MPRA

Munich Personal RePEc Archive

The relationship between budgetary expenditure and economic growth in Poland

Henryk Gurgul and Lukasz Lach and Roland Mestel

University of Science and Technology of Cracow AGH, University of Graz, Department of Economics

1. December 2011

The relationship between budgetary expenditure and economic growth in Poland

Henryk Gurgul · Łukasz Lach · Roland Mestel

Abstract   This paper investigates the association between different kinds of budgetary expenditure and economic growth of Poland. The empirical analysis makes use of linear and nonlinear Granger causality tests to evaluate the applicability of Wagner's Law and that of the contrasting Keynesian theory. We employ aggregate and disaggregate data with the sub-categories of most important budgetary expenditure, including health care and social security, education and science, national defence and public security expenditure and government administration expenditure for the period Q1 2000 to Q3 2008. This causality analysis indicates that total relation between budgetary expenditure and economic growth is consistent with Keynesian theory. The results of our computations have important policy implications. In case of Poland the health care expenditure was found to be as important for economic growth as expenditures on education and science. Furthermore, in order to stimulate economic growth, Polish government should consider reallocating some of national defence, public security and government administration expenditure to health care, social security, education and science expenditure.

Keywords   Government expenditure · Linear and nonlinear causality · Bootstrap techniques

H. Gurgul · Ł. Lach
Department of Applications of Mathematics in Economics, Faculty of Management,
AGH University of Science and Technology, Cracow, Poland
e-mail: henryk.gurgul@gmail.com

Ł. Lach
e-mail: lukilach1983@o2.pl

R. Mestel (✉)
Institute of Banking and Finance, University of Graz, Graz, Austria
e-mail: roland.mestel@uni-graz.at

 Springer

1 Introduction

One of the main issues in modern economies is the rapid growth in government expenditure not only in highly developed economies, but also in countries with emerging economies. This tendency has accelerated in recent years, especially in the case of Central European transition countries. The rise in government expenditure e.g. in Poland was accompanied by a high growth rate in GDP apart from last year. From an economic point of view the following question arises: what comes first—economic growth or government expenditure? This question may be answered by means of causality analysis. Two contrasting points of view concerning the relations between public expenditure and economic growth are those of Wagner and Keynes. Adolf Wagner was the first economist to notice a positive relationship between economic growth and public expenditure. One of the best known explanations of Wagner's Law is based on the assumption that an increase in economic activity reflected in economic growth leads to a rise in government activity, which in turn leads to public expenditure. The implication is that government expenditure is an endogenous factor in economic growth. On the other hand, John M. Keynes expected public expenditure to be an exogenous factor which could be used as a policy instrument to stimulate economic growth. These completely different points of view are the subjects of our discussion and empirical investigations.

In this paper we examine the case of Poland, because this country is the largest in Central Europe. Moreover, in 1988 Poland as the first former Eastern Bloc country started its transition process and is the only European country whose GDP growth rate in 2008 remained positive despite the global economic crisis and only little fiscal stimulus (as in most CESEE countries). To the best of our knowledge there are no contributions concerning Wagner's Law and Keynesian theory for a transitional country from Central Europe. Such an analysis may be of interest for policy makers both in Poland (in terms of maintaining its economic development) as well as in other emerging economies.

This paper is organized as follows. The next section contains a literature overview. The main research hypotheses to be tested by means of empirical analysis are formulated in Sect. 3. Section 4 provides a description of the dataset and this sets the context for the rest of the paper. Section 5 contains a description of the methodology of linear and nonlinear causality tests, details of the bootstrap technique as well as the results of some preliminary analysis of the variables. Section 6 contains the outcomes of the causality analysis. Section 7 concludes the paper.

2 Literature overview

In principle, causation could run from public expenditure to economic growth or vice versa. In this section the most important areas of government expenditure will be laid out. These include education, national defence, health, social and income security, administration and general government. In the existing literature some studies concentrate on a specific country, while others are applied for a panel data set. The results vary from country to country. Some researchers show that government expenditure

leads to the growth of a country's economy. Other researchers think in quite the opposite way and argue that economic growth stimulates economic development. These different conclusions may well depend on the political and economic systems of the countries under study. Differences in empirical results may also depend on sample size.

Pluta (1979) tested (but not by means of causality methodology) Wagner's Law using data from Taiwan. His empirical results contradicted Wagner's Law. Demirbas (1999) examined the long-run relationship between government expenditure and GNP in the light of Wagner's Law for Turkey over the time period 1950–1990. His results provided no evidence in favour of Wagner's Law. Contributions by Sinha (1998) for Malaysian data (1952–1992) and by Jackson et al. (1998) for Northern Cyprus data (1977–1996) deliver mixed evidence for the direction of causality. Some results support Wagner's Law, while others favour Keynesian theory.

There are also causality investigations which support Wagner's Law such as those of Park (1996) for Korea, by Khan (1990) for Pakistan and the results obtained by Nagarajan and Spears (1990) for Mexico.

In Anwar et al. (1996), which is one of the most extensive research projects on the link between public expenditure and economic growth, the authors examined 88 countries using unit root and cointegration techniques (over the period 1960–1992). Unidirectional causality was found for 23 countries and bidirectional causality was reported for 8 countries. The most important conclusion from this contribution is that the majority of countries do not exhibit causality running from GDP to public expenditure or vice versa.

Some weak evidence in favour of Keynesian theory on public expenditure and economic growth for OECD countries was found by Saunders (1985). With the exception of Pluta (1979) all studies dealt with aggregate data. But there are also studies which investigate how each sub-category of public expenditure relates to GDP growth. Some of the most important of these, not necessarily conducted by means of causality analysis, will now be briefly reviewed.

We start our review with the association between education and GDP. There is a widely accepted point of view that education essentially contributes to human capital improving people's productivity and thus speeding up economic growth. Endogenous growth theory assumes that the creation of new products or ideas is a function of human capital. The latter is reflected in accumulated skills, training and general knowledge. Government expenditure on research and development also supports growth in physical capital which in turn is a direct stimulus to economic growth.

