is bidirectional causality between military expenditures and economic growth in Belgium, Bulgaria, Canada, Germany, Greece, Latvia, Norway, Poland, Romania, Slovak Republic, Spain, and the United Kingdom.

By evaluating together the symmetric and asymmetric causality results, some economic implications are determined. For example, the findings indicate that the neutrality hypothesis is valid in Italy and the United States. This hypothesis implies that military expenditures do not influence economic activities and that economic growth is not a determinant of military expenditures. In addition, our findings support the military expenditure-led growth hypothesis in Albania, Czechia, Denmark, France, Hungary, Lithuania, Luxembourg, Netherlands, and Portugal. Thus, the Keynesian theory is confirmed, which implies an impact of military expenditures as a public expenditure on employment and output levels through an increase in demand in the country. On the other hand, the results of the present study indicate that the conservative hypothesis is valid in Croatia, Estonia, Slovenia, and Turkey. Therefore, there is unidirectional causality from economic growth to military expenditures in these countries. Finally, the findings confirm that the feedback hypothesis is valid in Belgium, Bulgaria, Canada, Germany, Greece, Latvia, Norway, Poland, Romania, Slovak Republic, Spain, and the United Kingdom. Thus, the causal relationship between military expenditures and economic growth differs from one country to another. The reasons why the causality relationship between military expenditures and economic growth gives different results across countries are based on various preferences applied in countries' defense and economic growth policies.

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Appendix

Table 3 Empirical Literature on the Military Expenditure and Economic Growth Nexus

Study / Author(s)	Methodology	Country	Period	Main finding(s)
Benoit (1973)	Multiple regression analysis	40 less developed countries	1950-1965	Positive effect
Frederiksen and Charles J. LaCivita (1987)	Granger causality	Philippines	1956-1982	$Y \rightarrow \text{MilEx}$
Dakurah, Davies, and Sampath (2001)	Panel Granger causality	62 developing countries	1975-1995	$Y \rightarrow \text{MilEx}$ in 23 countries $\text{MilEx} \leftrightarrow Y$ in 7 countries $\text{MilEx} \leftrightarrow Y$ in 18 countries No estimation for 14 countries
Abu-Bader and Abu-Qarn (2003)	Granger causality	Egypt, Israel and Syria	1975-1998 1976-1998 1973-1998	Negative effect
Candar (2003)	Engle-Granger cointegration	Turkey	1950-2001	Positive effect both short- and long-run
Galvin (2003)	Cross-section data analysis, 2SLS and 3SLS	64 developing countries	1999	Negative particularly stronger effect in middle income countries
Dritsakis (2004)	Johansen-Juselius cointegration and Hsiao causality	Greece and Turkey	1960-2001	$Y \rightarrow \text{MilEx}$ in all countries
Dunne and Smith (2019)	Static and dynamic panel data methods	46 OECD countries	1960-2014	The effects of MilEx on growth is negative, but is insignificant.
Yildirim, Sezgin, and Öcal (2005)	Fixed effects and GMM	Middle Eastern countries and Turkey	1989-1999	Positive effect
Heo (2010)	OLS regression	USA	1954-2005	No significant effect.
Ozun and Erbaykal (2014)	ARDL bounds testing approach and Toda-Yamamoto causality	13 NATO countries	1949-2006	$\text{MilEx} \leftrightarrow Y$ in Turkey $Y \rightarrow \text{MilEx}$ in France, UK, Norway $\text{MilEx} \rightarrow Y$ in Greece, Netherlands, Portugal. $\text{MilEx} \leftrightarrow Y$ Belgium, Canada, Denmark, Germany, Italy, USA
Aikaeli and Mlamka (2011)	Panel OLS regression	48 African states	2001-2005	$Y \rightarrow \text{MilEx}$ Negative effect, in both low and high income countries
Chang, Huang, and Yang (2011)	GMM dynamic panel causality	90 countries with high, low and middle income	1992-2006	Negative effect in low-income countries. Insignificant in other income groups
Dunne and Nikolaidou (2012)	Panel and time series methods.	EU-15	1961-2007	Negative or insignificant effect in EU-15
Andreas G. Georgantopoulos (2012)	Johansen cointegration and Granger causality	Bulgaria, Albania, Romania and Greece	1988-2009	$Y \rightarrow \text{MilEx}$ in Bulgaria and Albania. $Y \leftrightarrow \text{MilEx}$ in Greece and Romania.
Kung and Min (2013)	Bootstrap panel and Granger causality	18 Latin and South American countries	1988-2010	$\text{MilEx} \leftrightarrow Y$ in 12 countries $Y \rightarrow \text{MilEx}$ in Belize and Nicaragua. $Y \rightarrow \text{MilEx}$ in Bolivia and Ecuador.
Faek Menla Ali and Dimitraki (2014)	OLS regression and FTP-TVTP	China	1953-2010	Positive effect during a when slower growth Negative effect when faster growth
Amjad Ali and Muhammad Ather (2015)	2SLS regression	Pakistan	1980-2013	Negative effect
Tolulope O. Apanisile and Charles O. Okunlola (2014)	ARDL bounds testing approach	Nigeria	1989-2013	Negative effect in long-run Positive effect in long-run but insignificant

