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Linear and Non-Linear Causality between Public Spending and Income in Greece[1]

by

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I. Introduction

In the 1880s, the German economist Adolph Wagner analyzed the trends in the growth of public expenditure relatively to the size of the public sector. His observations led to what is now called "Wagner's law" or the "law of rising public expenditure" [Musgrave et al. (1989), Trotman-Dickenson (1996)], according to which the rise in public expenditure will be more than proportional to the increase in the national income and will thus result in a relative expansion of the public sector. This law has been the subject of extensive investigations, especially during the latest decades, as the development of modern industrial society is anticipated to have given rise to increasing political "pressure for social progress" and calls for increased allowance for "social consideration".

In their attempt to examine the existence of a short- and long- run relationship between government expenditure and economic development as well as to determine the causal flow running between these two variables, researchers carried on causality tests. Sahni and Singh (1984a) in their attempt to investigate the directions and patterns of causality between the government expenditures and the gross national expenditure in Canada, employed the Granger-Sims framework for the period 1926-1980 and found out that, at the aggregate level, government expenditure and national income enjoy a bi-directional causality. In another study, testing the nature and the direction of causality between public expenditure and national income in India and using the same framework for the time period 1950-81, Singh and Sahni (1984b), concluded that these two variables are related by a feedback causal mechanism. On the contrary, Chletsos and Kollias (1997) employed

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the linear Granger causality test at disaggregated data in the case of Greece over the time period 1958-93 and indicated that only the growth of defense and military expenditure may be explained in terms of Wagner's law.

Recent advances in econometrics allow the use of both linear and non-linear causality techniques to test for the directions and causal flows between government spending and income. The aim of this paper is to investigate Wagner's law hypothesis by applying the linear and the non-linear Granger causality tests in Greece over the post-war time period. All previous studies on causal relationships rely exclusively on traditional linear Granger causality tests. However, since linear causality tests can be weak in detecting non-linear causal relations (Baek and Brock, 1992), the non-linear Granger causality approach has been adopted in order to provide additional empirical evidence of Wagner's law. Granger (1989) argues that uni-variate and multi-variate non-linear models represent the proper way to model a real world that is almost certainly non-linear.

The remainder of the paper is organized as follows. Section II analyses the alternative functional forms of Wagner's law. Section III provides an overview of the empirical methodology. Section IV presents the data and the empirical findings of the relationship between government expenditure and economic development. Section V concludes and section VI gives suggestions for future research.

II. Alternative Functional Forms of Wagner's Law

The initial idea of Wagner's law, where the public sector size is assumed to be a function of economic development, has raised strong disagreements among researchers about the precise formulation of the law. In this paper, six alternative functional forms of the law are being examined:

$$(E)_t = A(GDP)_t^{\beta} \tag{I}$$

$$(C)_t = A(Y)_t^{\beta} \tag{II}$$

$$(E)_t = A\left(\frac{GDP}{N}\right)_t^{\beta} \tag{III}$$

$$\left(\frac{E}{GDP}\right)_t = A\left(\frac{GDP}{N}\right)_t^{\beta} \tag{IV}$$

$$\left(\frac{E}{N}\right)_t = A\left(\frac{GDP}{N}\right)_t^{\beta} \qquad \text{(V)}$$

$$\left(\frac{E}{GDP}\right)_t = A(GDP)_t^{\beta} \qquad \text{(VI)}$$

where E stands for government expenditure, GDP stands for gross domestic product, C stands for government consumption, Y for national income, N for the population.

The first formulation was adopted by Peacock and Wiseman (1961), who interpreted the law as follows: "public expenditures should increase by a higher rate than GDP". The second formulation was created by Pryor (1968), who stated that "in developing countries, the share of public consumption expenditure to the national income is increasing. In the same year, Goffman (1968) expressed the law in a different way: "during the development process, the GDP per capita increase should be lower than the rate of public sector activities increase". According to Musgrave (1969), in the fourth equation, "the public sector share to GDP is increasing as the GDP per capita raises, during the development process". Gupta (1967) considered per capita government expenditure as a function of per capita GDP (fifth equation). At last, Mann (1980), in his attempt to verify empirically the existence of Wagner's law, adopted the sixth formulation, according to which "public expenditure share to GDP is a function of GDP".