One may also hypothesize that causation might run in the opposite direction, that is from economic growth to human capital i.e. to education. Investment in capital stock may result in sufficient economic growth to provide the surplus which is necessary for further investment in the education sector. Moreover, investment in capital stock and new technologies stimulates demand for highly qualified staff (see Easterly et al. 1994; Caselli 1999). In some studies the fact that human capital and new technologies are complementary is also pointed out. In addition, some economists claim that more high education supports a tendency towards a reduction in current earnings in favour of higher future economic growth. The causality between human capital and economic growth has been the subject of contributions by De Meulemeester and Rochat (1995); In and Doucouliagos (1997) and Asteriou and Argiomirgianakis (2001). The

first one is about causality between higher education and economic growth in six countries, namely Sweden, the United Kingdom, Japan, France, Italy and Australia, over different time periods. The authors established causality from higher education to economic growth in Sweden, the United Kingdom, Japan and France and no causality between higher education and economic growth in Italy and Australia. The authors could not reject the null hypothesis of no cointegration for any of the six analyzed countries. In a more recent contribution by Narayan and Smyth (2006) the authors try to find causal relation between higher education, real income and real investment. They draw the conclusion that an increase in the rate of graduation from higher education has a positive effect on real income growth and on real investment.

The relationship between health care expenditure and gross domestic product has also been the subject of several contributions, e.g. Hitris and Posnett (1992), Hansen and King (1996), Blomqvist and Carter (1997), McCoskey and Seldon (1998), Hansen and King (1998), Roberts (1999). The results are in general inconclusive. In a more recent contribution by Devlin and Hansen (2001), the authors examined GDP from an exogenous angle. For some of the 20 OECD countries tested it appears that health care expenditure Granger causes GDP and vice versa for others.

Research concerning the effect of defence expenditure on economic growth started with Benoit (1978). A number of economists (e.g. Grobar and Porter 1989; Chen 1993; Kollias 1994; Dunne et al. 2005; Heo and Eger 2005; Lai et al. 2005; Reitschuler and Loening 2005; Kalyoncu and Yucel 2006; Narayan and Singh 2007) investigated the defence-growth relationship. The main controversy in the literature is not only "which comes first, the chicken or the egg?" but also whether defence expenditure is associated with higher or lower growth rates. While some researchers justify that the net effect of defence expenditure on economic growth is positive (Chang et al. 2001), others argue that defence expenditure is a reason for reduced savings and investment which results in reduced economic growth (see e.g. DeRouen 1995 and Landau 1996). Most economists report causality from defence expenditure to economic growth (Keynesian theory). On the other hand, Joerding (1986) and Kalyoncu and Yucel (2006) argue on the basis of their empirical results that causation runs from economic growth to defence expenditure in the case of Turkey, but that this is not the case for Greece. However, in the most recent contribution to the subject by Narayan and Singh (2007) the authors report that their findings are consistent with the Keynesian school of thought.

Liu et al. (2008) present results on the association between public expenditure and economic growth using aggregate US data as well as disaggregate data with sub-categories including national defence, human resource expenditure, physical resources expenditure, net interest payment and other expenditure. The results are mostly consistent with Keynesian theory. The policy recommendation resulting from this paper is that the US government should invest more money in human resource expenditure in order to stimulate economic growth.

Taking into account these various points of view and the results of empirical analyses, the main research hypotheses of this paper for the Polish economy will be formulated in the next section.

3 Main conjectures

The main goal of this paper is an investigation of the causal links between total public expenditure and economic growth as well as between economic growth and expenditure on sub-categories including health care and social security, education and science, national defence and public security expenditure and government administration expenditure. The causality analysis was conducted on the basis of aggregate as well as disaggregate data for Polish public expenditure. One important point that distinguishes our paper from other contributions on public expenditure and economic growth is that we employed less aggregated quarterly data. This is because the required data only covers a few recent years and thus the causality analysis based on annual data could not have been carried out due to the lack of degrees of freedom. Therefore, in order to get a sufficient data sample and in spite of quarterly fluctuations we chose quarterly data. The two main hypotheses on causality between public expenditure and economic growth are known as Wagner's Law and Keynesian theory. The theories have contrasting propositions.

From the above literature overview it seems obvious that in numerous contributions no evidence in favour of Wagner's Law was found. In some of them causality was found in the exact opposite direction. Hence, the formulation of the following hypothesis seems reasonable:

Hypothesis 1 Total public expenditure is an exogenous factor stimulating economic growth of the Polish economy, i.e. Keynesian theory applies.

Economic growth is the basis for a rise in public expenditure which in turn stimulates economic growth in subsequent time periods. This theoretical possibility, especially in the case of aggregate data, seems to be probable. Therefore some authors report the existence of feedback effects between government expenditure and economic growth, i.e. that both Wagner's Law and Keynesian theory hold true. We will also check the existence of feedback in the Polish economy.

After checking Wagner's Law and Keynesian theory for total public expenditure and economic growth we will examine the association between economic growth and sub-categories of expenditure, i.e. health care and social security, government administration expenditure, national defence and public security expenditure and outlays on education and science.

Empirical results from the literature concerning the impact of health care on economic growth are mostly inconclusive. The association between government administration expenditure and economic growth are also not exactly clear. Thus, we formulate the conjecture:

Hypothesis 2 There is no association between health care spending (government administration expenditure) and economic growth of the Polish economy.

In the literature there are conflicting results on the relation between defence spending and economic growth. Some researchers claim that defence expenditure has a positive effect on economic growth, while others take the view that defence expenditure is a reason for reduced economic growth. Several contributors claim that

economic growth is the source of the growth of defence expenditure. However, in most recent contributions Keynesian theory is approved.

Most economists are also convinced that education essentially extends human capital and hence employability, and therefore has an effect on economic growth. Thus, one may be interested in testing the joint hypothesis:

Hypothesis 3 Outlays on national defence and education, respectively Granger cause economic growth of the Polish economy.

In the next section we describe the dataset applied.