Gokmenoglu, Taspinar, and Sadeghieh (2015)	Johansen cointegration Granger causality	Turkey	1988-2013	Y → MiEx
Papanikos (2015)	Panel Granger causality	20 Mediterranean countries	1988-2013	No effect
Ramesh Chandra Das, Soumyananda Dinda, and Kamal Ray (2015)	Johansen cointegration VECM and Granger causality	20 randomly selected countries	1988-2013	Y → MiEx in 7 countries MiEx → Y in 5 countries. MiEx ↔ Y in Italy and Australia MiEx ↔ Y in six countries
Khalid and Noor (2015)	System GMM	67 developing countries	2002-2010	Positive effect
Künü, Hopoğlu, and Bozma (2016)	Random effects	20 Middle Eastern countries	1998-2012	Negative effect
Destek and Okumuş (2016)	Bootstrap panel and Granger causality	BRICS and MIST countries	1990-2013	Positive effect in China and Negative effect in Turkey, MiEx ↔ Y in Brazil, India, Indonesia, South Korea, Mexico and South Africa MiEx ↔ Y in Russia.
Odehnal and Neubauer (2016)	Pearson and Spearman correlation analysis	27 NATO countries	1993-2014	Positive correlation in Germany, Greece, Italy, Norway, the Netherlands. Negative correlation in Albania, Canada, Romania, USA. No any correlation in 18 countries.
Yolcu-Karadam, Yıldırım, and Öcal (2017)	Non-linear panel data models (PSTR estimation)	Middle Eastern countries and Turkey	1988-2012	Non – linear relationship Positive effect low values of military expenditures, Negative effect high values of military expenditures.
Yıldırım and Öcal (2016)	Spatial data analysis	128 countries	2000-2010	Positive effect
Kollias et al. (2017)	Linear (Toda Yamamoto) and non-linear causality (BDS test)	13 Latin American countries	1961-2014	Non – linear MiEx → Y in Chile, Colombia, Venezuela Non – linear Y → MiEx in Argentina, Salvador, Paraguay
Aziz and Asadullah (2017)	Pooled OLS, fixed effects, random effects and GMM	70 developing countries	1990-2013	Negative effect
Özer, Yağcıbaşı, and Karaoğlan (2017)	Time-varying asymmetric causality	Turkey	1967-2015	Y ↔ MiEx Y ⁺ ↔ MiEx ⁺
Mert Topçu and İlhan Aras (2017)	Panel cointegration and causality	Central and Eastern European countries	1993-2013	Y → MiEx short-run causality
Hatemi-J et al. (2018)	Asymmetric panel causality tests	6 defense spenders (China, Japan, France, Russia, Saudi Arabia and USA)	1988-2013	Asymmetric Y → MiEx in China and Japan Asymmetric Y → MiEx in France, Russia, Saudi Arabia and US.
Waszkiewicz (2018)	Granger causality	Visegrad countries	1993-2015	MiEx → Y in Czech Republic MiEx ↔ Y in Poland, Hungary and Slovakia
Gül and Torusdağ (2019)	Asymmetric panel causality	BRICS countries and Turkey	1995-2010	Asymmetric Y → MiEx

Notes: FTP and TVTP denote fixed and time-varying transition probability.

Source: Authors' compilation.