III. Methodology

A. The Linear Granger Causality test

A time series x_t causes another time series y_t in the Granger sense if present y can be predicted better by using past values of x than by not doing so, considering also other relevant information, including past values of y. Formally, y is caused by x, if

$$\sigma^2(y_t|y) > \sigma^2(y_t|y,x) \qquad (1)$$

where $y = \{y_{t-1}, y_{t-2}, \dots y_{t-r}\}$

$x = \{x_{t-1}, x_{t-2}, \dots x_{t-s}\}$

$\sigma^2(y_t|y)$ and $\sigma^2(y_t|y,x)$ represent the minimum predictive error variance of y_t obtained by regressing y_t respectively on y and (y, x).

In mathematical terms, x is said to cause y, provided some β_j is nonzero in the full regression equation (2):

$$y_t = \delta_0 + \sum_{i-1}^{r} \alpha_i y_{t-i} + \sum_{j-1}^{s} \beta_j x_{t-j} + \varepsilon_t \tag{2}$$

The relevance of x is indicated when comparing the error in (2) to that of the reduced equation

$$y_t = \delta_0 + \sum_{i-1}^{r} \alpha_i y_{t-i} + \varepsilon \tag{3}$$

The error terms are compared formally in the following F-statistic:

$$F = \frac{(SSE_r - SSE_f)/s}{SSE_f/(T-r-s-1)}$$

where

SSE_r, SSE_f = residual sum of squares of the reduced (3) and full (2) models respectively

T = total number of observations

r = number of lags for the *y*-variable

s = number of lags for the x-variable

F has an asymptotic F-distribution with s and T−r−s−1 degrees of freedom.

B. Non-Linear Granger Causality test

1. Baek and Brock test

Baek and Brock (1992) propose a non-parametric statistical method for detecting non-linear causal relations that cannot be uncovered by equivalent linear tests. Their approach employs the correlation integral, which provides an estimate of spatial dependence across time. Consider two stationary and weakly dependent time series $\{X_t\}$ and $\{Y_t\}$, t = 1, 2, ..., n. Let the m-length lead vector X_t be designated by X_t^m, and the Lx-length and the Ly-length lag vectors of X_t and Y_t be designated by X_{t-Lx}^{Lx} and Y_{t-Ly}^{Ly}, respectively.

For given values of m, Lx, and Ly ≥ 1 and for e > 0, Y does not strictly Granger cause X if:

$$\Pr(\|X_t^m - X_s^m\| < e \mid \|X_{t-Lx}^{Lx} - X_{s-lx}^{Lx}\| < e, \|Y_{t-Ly}^{Ly} - Y_{s-ly}^{Ly}\| < e)$$
$$= \Pr(\|X_t^m - X_s^m\| < e \mid \|X_{t-Lx}^{Lx} - X_{s-lx}^{Lx}\| < e),$$

where Pr(.) denotes probability and $\|\,.\,\|$ denotes the maximum norm (the maximum norm for $Z\ (Z_1, Z_2, \ldots, Z_K)$ is defined as the $\max(Z_i)$, $i = 1, 2, \ldots, K$).

The probability on the left hand side of the above equation is the conditional probability that the two arbitrary m-length lead vectors $\{X_t\}$ are within a distance e of each other, given that the corresponding L_x-length lag vectors of $\{X_t\}$ and L_y-length lag vectors of $\{Y_t\}$ are within e of each other. The probability on the right hand side of the equation is the conditional probability that two arbitrary m-length lead vectors of $\{X_t\}$ are within a distance e of each other, given that their corresponding L_x-length lag vectors are within a distance e of each other.

