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Do military expenditures converge in NATO countries? Linear and nonlinear unit root test evidence

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Abstract. *It is a public service that states defend their countries against internal and external threats. Military expenditures are made to this end. Although military expenditures contribute to economy, a safe environment is important for economic development. Military expenditures hold an important place within overall expenditures of countries. Although military expenditures and their share within GDP differ, they hold an important place within total public expenditures of countries. However, there aren't many studies on military expenditures in literature. We tested the convergence hypothesis of military expenditures for NATO countries covering a period from 1953 to 2014 by using linear and nonlinear unit root tests. According to the findings, the conclusion is that the military expenditures of Germany, Greece, Portugal, the UK and Luxembourg converge to the NATO mean whereas the convergence hypothesis does not hold true for other NATO countries.*

Keywords: military expenditures, convergence, NATO countries, linearity tests, linear and nonlinear unit root tests.

JEL Classification: C12, C22, H5.

1. Introduction

When we examine the last 30 years, we see that there is significant work on countries' defense services and expenditures. While there is increase in military expenditures of many relatively developed countries, there is decrease in military expenditures of small developing countries for financial reasons. Reasons such as financial structure, internal and external threats, the legitimacy of state etc. are the issues that still make military expenditures important.

In general terms, defense planning is the process of establishing a defense policy for a state and pursuing relevant objectives through the involvement of the military on the international and/or internal arena, the distribution of defense resources, and the development of domestic interinstitutional systems of cooperation. This system is very important due to its impact on the role and tasks of armed forces or, more precisely, on their insertion into overall governing principles and practices. (Maior and Matei, 2003, pp. 60-61). Countries need to attach importance to defense planning in order to ensure that there is democracy and good administration. Therefore, military expenditures, how such expenditures are to be made and the share of military expenditures within GDP are important issues.

Military expenditures are generally viewed as public investment while others view it as a socially costly enterprise that displaces investment in social welfare. When available resources are no longer sufficient to meet public program demands, the program competes for budgetary allocations. The trade-off relationship among health, education, and military expenditures and the major components of government budgets cause one program to win and the others to lose. (Lin et al., 2015, p. 33).

Table 1. *NATO countries economic and defence expenditure data*

Explanation	2011	2012	2013	2014	Average / 2010-2014
Defence Expenditure of NATO Countries (US Dollars- Current Prices)	1044470	996595	968585	942915	993254
Defence Expenditure of NATO Countries (US Dollars- 2010 Prices)	1011615	965443	919486	883606	958771
Gross Domestic Product per capita in US Dollars (Deflated by PPP)	38415	39240	40083	41256	39206.2
Gross Domestic Product per capita in US Dollars (2010 Prices and Exchange Rates)	37443	37615	37892	38427	37667
Defence Expenditure per capita in US Dollars (2010 Prices and Exchange Rates)	1116	1060	1004	960	1052.8
Armed Forces - Military (Thousands)	3497	3423	3397	3322	3442.2
Defence Expenditures as a Percentage of Gross Domestic Product (Current Prices)	3	2.8	2.7	2.5	2.8
Defence Expenditures as a Percentage of Gross Domestic Product (2010 Prices)	3	2.8	2.7	2.5	2.8
Armed Forces - Military and Civilian Personnel as a Percentage of Labour Force	1.1	1.1	1.1	1	1.08

Source: NATO Website, Public Diplomacy Division, NATO Publishes Defence Expenditures Data for 2014 and Estimates for 2015, June 2015.

Table 1 shows the data on the total economic and defence expenditures of NATO countries. When one examines the table, it can be seen that there is decrease in the military expenditures of NATO countries. Likewise, the share of defence expenditures within GDP is also in decline. The table also shows that although per capita GDP values have increased over the course of years, per capita defence expenditures have decreased. The table also shows that there is decrease in the number of military forces in recent years.