Table 4 Panel Granger Causality from *MilEx* to *Y*

Countries	Symmetric bootstrap causality						Asymmetric bootstrap causality					
	H ₀ : <i>MilEx</i> does not cause <i>Y</i>			H ₀ : <i>MilEx</i> * does not cause <i>Y</i> *			H ₀ : <i>MilEx</i> does not cause <i>Y</i>					
	Wald stats.	Bootstrap critical values			Wald stats.	Bootstrap critical values			Wald stats.	Bootstrap critical values		
	10%	5%	%1		10%	5%	%1		10%	5%	%1	
Panel A (time period: 1960-2019)												
Belgium	7.35 ^b	4.03	5.77	11.6	14.5 ^b	6.11	8.77	16.5	3.26	13.9	19.8	33.6
Canada	9.63 ^b	4.76	7.41	13.1	15.2 ^a	6.61	8.84	15.1	1.08	10.8	15.4	23.3
Denmark	12.2 ^a	4.18	6.34	10.8	10.1 ^b	6.35	9.01	15.6	24.8 ^b	12.1	16.3	25.9
France	6.77 ^b	4.79	6.62	12.7	10.8 ^b	6.04	8.69	16.1	16.8 ^c	15.0	18.8	27.0
Germany	8.96 ^b	4.10	5.76	13.3	14.6 ^a	4.33	6.77	11.7	0.06	13.2	17.9	32.0
Greece	0.78	4.52	6.79	11.2	4.24	9.36	12.9	21.8	15.6 ^c	12.0	17.4	30.1
Italy	2.70	5.30	7.02	13.2	0.41	7.18	10.5	18.4	1.63	15.2	20.2	32.3
Luxembourg	4.71 ^c	4.67	6.85	11.0	0.19	7.98	11.5	18.9	17.5 ^b	9.33	13.2	23.5
Netherlands	12.2 ^a	4.30	6.29	10.5	8.35 ^c	6.56	9.09	14.6	4.99	12.2	17.3	27.7
Norway	12.1 ^a	4.01	6.35	10.2	15.2 ^b	6.86	9.56	16.4	8.80	12.4	16.9	24.8
Portugal	0.04	4.78	6.65	12.5	9.56 ^b	6.67	9.10	14.9	0.88	12.3	15.8	30.4
Spain	5.84 ^b	4.16	5.82	11.2	4.07	6.66	8.91	14.1	7.94	14.3	18.3	26.0
Turkey	2.97	4.49	6.70	11.6	0.05	5.72	8.07	11.9	3.42	12.7	16.3	24.7
UK	0.05	4.53	6.20	11.7	12.6 ^b	6.52	9.80	15.7	20.9 ^b	10.7	15.2	26.3
USA	1.81	4.74	6.65	13.3	0.07	6.38	8.96	14.7	3.23	11.1	14.8	24.1
Panel B (time period: 1996-2019)												
Albania	16.7 ^c	11.7	17.9	27.5	12.7	19.1	29.2	59.6	1.71	11.0	15.7	32.4
Bulgaria	8.12	10.1	14.3	27.0	41.4 ^b	23.8	32.4	53.0	6.74	6.79	9.61	17.8
Croatia	4.13	13.0	19.3	32.8	0.27	14.2	20.1	41.1	28.3	33.9	51.6	96.1
Czechia	7.54	9.74	13.8	29.1	57.4 ^a	17.4	25.3	42.0	385.9 ^a	42.9	54.4	97.7
Estonia	6.55	19.3	27.8	53.3	1.63	29.0	39.8	70.7	4.64	39.4	50.1	13.4
Hungary	1.38	9.72	14.2	27.3	23.1 ^b	11.6	16.4	35.7	169.8 ^a	49.8	63.7	17.3
Latvia	0.13	12.9	19.5	34.7	14.9	21.9	29.8	51.9	131.8 ^a	34.4	52.1	42.5
Lithuania	1.84	14.1	19.9	36.9	0.22	18.7	26.1	51.2	52.5 ^a	48.9	62.9	36.1
Poland	17.2 ^b	9.20	14.2	25.7	11.2	14.1	20.0	35.3	9.87	13.4	18.7	48.6
Romania	1.21	9.35	13.5	24.7	2.03	14.7	23.9	41.7	22.2 ^c	17.3	24.3	52.8
Slovakia	7.31	14.2	19.6	33.6	6.78	17.5	23.7	48.9	70.2 ^b	42.5	62.7	144.1
Slovenia	3.32	13.7	19.5	35.1	8.72	21.0	30.4	54.9	2.93	36.1	46.2	75.7

Notes: ^a, ^b and ^c indicate rejection of the null hypothesis at the 1, 5, and 10 percent levels of significance, respectively. Bootstrap critical values are obtained from 1000 iterations.

Source: Authors' calculation with TSP.