In order to test for non-linear Granger causality, we need first to remove the linear dependence. For this reason we apply a Vector Autoregression (VAR) model and use the estimate residuals to test for non-linear causality. Let $GE_{i,t}$ be the dependent variable –in our case, government expenditure– for every equation (I, II, III, IV, V and VI) and ED the independent variable –economic development– at time t for country i, where $i = 1, 2, \ldots, 15$ and $\varepsilon_{i,t}$ the innovation at time t. The VAR model can be written as follows:

$$GE_{i,t} = \sum_{i-1}^{15} \beta_{i,j}\, ED_{j,t-1} + \varepsilon_{i,t} \quad \text{for } i, j = 1, 2, \ldots, 15$$

The strict Granger non-causality condition in the VAR model can be written as:

$$\frac{CI_1(m + L_x, L_y, e)}{CI_2(L_x, L_y, e)} = \frac{CI_3(m + L_x, e)}{CI_4(L_x, e)}$$

CI_1, CI_2, CI_3 and CI_4 in the above equation are the correlation-integral estimators of the joint probabilities, which are discussed in detail by Hiemstra and Jones (1994). For given values of m, Lx and Ly ≥ 1 and for $e > 0$ under the assumptions that $\{X_t\}$ and $\{Y_t\}$ are strictly stationary, weakly dependent and satisfy the mixing conditions of Denker and Keller (1983), if $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$ then,

$$\sqrt{n}\left[\frac{CI_1(m+L_x,L_y,e,n)}{CI_2(L_x,L_y,e,n)}=\frac{CI_3(m+L_x,e,n)}{CI_4(L_x,e,n)}\right]\sim N(0,\sigma^2(m, Lx, Ly, e)$$

A significantly positive test statistic in the above equation suggests that lagged values of Y help to predict X, whereas a significant negative value suggests that knowledge of the lagged values of Y confounds the prediction of X. For this reason, Hiemstra and Jones (1994) argue that the test statistic in the above equation should be evaluated with right-tailed critical values when testing for the presence of Granger causality. In order to test for non-linear Granger causality the above test is applied to the two estimated residual series from the VAR models.

2. Modified Baek and Brock test

Baek and Brock's version of the test has been applied by Hiemstra and Jones (1994) and is based on the assumption of mutually independent and individually iid for the errors of the maintained VAR model. The modified test holds under the more general case where the errors are allowed to be weakly dependent. The fundamental difference between the two versions of the test occurs in the estimators of σ^2(m, Lx, Ly, e) in the last equation.

IV. Data and Empirical Results

A. *Data*

The present analysis has been carried out using annual data for Greece for the period 1949-1998. It is important to mention that, for the purpose of our paper, all the variables involved, have been expressed in a logarithmic form. The data is obtained from various volumes of the International Financial Statistics. Expenditure comprises all non-repayable payments by government, whether requited or unrequited and whether for current or capital purposes. Gross Domestic Product (GDP) is the sum of final expenditures: exports of goods and services, imports of goods and services, private consumption, government consumption, gross fixed capital formation and increase/decrease in stocks. Adding net factor income/payments abroad to GDP produces Gross National Income, formerly known as Gross National Product.

B. *Results of the Linear Granger Causality Test*

As an initial step of the Granger causality test, stationarity tests must be performed for each of the relevant variables. There have been a variety of proposed methods for implementing stationarity tests and each has been widely used in the applied economics literature. However, there is now a growing consensus that the stationarity test procedure due to the Dickey-Fuller (1979) has superior small sample properties compared to each alternatives. Therefore, in this study, the augmented Dickey-Fuller (ADF) test procedure was employed for implementing stationarity tests. The ADF statistic suggests that all variables are integrated of order one, I(1), whereas the first difference are integrated of order zero, I(0). In the null hypothesis, the examined variable has a unit root which means that is non-stationary. Following the above procedure, the series have been proved to be stationary in the first differences[2].