Doctrine transformation and the behavior of NATO as an international alliance known as the response of NATO members have been examined through changes in defence expenditures. The distribution of defence expenditures among NATO members varies and thus raises questions about each nation's role in the collective defense effort that is the raison d'être of a military alliance. Since its establishment in 1949, NATO has adopted three distinct defense doctrines, namely Mutually Assured Destruction (MAD), Flexible Response, and Crisis Management. These distinct defense strategies should have had an impact on the level and distribution of contributions to the common defense. (Amara, 2008, pp. 449-450).

There are only a few studies on military expenditures in literature. One of the most important reasons for this is the fact that it is difficult to have access to defense data. There are empirical studies on the relationship between military expenditures and economic growth in literature. However, there are also empirical studies using linear and nonlinear methods to examine the convergence of military expenditures of the NATO established for the purpose of military alliance and defense.

The convergence hypothesis that has been the subject of numerous studies especially since 1980s is one of the important outcomes of the neoclassic growth theory and advocates that it will rule out income differences in general and that relatively poorer countries will converge to richer countries.

The neoclassical growth model, introduced by Solow (1956), has had a profound impact on the way in which economists define and conceptualize long-run interrelationships between macroeconomies. Economic growth is attributed to the joint impact of exogenous technical change and capital deepening on an economy with concave short-run production opportunities and thus the neoclassical model makes very strong predictions concerning the behavior of economies over time. In particular, given a microeconomic specification of technologies and preferences, per capita output in an economy will converge to the same level regardless of initial capital endowments. When different economies are compared, this means that differences in per capita output for economies with identical technologies and preferences will be transitory (Bernard and Durlauf, 1996, pp. 161-162).

The concept of convergence can be classified in general as beta (β) and sigma (σ) convergence. There are also concepts such as conditional and unconditional convergence, global or regional convergence, deterministic or scholastic convergence, total factor efficiency or income convergences in literature. All of these different concepts of convergence were not apparent from the very beginning at all. Research on convergence went through several stages, and it is only with time that these different definitions emerged and gained credit. Convergence research has also seen the use of different methodologies, which may be classified broadly. These methodologies are informal cross-section approach, formal cross-section approach, panel approach, time-series approach, and distribution approach. (Islam, 2003, p. 312). Among the abovementioned methods, the linear and nonlinear time series technique is the one used most commonly.

The use of linear and nonlinear time series methods or parallel data methods recently in convergence analysis has led to differentiation between deterministic and stochastic convergence. Stochastic convergence investigates whether there is a relationship between the permanent actions taken in a country's per capita production level and the permanent actions taken in another country's per capita production level (Bernard and Durlauf, 1991). Unit root tests are often used to test stochastic convergence analysis empirically.

Lau, Demir and Bilgin (2016) analyzed the convergence of military expenditures for 37 countries in their study. According to the results of the analysis made using nonlinear panel unit root test, 53 percent of the countries converge to the global mean of military expenditures, 39 percent converge to the military expenditures of Germany, 33 percent to the military expenditures of China, 22 percent to the military expenditures of the USA and 11 percent to the military expenditures of Russia.

The basic purpose of the study is to contribute to literature by carrying out an empirical analysis on the military expenditures of NATO countries since such a study does not exist and since the purpose is to identify discrepancies. The goal of the study is to make recommendations to the countries in which there is no convergence to change their economic policies. The basic problem encountered in the unit root tests frequently used in convergence analyses is to choose the right test. In this respect, the unit root test the structure of which is suitable will be chosen in order not to obtain any deviating results. The test introduced by Harvey et al. (2008) to literature will be used to examine the linearity or nonlinearity of series. The reason why this test is preferred is because it offers the basic advantage that variables are not influenced by their level of stationarity. Once the structure of relevant series is identified, relevant unit root tests will be applied to investigate the existence of convergence.

The methodology and the data set to be used in the empirical part of the study is going to be introduced in the second part and the third part is going to concentrate on the empirical results of the military expenditure convergence. The conclusion and the policy proposals are going to constitute the last part.