4 Dataset overview

One important issue that distinguishes this paper from previous contributions concerned with GDP-expenditure links is the fact that our analysis is not limited to only one specific relationship, but takes into account four most important budgetary areas as well as total budgetary expenditure. Hence, the dataset includes quarterly data on the real growth rates of GDP, total public expenditure, health care and social security expenditure, education and science expenditure, national defence and public security expenditure and government administration expenditure for the period Q1 2000 to Q3 2008. Therefore, our dataset contains 35 observations. All growth rates are calculated in comparison to the corresponding quarter of the previous year.[1] The application of real growth rates gives us the opportunity to examine the links between variables of interest which are not affected by movements of the inflation rate. In order to calculate real growth rates for the variables which describe budgetary expenditure we first calculated the GDP deflator for each quarter (with the help of nominal and real GDP). In the next step, we applied these quantities to filter the impact of inflation from the time series of budgetary expenditure. In order to keep the definition of the real growth rate of expenditure in line with the real GDP growth rate we used the following formula to calculate the real expenditure growth rate:

$$X_t^r := \frac{\frac{X_t}{\text{deflator}_t} - X_{t-4}}{X_{t-4}} \cdot 100\% \tag{1}$$

where X_t^r denotes the real growth rate of budgetary expenditure on sector X (or total public expenditure) in quarter t, X_t denotes the value of budgetary expenditure on sector X (or total public expenditure) in quarter t (expressed in actual prices) and deflator$_t$ denotes the value of the GDP deflator in quarter t (deflator$_t := \frac{\text{GDP}_t}{\text{GDP}_t^c}$, where GDP$_t$ stands for GDP in quarter t expressed in actual prices and GDP$_t^c$ stands for GDP in quarter t expressed in constant prices of the previous year). This definition shows that in order to construct all time series of real growth rates of budgetary expenditure for the period Q1 2000 to Q3 2008, quarterly data of budgetary expenditure for the period Q1 1999 to Q3 2008 had to be used. The quarterly data describing GDP in

---

[1] The seasonal adjustment of the data was not performed since we have used year-on-year growth rates.

Table 1 Abbreviations and short description of variables

Abbreviation	Description
GDP$_\%$	Real GDP growth rate in Poland
BUDGET$_\%$	Real growth rate of total budgetary expenditure in Poland
HEALTH$_\%$	Real growth rate of health care and social security expenditure in Poland
EDU$_\%$	Real growth rate of science and education (including higher education) expenditure in Poland
SEC$_\%$	Real growth rate of national defence and public security expenditure in Poland
ADM$_\%$	Real growth rate of government administration expenditure in Poland

Table 2 Descriptive statistics of variables

Quantity	Variable					
	GDP$_\%$ (%)	BUDGET$_\%$ (%)	HEALTH$_\%$ (%)	EDU$_\%$ (%)	SEC$_\%$ (%)	ADM$_\%$ (%)
Minimum	0.50	−4.84	−42.22	−24.22	−12.22	−15.32
1st quartile	2.40	−0.47	−5.91	−2.36	−0.32	−1.55
Median	4.40	4.36	1.62	5.80	2.88	2.98
3rd quartile	6.20	9.52	10.90	10.26	9.02	8.42
Maximum	7.50	20.63	32.42	28.91	25.11	24.42
Mean	4.25	4.98	0.06	3.32	3.76	3.19
Std. deviation	2.09	6.82	16.02	11.95	7.29	7.93
Skewness	−0.30	0.42	−0.56	−0.30	0.30	0.01
Excess kurtosis	−1.16	−0.62	0.46	−0.13	0.96	0.63

Poland in the period under study was collected from the Central Statistical Office in Poland. The time series of expenditure on four considered budgetary sections as well as total public expenditure were collected from the Ministry of Finance of Poland.[2]

A second important fact that distinguishes this paper from previous contributions on similar topics is the application of quarterly data. GDP data is published once a quarter, so the application of higher frequency data is not possible. Furthermore, most previous papers were based on the application of annual data. However, the application of such lower frequency data may not be adequate in testing for Granger causality between variables, as some important interactions may stay hidden (for more details see e.g. Granger et al. (2000)). Later in this paper we use abbreviations for all variables. Table 1 contains suitable information. Additionally, a brief description of each variable is presented.

The preliminary part of our analysis contains some descriptive statistics of all the variables. Table 2 contains the appropriate results.

There was a relatively stable development of the Polish economy in the period under study, since the real GDP growth rate was positive in each quarter. On the other hand, phases of rapid development (GDP growth at a level of 7.50%) as well as periods characterized by a relatively slow growth rate (at a level of 0.50%) are also present.

---

[2] Here the authors would like to acknowledge the help of the Ministry of Finance of Poland in acquiring the dataset.

The mean of the BUDGET$_\%$ variable was almost equal to 0.05 (i.e. 5%). It is also clear that the values of real growth rates of budgetary expenditure are much more volatile than GDP growth. The biggest drop in expenditure (in comparison with the corresponding quarter of the previous year) was reported for the health care and social security expenditure time series and reached a value of 42.22%. The HEALTH$_\%$ time series also showed the highest growth (32.42%). Furthermore, we shall note that the standard deviations of all time series are relatively large (except for the GDP growth rate). All these facts together seem to prove that in the period under study the growth rates of expenditure on budgetary areas have evolved dynamically. This phenomenon may be related to the whole gamut of transformations of the system of financing the crucial budgetary areas which has taken place in Poland in recent years.