By applying the Granger causality test, the causal flow between the public sector size and economic development, expressed by different economic indicators in each form of equation, has been examined. Table 1 provides a summary view of the linear Granger causality results. The null hypothesis declares that no Granger causality exists; thus, no linear relationship between government expenditure and national income is observed in Greece from 1949 to 1998. On the other hand, the alternative hypothesis suggests that a linear Granger causality exists. A bi-directional flow of causality indicates that as the economic activity grows there is a long-run tendency for government activities to grow.

In order to be able to assign whether linear Granger causality exists or not, we need to compare the probability that the null hypothesis exists with the critical value. If the critical value is greater than the probability, the null hypothesis is not considered to be significant and we accept the alternative hypothesis. In case that the probability is greater than the critical value, the null hypothesis is considered as significant and we accept it as the true case.

In the case of Greece, there are significant signs of a linear causal relationship between government spending and national income in most equations. More specifically, a bi-directional linear Granger causality is

2. All results are available upon request by the authors.

Table 1
Granger Causality Test

Equations	Causation	Null Hypothesis	Probability	Critical value	Comments
I	E-GDP	DLE does not Granger Cause DLGDP	0.02757	0.05	Linear Granger causality exists
	GDP-E	DLGDP does not Granger Cause DLE	0.04506		Linear Granger causality exists
II	C-Y	DLC does not Granger Cause DLY	0.31369	0.05	Linear Granger causality does not exist
	Y-C	DLY does not Granger Cause DLC	0.00293		Linear Granger causality exists
III	E- (GDP/N)	DLE does not Granger Cause DLGDPN	0.02911	0.05	Linear Granger causality exists
	(GDP/N)- E	DLGDPN does not Granger Cause DLE	0.0543		Linear Granger causality does not exist
IV	(E/GDP)- (GDP/N)	DLNEGDP does not Granger Cause DLGDPN	0.02894	0.05	Linear Granger causality exists
	(GDP/N)- (E/GDP)	DLGDPN does not Granger Cause DLNEGDP	0.69584		Linear Granger causality does not exist
V	(E/N)- (GDP/N)	DLEN does not Granger Cause DLGDPN	0.06467	0.05	Linear Granger causality does not exist
	(GDP/N)- (E/N)	DLGDPN does not Granger Cause DLEN	0.40697		Linear Granger causality does not exist
VI	(E/GDP)- GDP	DLEGDP does not Granger Cause DLGDP	0.02757	0.05	Linear Granger causality exists
	GDP- (E/GDP)	DLGDP does not Granger Cause DLEGDP	0.64593		Linear Granger causality does not exist

observed in the first equation, while uni-directional flows are observed in the remaining equations, except for the fifth equation, where linear Granger causality does not exist at all. Thus, E and GDP enjoy bi-directional linear causality and this means that these two variables should be treated as jointly dependent variables. Similarly, the results show a linear relationship between Y and C (equation II), E and GDP/N (equation III), E/GDP and GDP/N (equation IV) as well as E/GDP and GDP (equation VI).

In the light of the reported empirical results, one may tentatively suggest that the growth of government expenditure in the case of Greece is dependent on and determined by economic growth as Wagner's law states. The results of our study are comparable to those of other researchers [Sahni et al. (1984a), Sahni et al. (1984b)] that applied linear causality tests in other countries, since they found signs of linear causality between government expenditure and national income at the aggregate level. However, our results cannot be compared to those accruing from studies employing disaggregated data (Chletsos and Kollias, 1997).

C. *Results of the Non-Linear Granger Causality Test*

Before the application of the non-linear Granger causality test, the cases where linear Granger causality exists and the ones where linear Granger causality does not exist should be separated and different methodology in each case should be followed. Specifically, in the equations, where linear Granger causality exists, either bi-directional or uni-directional, we make filtering with VAR and then, we apply the modified Baek and Brock (1992) test to the residual series. In the cases, where linear Granger causality does not exist, we directly apply the modified Baek and Brock (1992) test to the returns.