2. Data and methodology

The data used in this study that investigates the convergence of military expenditures among NATO countries are the annual data covering the years 1953-2014. The data used in this study were obtained from the database of the Stockholm International Peace Research Institute (Sipri). The data to be used after the studies investigating stochastic convergence were calculated as $\bar{y}_{it} = \ln(me_{i,t} / me_{j,t})$. In this study, $\bar{y}_{it}$ indicates military expenditure between relevant country and that country's mean, $me_{i,t}$ indicates *i*. country's military expenditure and $me_{j,t}$ indicates total military expenditure.

In the 20th century, linear models have been the focus of mostly theoretical and applied econometrics. It was only starting from 1990s that nonlinear models were greatly developed, also under the stimulus of economic theory that frequently suggested nonlinear relationships between variables. Consequently emerged the interest in testing whether or not a single or a group of economic series could be generated by a linear model against the alternative that they were nonlinearly related instead.

Linear models have the advantage of being undoubtedly simple and intuitive. However, they also have several limitations, some of which can be overcome via nonlinear modeling. These limitations are as follows: linear models cannot allow for strong asymmetries in data, they are not suitable for data characterized by sudden and irregular jumps, they neglect nonlinear dependence, they are useful for prediction and they are not suitable for series which are not time reversible. In addition, a failure to recognize and deal with the presence of nonlinearity in generating a mechanism of a time series can often lead to poor parameter estimates and to models which miss important serial dependencies altogether (Bisaglia and Gerolimetto, 2014, p. 1). Therefore, linear and nonlinear structure should be investigated for the corresponding time series.

In theoretical and empirical econometric studies, investigating linearity is one of the crucial issues. McLeod-Li (1983), Keenan (1985), Tsay (1986), Brock, Dechert and Scheinkman (1987) and Harvey and Leybourne (2007) are those who developed linearity tests in the last 30 years. The classic linearity tests are based upon the assumption that the variables are $I(0)$ or $I(1)$ processes. This issue is especially problematic in empirical studies. Therefore, the recent contribution by Harvey et al. (2008) proposes a new linearity test which can be applied either to $I(0)$ or $I(1)$ processes. This study proposes a Wald test when the order of integration is unknown, which is a weighted average of the Wald tests for the null of linearity when the variable is known to have a unit root and when it is known to be stationary (Cuestas et al., 2012, p. 9).

Harvey et al. (2008), at first, is a nonlinear AR(1) model for the I(0) series y_t, $t = 1,...,T$ where T is the sample size and the following y_t time series is estimated:

$$y_t = \mu + u_t$$

$$u_t = \rho u_{t-1} + \delta f(u_{t-1}, \theta) u_{t-1} + \varepsilon_t \tag{1}$$

where ρ, δ and using function $f(.,\theta)$ are chosen such that u_t is globally stationary. In (1), ε_t is a zero mean *iid* white noise process. The function $f(.,\theta)$ is assumed to admit a Taylor series expansion around $\theta = 0$, thus model (1) is approximated to the second order by

$$u_t = \delta_1 u_{t-1} + \delta_2 u_{t-1}^2 + \delta_3 u_{t-1}^3 + \varepsilon_t \tag{2}$$

Model (2), the null hypothesis of linearity and alternative hypothesis of nonlinearity, can be represented respectively as

$H_{0,0} : \delta_2 = \delta_3 = 0$

$H_{1,0} : \delta_2 \neq 0 \;\; and\, /\, or \;\; \delta_3 \neq 0$

where $H_{1,0}$ indicates a hypothesis under the assumption of y_t being $I(0)$. Under these conditions y_t becomes

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-1}^2 + \beta_3 y_{t-1}^3 + \varepsilon_t \qquad (3)$$

In this case, the null hypothesis and alternative hypothesis are as follows:

$H_{0,0} : \beta_2 = \beta_3 = 0$

$H_{1,0} : \beta_2 \neq 0 \;\; and\, /\, or \;\; \beta_3 \neq 0$

Under these restrictions, the standard Wald statistics for testing are as follows:

$$W_0 = T\left(\frac{RSS_0^r}{RSS_0^u} - 1\right)$$

where RSS_0^u denotes the residual sum of squares from the unrestricted OLS regression in (3) and RSS_0^r is a restricted ordinary least square(OLS) regression imposing $\beta_2 = \beta_3 = 0$ in (3), then

$$y_t = \beta_0 + \beta_1 y_{t-1} + \varepsilon_t \qquad (4)$$

W_0 will follow an asymptotically χ^2 distribution under the null $H_{0,0}$.

The nonlinear AR(1) model for an $I(1)$ series admits the following first differences of y_t,

$$y_t = \mu + u_t$$

$$\Delta u_t = \phi \Delta u_{t-1} + \lambda f(\Delta u_{t-1}, \theta) \Delta u_{t-1} + \varepsilon_t \qquad (5)$$

in which ϕ, λ and the function $f(.,\theta)$ are again chosen such that Δu_t is globally stationary. The function again allows for a Taylor series expansion around $\theta = 0$, the model (5) can be approximated to the second order by

$$\Delta u_t = \lambda_1 \Delta u_{t-1} + \lambda_2 (\Delta u_{t-1})^2 + \lambda_3 (\Delta u_{t-1})^3 + \varepsilon_t \qquad (6)$$

Model (6), the null hypothesis of linearity and alternative hypothesis of nonlinearity, can be represented respectively as:

$H_{0,1} : \lambda_2 = \lambda_3 = 0$

$H_{1,1} : \lambda_2 \neq 0 \;\; and / or \;\; \lambda_3 \neq 0$

where $H_{.,1}$ indicates a hypothesis under the assumption of y_t being I(1). Under these conditions with $\Delta y_t = \Delta u_t$, y_t becomes

$$\Delta y_t = \lambda_1 \Delta y_{t-1} + \lambda_2 (\Delta y_{t-1})^2 + \lambda_3 (\Delta y_{t-1})^3 + \varepsilon_t \tag{7}$$

The corresponding Wald statistics for (7) is

$$W_1 = T\left(\frac{RSS_1^r}{RSS_1^u} - 1\right)$$

where RSS_1^u denotes the residual sum of squares from the unrestricted OLS regression in (7) and RSS_1^r is a restricted OLS regression imposing $\lambda_2 = \lambda_3 = 0$ in (7). W_1 follows an asymptotically χ^2 distribution under the null $H_{0,1}$.

Harvey et al. (2008) offers a weighted average of W_0 and W_1 statistics:

$$W_\lambda = \{1 - \lambda\} W_0 + W_1 \; . \tag{8}$$

In (8), λ is a function that converges in probability to zero when y_t is I(0) and to one when y_t is I(1). W_λ is asymptotically distributed as χ_2^2. Harvey et al. (2008) investigate the finite sample size and power behavior of this linearity test by using the Monte Carlo simulation. The Monte Carlo simulation shows clearly W_λ that the tests with finite sample properties (size and power) are the best performing and favorable tests.

The KSS test is based on the assumption that mean reversion is symmetrical. This assumption means that negative and positive deviations have got the same impact. Sollis (2009) further extended the scope of this assumption and developed a new test procedure that allows for symmetrical or asymmetrical nonlinear adjustments. In this test, the speed of mean reversion will be different depending on the sign of the shock, not only the size (Cuestas and Ramlogan-Dobson 2013). The model to be used for the test advocated by Sollis (2009) is as follows;

$$\Delta y_t = G(\gamma_1, y_{t-1})\{S_t(\gamma_2, y_{t-1})\rho_1 + \left(1 - S_t(\gamma_2, y_{t-1})\right)\rho_2\} y_{t-1} +$$
$$+ \sum_{i=1}^{k} k_i \Delta y_{t-i} + \varepsilon_i \tag{9}$$