Table 5 Panel Granger Causality from Y to *MilEx*

Countries	Symmetric bootstrap causality						Asymmetric bootstrap causality					
	H ₀ : Y does not cause <i>MilEx</i>			H ₀ : Y* does not cause <i>MilEx</i> *			H ₀ : Y does not cause <i>MilEx</i>					
	Wald stats.	Bootstrap critical values			Wald stats.	Bootstrap critical values			Wald stats.	Bootstrap critical values		
		10%	5%	%1		10%	5%	%1		10%	5%	%1
Panel A (time period: 1960-2019)												
Belgium	21.4^a	7.20	9.17	16.0	6.64	11.2	14.3	22.3	5.13	7.80	9.98	16.3
Canada	2.90	5.67	7.79	12.7	6.55	12.1	15.3	23.7	12.2^b	9.10	12.0	20.5
Denmark	0.06	4.69	6.94	11.3	10.6	12.9	16.9	25.4	0.66	5.83	7.67	11.1
France	0.50	7.66	10.4	19.4	4.66	12.7	15.5	23.3	1.43	8.77	11.3	18.0
Germany	9.90^b	6.34	8.94	13.3	19.0^a	8.07	11.0	18.4	0.09	6.06	9.02	16.4
Greece	0.01	6.92	10.4	21.0	31.0^a	12.6	16.5	27.9	0.67	8.24	11.7	24.1
Italy	0.87	8.72	12.7	21.3	2.81	13.1	15.8	23.7	1.42	7.33	9.70	15.2
Luxembourg	3.94	8.59	12.6	19.5	7.78	15.8	19.0	31.4	0.95	7.10	10.4	16.8
Netherlands	3.24	7.32	10.2	16.2	2.69	12.9	16.7	25.2	6.79	8.18	11.8	19.6
Norway	9.52^b	5.06	7.39	14.0	6.93	14.5	17.8	29.0	1.72	6.52	9.17	16.5
Portugal	0.02	8.76	12.0	18.6	0.03	13.7	17.3	30.7	2.56	8.56	11.5	21.7
Spain	0.04	6.91	9.75	16.1	2.31	10.8	14.9	22.9	6.92^c	5.99	8.69	15.3
Turkey	8.36^c	6.85	10.5	17.0	0.52	14.5	18.8	31.8	0.21	8.68	12.0	23.1
UK	0.08	5.40	7.40	11.3	5.28	16.1	19.9	31.9	19.6^a	8.74	12.8	18.4
USA	0.02	5.83	8.39	16.5	3.60	15.7	18.3	25.8	6.06	6.89	9.52	17.8
Panel B (time period: 1996-2019)												
Albania	9.98	20.8	31.7	58.0	13.6	29.0	37.7	61.7	3.61	11.1	19.2	39.2
Bulgaria	1.90	12.4	18.0	31.0	22.2^b	14.6	19.8	35.2	0.03	13.2	21.1	57.1
Croatia	2.53	11.1	16.5	29.0	28.0^a	11.1	16.9	26.1	1.83	11.5	17.3	31.4
Czechia	2.87	13.3	20.0	38.8	1.09	22.8	31.1	49.2	0.15	13.4	19.7	38.7
Estonia	26.8^b	15.6	22.3	43.9	9.42	22.1	29.4	47.9	28.6^c	19.3	29.6	55.7
Hungary	0.09	11.5	16.8	38.1	8.16	14.1	21.6	46.3	0.51	13.7	18.9	36.0
Latvia	25.0^c	17.6	25.6	48.7	3.13	31.8	41.8	66.5	155.9^a	20.7	29.0	62.0
Lithuania	11.2	28.9	37.7	69.9	10.7	15.9	21.5	39.6	10.8	14.4	20.3	40.5
Poland	18.0^b	11.6	16.1	32.2	6.48	32.1	42.8	76.4	30.5^b	14.9	22.5	48.1
Romania	5.15	8.13	12.1	20.7	10.8^c	8.76	12.9	19.8	3.81	16.3	23.7	52.4
Slovakia	2.47	7.03	10.5	20.4	0.21	15.7	22.2	38.6	74.6^a	11.1	14.9	33.6
Slovenia	0.08	13.0	19.2	39.4	4.54	27.8	34.5	54.1	27.8^b	16.6	24.4	51.2

Notes: ^a, ^b and ^c indicate rejection of the null hypothesis at the 1, 5, and 10 percent levels of significance, respectively. Bootstrap critical values are obtained from 1000 iterations.

Source: Authors' calculation with TSP.