To implement the modified Baek and Brock (1992) test, as proposed by Hiemstra and Jones (1994), a subjective choice of values for the lead length, m, the lag lengths Lx and Ly, and the scale parameter, e, must be selected. In this study, we have set the lead length at $m = 1$ and $Lx = Ly$ and we have used common lag length of 1 to 10 lags. This study also uses common scale parameter of $e = 1.5\sigma$, where σ denotes the standard deviation of the standardized time series.

Table 2 presents the empirical results of the non-linear Granger causality test. The standardized test statistic (TVAL) results of the non-linear Granger causality are significantly different from those derived by the linear Granger causality test.

The empirical results indicate some individual cases of uni-directional non-linear causality flows. A uni-directional flow indicates that either national income effects government expenses or vice versa. Non-linear uni-directional causality between the variables appears in the cases of the 1st, 2nd and 3rd equations. The results show a non-linear relationship between E and GDP (equation I), E and GDP/N (equation III), as well as C and Y (equation II). Signs of non-linear causality are not observed in the cases of the 4th, 5th and the 6th equation, namely there is no evidence of non-linear relationship between E/GDP and GDP/N (equation IV), E/N and GDP/N (equation V) as well as E/GDP and GDP (equation VI).

The results reveal evidence of non-linear causality in Greece, where the structural relationship seems to be strong, although the number of observations is limited. Extending the time-series could strengthen this intense non-linear causal relation even more. The results also suggest that research should consider non-linear mechanisms when evaluating models of the relationships between government expenditure and national income.

Table 2

Non-Linear Granger Causality Test

Equations	I				II			
Lx=Ly	E-GDP		GDP-E		C-Y		Y-C	
	Cs	T-Val	Cs	T-Val	Cs	T-Val	Cs	T-Val
1	0.0448	1.149	0.0317	0.806	0.0324	1.419	-0.0126	-1.097
2	0.0535	1.122	0.0139	0.348	0.0228	0.733	0.0093	0.268
3	0.0494	1.024	-0.0056	-0.107	0.0339	0.917	-0.0169	-0.344
4	0.0372	0.71	-0.0227	-0.348	0.0672	1.534	-0.0288	-0.405
5	0.0936	1.42	-0.0237	-0.325	0.0524	1.105	-0.0157	-0.247
6	0.0778	0.997	-0.1297	-2.313*	0.064	0.931	0.0169	0.246
7	0.2117	2.689*	0.0032	0.034	0.1371	1.461	0.0757	0.858
8	0.1459	2.639*	0.0063	0.057	0.1881	2.012*	0.1684	1.431
9	0.1444	2.366*	0.047	0.495	0.1837	1.65	0.1281	1.205
10	0.1212	1.868	0.0682	0.651	0.2333	2.12*	0.0167	0.135