Here $G(\gamma_1, y_{t-1}) = 1 - \exp(-\gamma_1(y_{t-1}^2))$ with $\gamma_1 \geq 0$ and $S_t(\gamma_2, y_{t-1}) = \{1 + \exp(-\gamma_2 y_{t-1})\}^{-1}$ with $\gamma_2 \geq 0$. As it is the case in the Sollis (2009) KSS test, the model is going to look as follows by using the Taylor approximations.

$$\Delta y_t = a(\rho_2^* - \rho_1^*)\gamma_1\gamma_2 y_{t-1}^4 + \rho_2^*\gamma_1 y_{t-1}^3 + \eta_i \tag{10}$$

Where ρ_1^* ve ρ_2^* are linear functions of ρ_1 and ρ_2. Where $a = 1/4$, which can be written as:

$$\Delta y_t = \phi_1 y_{t-1}^3 + \phi_2 y_{t-1}^4 + \eta_i \tag{11}$$

Where $\phi_1 = \rho_2^* \gamma_1$ and $\phi_2 = a(\rho_2^* - \rho_1^*)\gamma_1\gamma_2$. An augmented version is

$$\Delta y_t = \phi_1 y_{t-1}^3 + \phi_2 y_{t-1}^4 + \sum_{i=1}^{k} k_i \Delta y_{t-i} + \eta_i \tag{12}$$

Where y_t, similar to the KSS test, is raw, demeaned or detrended data. The null hypothesis of nonstationarity is $H_0\colon \phi_1 = \phi_2 = 0$. Sollis (2009) derives the asymptotic distribution of an F test of $H_0\colon \phi_1 = \phi_2 = 0$ showing it to be a nonstandard function of Brownian motions. The test statistic can be written as follows:

$$F = \left(R\hat{\beta} - r\right)' [\hat{\sigma}^2 R\{\textstyle\sum_t x_t x_t'\}^{-1} R']^{-1} \left(R\hat{\beta} - r\right)/m \tag{13}$$

The critical values of F statistics are tabulated by Sollis (2009). When the null hypothesis is rejected, the null hypothesis of symmetric ESTAR, $H_0\colon \phi_2 = 0$, can be tested against the alternative of asymmetric ESTAR, $H_0\colon \phi_2 \neq 0$, by means of a standard hypothesis test. For standard F critical values to be applicable for this test, $\phi_1 < 0$, so that the series is stationary under the null being tested (Sollis, 2009).

In empirical econometrics studies, researchers developed structural unit root tests with different specifications to investigate the presence of unit root. Perron (1989) firstly generated exogenous structural unit root tests. Many other different structural unit root tests have been developed in time. In literature various structural unit root tests suffer from severe spurious rejections in finite samples when a break is present under the null hypothesis(1) (Narayan and Popp, 2010:1426).

Narayan and Popp (2010) developed a new unit root test with two structural breaks. Narayan and Popp (2010) unit root test generalizes the unit root test with one break by Popp (2008). The Innovational Outlier (IO) type test allows for structural breaks under the null and alternative hypothesis and is applicable for all model specifications (Narayan and Popp, 2013: 723).

Narayan and Popp (2010) test has got two different specifications for both of the trending data. While one of them allows for two breaks in level (M1), the other allows for two breaks in level as well as slope (M2). The specifications of M1 and M2 models differ from one another in how the deterministic component, d_t, is defined,

$$d_t^{M1} = \alpha + \beta t + \Psi^*(L)(\theta_1 DU'_{1,t} + \theta_2 DU'_{2,t})$$

$$d_t^{M2} = \alpha + \beta t + \Psi^*(L)(\theta_1 DU'_{1,t} + \theta_2 DU'_{2,t} + \gamma_1 DT'_{1,t} + \gamma_2 DT'_{2,t}) \tag{14}$$