5 Methodology and preliminary analysis

5.1 Short-run Granger causality

In this paper we use both linear and nonlinear Granger causality tests to explore short-run dynamic relationships between real growth rates of GDP, expenditure on major budgetary areas and total public expenditure in Poland. The definition of causality used in this paper is the one of Granger (1969). Let $\{X_t\}$ and $\{Y_t\}$ be two scalar-valued, stationary and ergodic time series. Furthermore, let $F(X_t|I_{t-1})$ denote the conditional probability distribution of X_t given the bivariate information set I_{t-1}. The latter consists of an L_X-lagged vector of X_t (i.e. $X_{t-L_X}^{L_X} := (X_{t-L_X}, X_{t-L_X+1}, \ldots, X_{t-1})$) and an L_Y-lagged vector of Y_t (i.e. $Y_{t-L_Y}^{L_Y} := (Y_{t-L_Y}, Y_{t-L_Y+1}, \ldots, Y_{t-1})$). After choosing values for the parameters L_X and L_Y one may say that the time series $\{Y_t\}$ does not strictly Granger cause the time series $\{X_t\}$, if:

$$F(X_t|I_{t-1}) = F\left(X_t|I_{t-1}^*\right), \quad t = 1, 2, \ldots, \tag{2}$$

where I_{t-1}^* denotes an information set including lagged values of X_t only. On the other hand, if equality (2) does not hold then knowledge of the past values of time series $\{Y_t\}$ improves the short-run prediction of current and future values of $\{X_t\}$. In this case $\{Y_t\}$ is said to strictly Granger cause $\{X_t\}$.

5.1.1 Stationarity properties of the data

The definition of causality was deliberately formulated for stationary time series. It has been shown by empirical (Granger and Newbold 1974) and theoretical (Phillips 1986) analysis that if the time series under study are nonstationary then the results of typical linear causality tests may lead to spurious conclusions. Thus, testing time series for stationarity and identifying their order of integration is the crucial stage in causality analysis and should be carried out with great precision. First, we conducted an Augmented Dickey-Fuller (ADF) unit root test. Before conducting the test we set up a maximal lag length equal to 6 and then we used AIC information criteria to choose an optimal lag length from the set $\{0, 1, \ldots, 6\}$.

Table 3 Results of ADF tests (levels)

Variable	Only constant		Constant and linear trend	
	Test statistic (p value)	Optimal lag	Test statistic (p value)	Optimal lag
GDP$_\%$	−1.54 (0.51)	4	−2.56 (0.29)	2
BUDGET$_\%$	−6.28 (0.00)	0	−6.25 (0.00)	0
HEALTH$_\%$	−1.82 (0.36)	5	−1.77 (0.71)	5
SEC$_\%$	−2.13 (0.23)	1	−2.84 (0.18)	4
EDU$_\%$	−4.89 (0.00)	3	−4.75 (0.00)	4
ADM$_\%$	−2.56 (0.10)	1	−2.74 (0.21)	1

From Table 3 one can easily notice that all time series (except for BUDGET$_\%$ and EDU$_\%$) were found to be nonstationary (at a 5% significance level), regardless of the form of the deterministic term. However, the results of the ADF test are rather sensitive to an incorrect specification of the lag parameter. Furthermore, as other papers have shown this test tends to under-reject the null hypothesis thereby pointing at nonstationarity too often. Therefore, the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test with no unit root as the null hypothesis was additionally conducted to check the results of the ADF tests.

This time (Table 4) only the GDP$_\%$ and SEC$_\%$ time series were found to be nonstationary around constant (at a 5% significance level).

The relatively different results of both tests forced us to use a third test, namely the Phillips-Perron (PP) test. This test is based on a nonparametric method of controlling for serial correlation when testing for a unit root (for more details see Phillips and Perron 1988). We should note that the null hypothesis refers to nonstationarity.

One can easily see that all time series except for GDP$_\%$ were found to be stationary at reasonable significance levels (Table 5). In order to make a final decision about the orders of integration of all the variables we re-ran all tests for their first differences. Naturally, this was performed only in those cases for which the test results for the variables at their absolute levels pointed at nonstationarity. The appropriate outcomes are presented in Table 6 (Δ denotes the differencing operator).

Taking into consideration all results presented in Tables 3, 4, 5, 6 we may state that GDP$_\%$ and SEC$_\%$ time series are indeed integrated of order one while the other variables are stationary. This final conclusion will be crucial for the subsequent research as it provides the starting point of causality analysis.

5.1.2 Toda-Yamamoto testing procedure

In this paper we use the Toda–Yamamoto (TY) approach to test for short-run linear Granger causality. This method has been commonly applied in recent studies (see e.g. Wolde-Rufael 2006) since it is relatively simple to perform and free of complicated pretesting procedures, which may affect the test results, especially when dealing with nonstationary variables. The motivation to use the Toda-Yamamoto technique is also related to the fact that this method is useful in testing for causality between variables

Table 4 Results of KPSS test of variables (levels)

Variable	With constant (test statistic*)	With constant and linear trend (test statistic**)
GDP$_\%$	0.54	0.08
BUDGET$_\%$	0.32	0.13
HEALTH$_\%$	0.10	0.10
SEC$_\%$	0.68	0.05
EDU$_\%$	0.31	0.07
ADM$_\%$	0.16	0.08

* Critical values: 0.347 (10%), 0.463 (5%), 0.739 (1%)
** Critical values: 0.119 (10%), 0.146 (5%), 0.216 (1%)

Table 5 Results of PP test of variables (levels)

Variable	Only constant (p value)	Constant and linear trend (p value)
GDP$_\%$	0.38	0.18
BUDGET$_\%$	0.00	0.00
HEALTH$_\%$	0.00	0.00
SEC$_\%$	0.00	0.00
EDU$_\%$	0.00	0.00
ADM$_\%$	0.00	0.00

Table 6 Results of testing for stationarity (first differences)

Variable	ADF with constant		ADF with constant and linear trend	
	Test statistic (p value)	Optimal lag	Test statistic (p value)	Optimal lag
ΔGDP$_\%$	−2.96 (0.03)	3	−2.76 (0.21)	3
ΔHEALTH$_\%$	−7.11 (0.00)	3	−7.01 (0.00)	3
ΔSEC$_\%$	−5.00 (0.00)	2	−4.91 (0.00)	2
Variable	KPSS with constant (test statistic)		KPSS with constant and linear trend (test statistic)	
ΔGDP$_\%$	0.14		0.11	
ΔSEC$_\%$	0.06		0.06	
Variable	PP with constant (p value)		PP with constant and linear trend (p value)	
ΔGDP$_\%$	0.00		0.01	

which are characterized by different orders of integration (which is true for most cases analyzed in this paper). In such cases a linear causality analysis cannot be carried out even through the application of a suitable Vector Error Correction (VEC) model (since the orders of integration of these variables are not equal). However, we additionally apply the VECM methodology to the variables GDP$_\%$ and SEC$_\%$, since they are both integrated of order one (and therefore they may indeed be cointegrated). This seems to be important as cointegration analysis may help to describe the possible long-run causal interactions between these two variables.