Equations	III				IV			
Lx=Ly	E-GDP/N		GDP/N-E		E/GDP-GDP/N		GDP/N-E/GDP	
	Cs	T-Val	Cs	T-Val	Cs	T-Val	Cs	T-Val
1	0.0434	1.097	0.0398	1.09	-0.01	-0.8	0.0369	1.035
2	0.0469	0.989	0.0299	0.808	-0.007	-0.35	0.0216	0.595
3	0.0415	0.848	0.0127	0.278	0.0078	0.33	0.01	0.214
4	0.0134	0.226	-0.0124	-0.24	-0.0133	-0.466	0.0206	0.405
5	0.0916	1.304	-0.0276	-0.449	0.0177	0.291	0.0098	0.14
6	0.0794	0.981	-0.1032	-1.997*	-0.0827	-1.391	-0.1029	-1.541
7	0.1691	2.101*	0.0314	0.451	0.0959	1.43	-0.0341	-0.419
8	0.1455	3.434*	0.0269	0.335	0.1058	1.339	-0.0757	-0.809
9	0.128	2.76*	0.0772	1.035	0.1128	1.153	-0.0501	-0.487
10	0.1	2.287*	0.0942	1.136	0.055	0.616	0.0255	0.333
Equations	V				VI			
Lx=Ly	E/N-GDP/N		GDP/N-E/N		E/GDP-GDP		GDP-E/GDP	
	Cs	T-Val	Cs	T-Val	Cs	T-Val	Cs	T-Val
1	0.0094	0.778	-0.0011	-0.147	-0.0075	-0.574	0.0391	0.975
2	-0.0066	-0.296	0.011	0.472	0.0011	0.048	0.0217	0.537
3	-0.043	-0.763	0.0726	1.682	0.0228	0.939	0.0056	0.112
4	0	0	0.0542	1.649	0.0129	0.552	0.0126	0.225
5	0.0712	1.089	0.1016	1.767	0.0352	0.581	-0.0146	-0.18
6	0.1266	1.291	0.1061	1.611	-0.0341	-0.615	-0.1297	-1.647
7	0.0545	0.818	0.1091	1.445	0.105	1.776	-0.0612	-0.677
8	0.0105	0.131	0.1133	1.371	0.1024	1.424	-0.1085	-1.027
9	-0.0714	-0.61	0.0915	0.915	0.0962	1.099	-0.0385	-0.33
10	-0.2273	-1.373	0.2593	1.951	0.055	0.616	0.0455	0.476

Notes: * statistically significant at 5% level

However, one should point out that, although the non-linear approach to causality testing can detect non-linear causal dependence, it provides no guidance regarding the source of non-linear dependence.

V. Conclusion

In this paper, we have tried to determine the existence of linear and non-linear causality between government expenditure and national income in Greece. Linear and non-linear causality tests are implemented in six alternative functional interpretations of Wagner's law for the time-period 1949-1998.

The results accruing from the implementation of the linear and the non-linear Granger causality tests are summarized as follows:

1) As far as the linear causality is concerned, linear relations between government expenditure and national income are observed in all –but the fifth– equations. A linear relationship between E and GDP as well as E and GDP/N means that the effects of a shock in one variable are proportional to its causes. Noteworthy is that, our results are comparable to those of other researchers that applied linear causality tests in other countries, since signs of linear causality between government expenditure and national income have been found at the aggregate level.

2) As far as the non-linear Granger causality test is concerned, we observe that:

a) There is evidence of non-linearity in equations I, II and III. Specifically, equations I and III present a mixed structure, since there is both a linear and a non-linear relation observed. Moreover, the slight differentiation in the structure of these two equations does not differentiate final results even in the non-linear causality case.

b) In the case of the 2nd equation, we observe only a non-linear relation running between C and Y.

Our results on non-linearity provide additional empirical evidence on the relationship between government spending and income in Greece, while they may prove useful theoretical and empirical research for the regulators and the policy makers. More specifically, the results indicate that a shock in government expenditures is expected to have disproportionate effects on national income. Thus, policy makers should be very careful with the shocks they intend to raise in an economy, since they do not know how a modification (increase or decrease) in a component of government expenditure is going to affect national income.

VI. Suggestions for Future Research

Future research can be pursued by disaggregating national accounts' data and by examining non-linear causality in each component of government expenditures. It is anticipated that each component of public expenditure is linked to the national income with either a linear or a non-linear relation. Since both a linear and a non-linear causality has been observed, policy makers should be cautious with the shocks they intend to raise in each component of government expenditure.

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Abstract

This paper deploys the linear and non-linear Granger causality methods in order to determine the causal relationship between national income and government expenditure in Greece over the post-war time period. For this purpose, six alternative functional forms of Wagner's law have been adopted. The empirical results indicate support for both linear and non-linear causality between income and government expenditure. The results provide additional empirical evidence on the relationship between government spending and income in Greece, while they may prove useful theoretical and empirical research for the regulators and the policy makers.