$$DU'_{i,t} = 1(t > T'_{B,i}), \qquad DT'_{i,t} = 1(t > T'_{B,i})(t - T'_{B,i}), \qquad i = 1,2.$$

where $T'_{B,i}, i = 1,2$ denote the true break dates. θ_i and γ_i indicate the magnitude of the level and slope breaks, respectively. The IO-type test equation for M1 model is as follows:

$$y_t^{M1} = \rho y_{t-1} + \alpha_1 + \beta^* t + \theta_1 D(T_B')_{1,t} + \theta_2 D(T_B')_{2,t} + \delta_1 DU_{1,t-1}' +$$
$$+ \delta_2 DU_{2,t-1}' + \sum_{j=1}^{k} \beta_j \Delta y_{t-j} + e_t \quad (15)$$

with $\alpha_1 = \Psi^*(1)^{-1}[(1-\rho)\alpha + \rho\beta] + \Psi^{*'}(1)^{-1}(1-\rho)\beta$, $\Psi^*(1)^{-1}$ being the mean lag, $\beta^* = \Psi^*(1)^{-1}(1-\rho)\beta$, $\phi = \rho - 1$, $\delta_i = -\phi\theta_i$ and $D(T_B')_{i,t} = 1(t = T_{B,i}' + 1), i = 1,2$. $DU_{1,t}' = 1(t > T_{B,i}')$, $DT_{1,t}' = 1(t > T_{B,i}')(t - T_{B,i}')$, i=1,2. The IO-type test equation for M2 model is as follows:

$$y_t^{M2} = \rho y_{t-1} + \alpha^* + \beta^* t + \kappa_1 D(T_B')_{1,t} + \kappa_2 D(T_B')_{2,t} + \delta_1^* DU_{1,t-1}' +$$
$$+ \delta_2^* DU_{2,t-1}' + \gamma_1^* DT_{1,t-1}' + \gamma_2^* DT_{2,t-1}' + \sum_{j=1}^{k} \beta_j \Delta y_{t-j} + e_t \quad (16)$$

In this equation, κ_i=$(\theta_i + \gamma_i)$, $\delta_i^* = (\gamma_i - \phi\theta_i)$ and $\gamma_i^* = -\phi\gamma_i$ i = 1, 2. In order to test the unit root null hypothesis of $\rho = 1$ against the alternative hypothesis of $\rho < 1$, the t-statistics of $\hat{\rho}$ denote $t_{\hat{\rho}}$. The break dates are selected using the sequential procedure proposed by the Narayan and Popp (2010) test and appropriate critical values as provided in the Narayan and Popp (2010) paper are used to test the hypothesis for unit root (Salisu and Mobolaji, 2013, p. 172). Narayan and Popp (2010) tabulated their test critical values for M1 and M2 models.

Narayan and Popp (2013) compares the Lumsdaine and Papell (1997), Lee and Strazicich (2003) and Narayan Popp (2010) two structural break unit roots test. Their study shows that the Narayan Popp (2010) test has good size and stable power, and identifies the structural breaks accurately in finite samples by using Monte Carlo simulations. According to the findings in their study, Narayan and Popp (2010) test is significantly superior to Lumsdaine and Papell (1997) and Lee and Strazicich (2003) two structural break unit root tests.

3. Empirical results

In the first part of this study that investigates military expenditures in NATO countries, the test developed by Harvey et al. (2008) that offers the basic advantage of not being influenced by the stationarity levels of variables was used and the results are tabulated in Table 2.

Table 2. *Linearity tests results*

Country	Harvey Stat	Country	Harvey Stat
Canada	0.15	Italy	0.78
USA	4.11	Luxembourg	3.3
Belgium	10.52*	Netherlands	4.26
Denmark	1.81	Norway	7.52**
France	3.7	Portugal	5.41***
Germany	38.7*	Turkey	5.05***
Greece	6.21**	UK	9.58*

Note: The symbols *, ** and *** mean rejection of the null hypothesis of linearity at the 1%, 5% and 10% respectively. Harvey et al. (2008) test critical values, 9.21, 5.99 and 4.60 respectively.