The idea behind the Toda and Yamamoto (1995) approach for causality testing is relatively uncomplicated. It is just a simple modification of the standard Wald test. This method requires the researcher to establish the highest order of integration of all the variables in the Vector AutoRegression (VAR) model (let d denote this value). To shed light on this procedure let us assume that the true DGP is an n-dimensional VAR(p) process. We shall also assume that the order of this process (p) is known, otherwise it may be established with the help of standard model selection criteria (for more details see e.g. Paulsen 1984). The Toda–Yamamoto procedure is based on fitting the augmented VAR($p + d$) model to the dataset. In the last step of the TY procedure a standard Wald test is applied to test null restrictions only for the first p lags of the augmented VAR model. There we should also underline the fact that if some modelling assumptions (e.g. the error term being white noise etc.) hold true for the augmented model then the test statistic has the usual asymptotic $\chi^2(p)$ distribution. The Reader may find an exhaustive description of this approach in Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996).

5.1.3 Bootstrap techniques

If the error term of an augmented VAR model is not white noise (e.g. heteroscedastic etc.) then the application of asymptotic theory may lead to spurious results. Furthermore, even if the modelling assumptions are generally fulfilled, the distribution of the TY test statistic may be significantly different from chi-square when dealing with extremely small samples. In order to avoid these problems we decided to additionally use a bootstrap technique. This method is used for estimating the distribution of the test statistic by resampling the data. We should underline, that the estimated distribution depends only on the available data set, therefore it may be reasonable to expect that none of the assumptions required for parametric methods has to be fulfilled for the proper application of a bootstrap technique. Moreover, the size and power properties of causality tests based on bootstrap techniques remain relatively good even in cases of nonstationarity and various error term structures (including heteroscedasticity etc.; for more details see Dolado and Lütkepohl 1996; Mantalos 2000; Hacker and Hatemi 2006). However, we cannot forget that bootstrap methods have some drawbacks too and cannot be treated as perfect tools for solving all possible model specification problems. The bootstrap approach is likely to fail in some specific cases and therefore should not be used without caution (see e.g. Horowitz 1995; Chou and Zhou 2006).

Every bootstrap simulation behind this article is based on the resampling of *leveraged residuals* (i.e. regression's raw residuals adjusted to have constant variance through the use of leverages; for more details see Hacker and Hatemi 2006). We have decided to use leverages as this is just a simple modification of the regression raw residuals which helps to stabilize their variance (more details on leverages may be found in Davison and Hinkley 1999). For every pair of variables we estimated the nonaugmented bivariate VAR model through OLS with the null hypothesis (that one variable does not Granger cause the other one) assumed. In fact this means that some elements of the coefficient matrices were restricted to zero. Next, we used leverages to transform the regression raw residuals (set of the vectors of the residuals modified

by this transformation will be denoted $\{\hat{\varepsilon}_i^m\}_{i=i_0,\ldots,T} = \left\{ \begin{bmatrix} \hat{\varepsilon}_{1,i}^m \\ \hat{\varepsilon}_{2,i}^m \end{bmatrix} \right\}_{i=i_0,\ldots,T}$, T stands for the sample size, i_0 is equal to the VAR lag length plus one). Finally, the following algorithm was conducted:

- Drawing randomly with replacement (each point has probability measure equal to $\frac{1}{T-i_0+1}$) from the elements of the set $\{\hat{\varepsilon}_i^m\}_{i=i_0,\ldots,T}$ (as a result we get the set $\{\hat{\varepsilon}_i^{**}\}_{i=i_0,\ldots,T}$);
- Subtracting the mean to guarantee the mean of bootstrap residuals to be zero (so creating a set $\{\hat{\varepsilon}_i^*\}_{i=i_0,\ldots,T}$ such that $\hat{\varepsilon}_{k,i}^* = \hat{\varepsilon}_{k,i}^{**} - \frac{\sum_{j=i_0}^{T} \hat{\varepsilon}_{k,j}^{**}}{T-i_0+1}$, $i = i_0,\ldots,T$, $k = 1, 2$);
- Generating the simulated data (Y_t^{sim}) through the use of original data (Y_t^{org}), coefficient estimates from the regression of the restricted nonaugmented VAR model $(c^{OLS}, A_1^{OLS}, \ldots, A_{i_0-1}^{OLS})$ and the bootstrap residuals $\{\hat{\varepsilon}_i^*\}_{i=i_0,\ldots,T}$, i.e. $Y_t^{sim} = c^{OLS} + \sum_{j=1}^{i_0-1} A_j^{OLS} Y_{t-j}^{org} + \hat{\varepsilon}_t^*$;
- Perform the TY procedure (for simulated data).

After repeating this procedure N times[3] it was possible to create the empirical distribution of the TY test statistic and next get empirical critical values (bootstrap critical values). The appropriate procedure written in Gretl (along with data and preliminary results of our research which are not presented in this paper) is available from the authors upon request.

5.1.4 Impulse response analysis

As a complement to standard linear Granger causality tests, we also applied an Impulse Response (IR) analysis. Standard Granger causality analysis provides an opportunity for the establishment of the direction of any linear causal link between variables, but it does not say anything about the signs of this relationship. Therefore, the linear Granger causality testing is usually supplemented with the impulse response analysis as it allows predicting the reaction of the dynamic system to the shock in one or more variables.[4] In order to examine the nature of this reaction (which is transmitted through the dynamic structure of the VAR model) we applied an impulse response function based on orthogonal residuals (established through the application of Cholesky decomposition). The reader may find the theoretical background of this method (concerning analysis of Wold instantaneous causality etc.) in Lütkepohl (1993) and Hamilton (1994).