According to the linearity test results in Table 2, Belgium, Germany, Greece, Norway, Portugal, Turkey and the UK series display nonlinear characteristics. The unit root test advocated in the study by Sollis (2009) was used for these countries and the results are given in Table 3.

Table 3. *Nonlinear unit root tests results*

Country	k	$Ho:\phi_1=\phi_2=0$	$Ho:\phi_2=0$
Belgium	2	1.419173	0.05876
Germany	3	21.03265*	4.30529**
Greece	1	4.595211***	1.41139
Norway	2	2.811195	0.60443
Portugal	1	12.64718*	3.92743***
Turkey	1	1.254721	0.01659
UK	1	4.843415***	0.38328

Note: The symbols *, ** and *** mean rejection of the null hypothesis of unit root at the 1%, 5% and 10%, respectively.

According to the Sollis (2009) nonlinear unit root test result provided in Table 3, the results indicate stationarity for Germany, Greece, Portugal and the UK, in other words military expenditures converge to the mean. The presence of the impact of asymmetry for these countries the unit root null hypothesis for which was rejected could be tested by $Ho:\phi_2=0$. As the table indicates, the symmetrical ESTAR nonlinearity was rejected for Germany and Portugal under the null hypothesis. Therefore, there is asymmetrical ESTAR nonlinearity in these countries.

The unit root test with structural break introduced into literature by the Narayan and Popp (2013) study was used for Canada, the USA, Denmark, France, Italy, Luxembourg and the Netherlands, in other words the countries the linearity of which has been identified and the results are tabulated in Table 4.

Table 4. *Linear unit root tests results with two options*

Country	Model 1: Two Breaks in Level			
	k	t-statistic	TB1	TB2
Canada	1	-2.921	1965	1982
USA	1	-2.535	1965	1991
Denmark	4	-3.108	1965	1969
France	1	-2.111	1965	1990
Italy	4	0.2438	1990	1995
Luxembourg	0	-4.239***	1966	2000
Netherlands	0	-1.989	1965	1983

Note: The symbols *, ** and *** mean rejection of the null hypothesis of unit root at the 1%, 5% and 10%, respectively.

According to the results of the Narayan and Popp (2013) unit root test with structural break, only the military expenditures of Luxembourg converge to the mean.

4. Conclusions

The nonlinearity test developed by Harvey et al. (2008) was used in the first part of this study that investigates the convergence of the military expenditures of the NATO countries between 1953-2014. The nonlinearity of Belgium, Germany, Greece, Norway, Portugal, Turkey and the UK series were identified by using this test and the Sollis (2009) test was used to test the validity of the convergence hypothesis. According to the findings of this test, the military expenditures of Germany, Greece, Portugal and the UK converge to the NATO mean. The convergence hypothesis was tested using the Narayan and Popp (2013) test for Canada, the USA, Denmark, France, Italy, Luxembourg and the Netherlands the linearity of which were identified. These findings show that the military expenditure policies of the countries for which the convergence hypothesis does not apply should be reviewed.

Note

(1) See the Perron (1989), Zivot and Andrews (1992), Lumsdaine and Papell (1997) structural break unit root tests.

References

Amara, J., 2008. NATO Defence Expenditures: Common Goals or Diverging Interests? A Structural Analysis. *Defence and Peace Economics,* 19(6), pp. 449-469.

Bernard, A.B. and Durlauf, S.N., 1996. Interpreting Tests of the Convergence Hypothesis. *Journal of Econometrics,* 71, pp. 161-173.

Bisaglia, L. and Gerolimetto, M., 2014. Testing for (Non)Linearity in Economic Time Series: A Monte Carlo Comparison. University of Padua, *Department of Statistical Sciences Working Paper Series,* No. 3, Italy.

Brock, W., Dechert, W. and Scheinkman, J., 1987. A Test for Independence Based on the Correlation Dimension. *University of Wisconsin at Madison, Department of Economics Working Paper.*

Tsay, R.S., 1986. Nonlinearity Tests for Time Series. *Biometrika*, 73, pp. 461-466.

Cuestas, J.C. and Ramlogan-Dobson, C., 2013. Convergence of Inflationary Shocks: Evidence from the Caribbean. *The World Economy,* 36(9), pp. 1229-1243.

Cuestas, J.C., Gil-Alana, L.A. and Taylor, K., 2012. Inflation Convergence in Central and Eastern Europe with a View to Adopting the Euro. *Sheffield Economics Research Papers*, No: 2012005, Department of Economics, University of Sheffield.

Harvey, D.I. and Leybourne, S.J., 2007. Testing for Time Series Linearity. *Econometrics Journal,* 10, pp. 149-165.

Harvey, D.I., Leybourne, S.J. and Xiao, B., 2008. A Powerful Test for Linearity When the order of Integration is Unknown. *Studies Nonlinear Dynamics and Econometrics,* 12 (3) (article 2).

Islam, N., 2003. What Have We Learnt from the Convergence Debate?. *Journal of Economic Surveys,* 17(3), pp. 310-362.

Keenan, D.M., 1985. A Tukey Nonadditivity-Type Test for Time Series Nonlinearity. *Biometrika,* 72, pp. 39-44.

Lau, C.K.M., Demir, E. and Bilgin, M.H., 2016. A Nonlinear Model of Military Expenditure Convergence: Evidence from ESTAR Nonlinear Unit Root Test. *Defence and Peace Economics,* 27(3), pp. 392-403.

Lee, J. and Strazicih, M.C., 2003. Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks. *The Review of Economics and Statistics,* 85(4), pp. 1082-1089.

Lin, E.S., Ali, H.E. and Lu, Y-L., 2015. Does Military Spending Crowd Out Social Welfare Expenditure? Evidence from a Panel of OECD Countries. *Defence and Peace Economics,* 26(1), pp. 33-48.

Lumsdaine, R.L. and Papell, D.H., 1997. Multiple Trend Breaks and the Unit-Root Hypothesis. *The Review of Economics and Statistics,* 79(2), pp. 212-218.

Maior, G.C. and Matei, M., 2003. Bridging the Gap in Civil-Military Relations in Southeastern Europe: Romania's Defense-Planning Case. *Mediterranean Quarterly,* 14(2), pp. 60-76.

McLeod, A.I. and Li, W.K., 1983. Diagnostic Checking ARMA Time Series Models Using Squared-Residual Autocorrelations. *Journal of Time Series Analysis,* 4(4), pp. 269-273.

Narayan, P.K. and Popp, S., 2010. A New Unit Root Test with Two Structural Breaks in Level and Slope at Unknown Time. *Journal of Applied Statistics,* 37, pp. 1425-1438.

Narayan, P.K. and Popp, S., 2013. Size and Properties of Structural Break Unit Root Tests. *Applied Economcis,* 45, pp. 721-728.

NATO Website, 2016. Public Diplomacy Division. NATO Publishes Defence Expenditures Data for 2014 and Estimates for 2015. June 2015.

Popp, S., 2008. New Innovational Outlier Unit Root Test with a Break at an Unknown Time. *Journal of Statistical Computation and Simulation,* 78(12), pp. 1145-1161.

Salisu, A.A. and Mobolaji, H., 2013. Modelling Returns and Volatility Transmission between Oil Price US-Nigeria Exchange Rate. *Energy Economics,* 39, pp. 169-176.

Sollis, R., 2009. A Simple Unit Root Test against Asymmetrical STAR Nonlinearity with an Application to Real Exchange Rates in Nordic Countries. *Economic Modelling,* 26(1), pp. 118-125.

Solow, R.M., 1956. A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics,* 70(1), pp. 65-94.