---

[3] To evaluate on how the number of bootstrap replications (parameter N) may affect the performance of bootstrap techniques we examined several possibilities for this parameter. For the comparability of results obtained for different values of number of replications we followed a simple procedure. In each case we drew independent bootstrap samples using $N_1 = 100$, $N_2 = 400$ and $N_3 = 500$ replications. Finally, we examined bootstrap samples containing first N_1 observations, $N_1 + N_2$ observations and all $N_1 + N_2 + N_3$ observations.

[4] See e.g. Granger et al. (2000).

5.1.5 Nonlinear short-run Granger causality test

Alongside a bootstrap-based linear causality test and IR analysis, a nonlinear test for Granger causality was also used in this paper. There are two main facts justifying this decision. Firstly, standard linear Granger causality tests tend to have extremely low power in detecting certain kinds of nonlinear relationships (see e.g. Brock 1991). Secondly, since the traditional linear approach is based on testing the statistical significance of suitable parameters only in the mean equation causality in higher-order structure (for example causality in variance etc.) cannot be explored (Diks and DeGoede 2001). The application of a nonlinear approach may be a solution to this problem as it allows an exploration of the complex dynamic links between variables. On the other hand, the interpretation of nonlinear causality running from one variable to another is not as simple as in the linear case. Since testing for linear causality is based on analysis of estimation results of specific equation one may also easily "measure" the impact of the causal factor on the caused variable (e.g. using impulse response analysis etc.). The existence of nonlinear causality informs about the direction of dynamic impact but provides no details about the way of transmitting shocks.

In this article we use the nonlinear causality test proposed by Diks and Panchenko (2006). In our research we decided to use some representative values of the technical parameters of this method. Namely, we set up the bandwidth parameter at different levels, namely 0.5, 1 and 1.5 for all conducted tests. These values have been commonly used in previous papers (see e.g. Hiemstra and Jones 1994; Diks and Panchenko 2005, 2006). We also decided to use the same lags for every pair of time series being analyzed establishing them at the order of 1 and 2. More details about the meaning of these technical parameters and the form of test statistic applied may be found in Diks and Panchenko (2006).

We performed our calculations on the basis of residual time series resulting from the appropriate augmented VAR model. The structure of linear dependences had been filtered out by the application of suitable VAR models and the TY procedure, so that the residual time series reflect strict nonlinear dependencies (see e.g. Baek and Brock 1992; Chen and Lin 2004; Ciarreta and Zarraga 2007). The time series of residuals were both standardized, thus they shared a common scale parameter. Finally we must note that we used a one-sided test to reject the null whenever the calculated test statistic was significantly large. There are at least two main reasons justifying this choice. Firstly, in practice a one-sided test is often found to have greater power than a two-sided one (see e.g. Skaug and Tjøstheim 1993). Secondly, although significant negative values of test statistic also provide a basis for rejection of the null hypothesis of Granger non-causality, they additionally indicate that knowledge of past values of one time series may interfere with the prediction of another one. In contrast, causality analysis is usually conducted to judge whether this knowledge is a help (not a hindrance) in the prediction process.

Finally we should note that the former research has provided a solid basis for claiming that the considered nonlinear causality test tends to over-reject where there are heteroscedastic structures in time series (see e.g. Diks and Panchenko 2006). Thus, we also decided to test all residual time series for the presence of GARCH structures. However, we did not find any significant evidence of the presence of conditional

heteroscedasticity in the residuals of any VAR model analyzed. Therefore, we did not decide to re-run nonlinear causality tests for the filtered series of residuals. We should also note that GARCH filtering should be carried out carefully as it may sometimes lead to a loss of power of the test, which would arise from the possible misspecification of the conditional heteroscedasticity model. This of course may simply lead to misleading test results (Diks and Panchenko 2006).

5.2 Cointegration analysis and long-run Granger causality tests

Since we had found relatively strong support for claiming that both GDP$_\%$ and SEC$_\%$ time series are integrated of order one, we decided to perform also an analysis of the cointegration for this pair of variables. This was the only combination for which it was possible to perform a cointegration analysis. That is why for other pairs of variables only short-run causality was examined. The motivation for performing long-run causality analysis is based on the fact that cointegration properties may be useful in describing long-run equilibrium relationships between variables. We applied the Engle-Granger and Johansen (Trace and Maximal Eigenvalue variants) cointegration tests (for more details see Engle and Granger 1987; Johansen 1988). The results of these tests provided a solid basis for claiming that both variables are indeed cointegrated which implies (see Granger 1988) that long-run causality runs in at least one direction. Finally, to test for long-run Granger causality from variable X to variable Y we considered an appropriate equation (with Y on left side) and then tested whether the coefficient of the error correction term on the right side of the equation was statistically significant. If so then one may say that X long-run Granger causes Y. To justify this fact let us assume that error-correction coefficient (denote it as B) is indeed significantly different from zero. A change in X without a contemporaneous change in Y causes fluctuations of the error-correction component. The system returns to its equilibrium as the assumption $B \neq 0$ causes subsequent changes in Y. Changes in the X time series preceding changes in the Y time series imply Granger causality. The reader may find technical details of this approach in Cheng et al. (2006).

6 Analysis of empirical results

In this section the results of linear and nonlinear Granger causality tests as well as the impulse response analysis are presented. These findings may be helpful in describing the structure of the dynamic links between real GDP growth and crucial budgetary expenditure in Poland in the period under study. These outcomes should provide a basis for judging which of the two main concepts described in previous sections, namely Wagner's Law or Keynesian theory, seems to be the more adequate for the Polish economy. We shall start the presentation of the results of our research with outcomes arising from the analysis of linear Granger causality. Tables 7, 8, 9, 10, 12 (except for Table 11) contain p values obtained from tests for linear Granger causality through the application of a bootstrap-based Toda-Yamamoto procedure. The numbers in brackets denote corresponding p values obtained with the help of a standard (chi-square) distribution of modified Wald test statistic. The value of the N parameter

Table 7 Results of Toda-Yamamoto test for linear Granger causality between GDP$_\%$ and BUDGET$_\%$ (set of lag lengths indicated by information criteria: {1, 5}, final lag length: $p = 5$)

Null hypothesis	p value		
	$N = 100$	$N = 500$	$N = 1,000$
GDP$_\%$ does not Granger cause BUDGET$_\%$	0.58 (0.63)	0.63 (0.63)	0.68 (0.63)
BUDGET$_\%$ does not Granger cause GDP$_\%$	0.09 (0.06)	0.07 (0.06)	0.09 (0.06)

Table 8 Results of Toda-Yamamoto test for linear Granger causality between GDP$_\%$ and HEALTH$_\%$ (set of lag lengths indicated by information criteria: {1, 5}, final lag length: $p = 5$)

Null hypothesis	p value		
	$N = 100$	$N = 500$	$N = 1,000$
GDP$_\%$ does not Granger cause HEALTH$_\%$	0.77 (0.87)	0.82 (0.87)	0.85 (0.87)
HEALTH$_\%$ does not Granger cause GDP$_\%$	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Table 9 Results of Toda-Yamamoto test for linear Granger causality between GDP$_\%$ and ADM$_\%$ (set of lag lengths indicated by information criteria: {1}, final lag length: $p = 4$)

Null hypothesis	p value		
	$N = 100$	$N = 500$	$N = 1,000$
GDP$_\%$ does not Granger cause ADM$_\%$	0.42 (0.29)	0.38 (0.29)	0.45 (0.29)
ADM$_\%$ does not Granger cause GDP$_\%$	0.05 (0.06)	0.04 (0.06)	0.08 (0.06)

denotes the number of bootstrap replications used to construct the distribution of the TY test statistic. For every pair of variables we first tested several possibilities of the number of lags (parameter p) in the nonaugmented two-dimensional VAR model.[5] If all possibilities were rejected then we set up the lag parameter at the level of 4.[6] We should once again note that since the GDP time series was found to be I(1), parameter d was set at one in the case of all pairs of variables.

Table 7 contains results arising from the VAR model constructed for GDP$_\%$ and BUDGET$_\%$ time series. As we can see the test results support the hypothesis that BUDGET$_\%$ Granger causes GDP$_\%$ (at a 10% significance level). Furthermore, the test results provided no basis for claiming that linear Granger causality runs in the opposite direction. It should also be noted that both these findings were reflected in the results

---

[5] We set up a maximal possible lag length at the level of 6 and then we used several information criteria (namely, AIC, BIC, HQ and FPE) to choose the optimal lag length. If there were several possibilities indicated by information criteria for one specific model then we analyzed model residuals (in each variant) and rejected the value of the lag parameter for which a significant autocorrelation of the error vector was reported.

[6] This value was established arbitrarily and seemed to be a proper choice for quarterly data. This procedure (the arbitrary establishment of lag parameter) is an alternative method to the application of popular model selection criteria and it has been commonly used in previous papers (e.g. see Granger et al. 2000).

Table 10 Results of Toda-Yamamoto test for linear Granger causality between GDP% and SEC% (set of lag lengths indicated by information criteria: {1, 4}, final lag length: $p = 4$)

Null hypothesis	p value		
	$N = 100$	$N = 500$	$N = 1,000$
GDP% does not Granger cause SEC%	0.43 (0.67)	0.42 (0.67)	0.43 (0.67)
SEC% does not Granger cause GDP%	0.08 (0.11)	0.12 (0.11)	0.14 (0.11)

Table 11 Long-run causality analysis for GDP% and SEC% variables

Null hypothesis	t test statistic	p value
GDP% does not long-run Granger cause SEC%	−0.98	0.33
SEC% does not long-run Granger cause GDP%	2.86	0.01

Table 12 Results of Toda-Yamamoto test for linear Granger causality between GDP% and EDU% (set of lag lengths indicated by information criteria: {4}, final lag length: $p = 4$)

Null hypothesis	p value		
	$N = 100$	$N = 500$	$N = 1,000$
GDP% does not Granger cause EDU%	0.25 (0.16)	0.31 (0.16)	0.26 (0.16)
EDU% does not Granger cause GDP%	0.01 (0.00)	0.02 (0.00)	0.01 (0.00)

of the asymptotic and bootstrap-based TY procedure (regardless of the value of parameter N).

Table 8 contains results computed by the VAR model constructed for the GDP% and HEALTH% time series. After analyzing the outcomes one can easily see that the results of the Toda-Yamamoto test strongly indicate the existence of unidirectional linear Granger causality in the direction from changes in the real growth rate of budgetary expenditure on health care and social security to fluctuations in real GDP growth. This finding is in line with the fundaments of a Keynesian economy. This result was reported for both types of distribution of test statistic, namely a $\chi^2(5)$ distribution and a bootstrap-based distribution. It is worth mentioning that this phenomenon was reported for all of numbers of bootstrap replications.

Table 9 contains results gained on analysis of a VAR model constructed for GDP% and ADM% time series.

In this case neither variant of the Toda-Yamamoto procedure indicated that there is linear Granger causality running from GDP% to ADM%. On the contrary, a causal link in the opposite direction was indicated by the application of both asymptotic and bootstrap-based distributions of test statistic. It is worth mentioning that both these findings were obtained regardless of the number of bootstrap replications used.

Table 10 contains results gained on analysis of a VAR model constructed for GDP% and SEC% time series. The outcomes provided a solid basis for claiming that there is no linear Granger causality running from GDP% to SEC%. This result was reported in

both asymptotic and bootstrap-based (once again nonetheless value of parameter N) variants of the TY procedure. On the other hand, the results of linear causality analysis provided relatively convincing arguments (p values close to 0.1) for the existence of a causal link running from a real growth rate in budgetary expenditure on national defence and public security to the real GDP growth rate. All these facts are once again in line with Keynesian approach to the expenditure-GDP relationship.

As already mentioned a cointegration analysis was also performed on the $GDP_\%$ and $SEC_\%$ variables. Our analysis led to results which are presented in the Table 11.

As we can see the test results strongly support the hypothesis that for this pair of variables long-run Granger causality runs from a growth rate in budgetary expenditure on national defence and public security to the real GDP growth rate in Poland in the period under study. Causality in the opposite direction was not found. One may interpret these findings as evidence of an extremely strong unidirectional causal link, especially when we analyze them together with the outcomes presented in Table 10.

A final VAR model was constructed for the $GDP_\%$ and $EDU_\%$ variables. Table 12 contains results of the appropriate causality analysis.

While the Toda-Yamamoto procedure based on asymptotic distribution theory did provide some support, albeit weak for claiming that $GDP_\%$ Granger causes $EDU_\%$ (p value at a level of 0.16), the application of a bootstrap-based distribution provided much more convincing evidence of noncausality in this direction (p value no less than 0.25). On the other hand, both considered variants of the TY procedure strongly indicate the existence of a causal link in the direction from a growth rate in budgetary expenditure on education and science to the growth rate in GDP. As in all previous cases, the fundamentals of Keynesian economic theory emerged as a suitable explanation of the GDP-expenditure relationship. It is worth mentioning again that both these findings were obtained regardless of the number of bootstrap replications used. This robustness of bootstrap approach makes the results of this causality analysis even more convincing. It is worth underlying that for the other pairs of variables the results of asymptotic and bootstrap-based tests were also relatively in line with one another.

From the outcomes presented in Tables 7, 8, 9, 10, 11, 12 one can easily see that for the Polish economy total public expenditure as well as expenditure on particular budgetary areas were found to be causal factors in movements in the real growth rate of GDP. Keynesian economies therefore are the source of suitable rules for describing the relationship between GDP and budgetary expenditure in Poland in the period under study. However, an analysis of linear Granger causality in terms of the TY procedure may not provide complete information about the dynamic interactions between these variables. That is why an impulse response analysis was also performed. Every IR function illustrates the response of the $GDP_\%$ variable to one s.d. (standard deviation) shock in the time series of the real growth rate in budgetary expenditure for 20 quarters. Impulses hitting each VAR system from the opposite direction were not examined since causality analysis had provided no basis for claiming that there is any dynamic link from GDP to budgetary expenditure. Fig. 1 contains illustration of all shock responses.

The one s.d. (6.82%) shock from $BUDGET_\%$ causes a negative (-0.13%) response of $GDP_\%$ in the first quarter. However, positive responses were reported in quarters 2–7. The highest positive response was reported for the fifth quarter and reached a
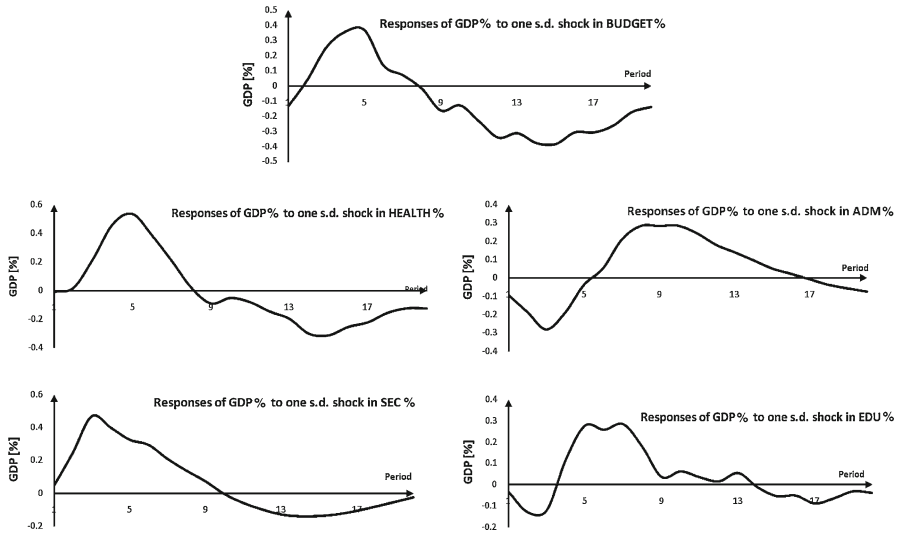
Fig. 1 Impulse responses of GDP% to a one s.d. shocks in the time series of the real growth rates of budgetary expenditure

value of 0.36%. From the eight quarter onward negative responses occur. The biggest drop in GDP% was found for quarter 14. It reached a value of −0.37%.

The one s.d. (16.02%) shock from HEALTH% causes a slight negative (−0.01%) response of GDP% in the first quarter. However, in quarters 2 to 8 positive responses were indicated. The highest positive response was reported for the fifth quarter and reached a value of 0.53%. From the ninth quarter negative responses occur. The biggest drop in GDP% was found for quarter 15. It reached a value of −0.31%.

We also visualized the responses of GDP% to the one s.d. (7.93%) shock from ADM%. The strongest negative response (−0.28%) was found for period 3. The first positive response was found for quarter 6 and the highest positive response was reported in tenth. It reached a value of 0.29%. Starting from period 17 slight negative responses occurred once again.

A positive response of GDP% to the one s.d. (7.29%) shock from SEC% was found for the first nine quarters. The highest positive response was reported for quarter 3 and reached a value of 0.46%. Starting from period 10 the negative responses were observed. The biggest drop of growth rate in GDP was in quarter 14. It reached a value of −0.14%.

Negative responses of GDP% to one s.d. (11.95%) shock from EDU% were noted for the first three quarters with a lowest value (−0.13%) occurring in the second quarter. On the other hand, in periods 4–13 positive responses were reported with the highest value (0.28%) for quarter 7. Starting from quarter 14 slight negative responses occurred once again.

As a complement to linear causality tests and impulse response analysis nonlinear Granger causality tests were also conducted. However, results of nonlinear analysis were not significant (i.e. all obtained p values were greater than 0.1) thus we did not find a reason to present them in a separate table.

7 Final remarks

The mechanism and factors determining economic growth have been the subject of numerous theoretical and empirical contributions. Most of them are concerned with highly developed economies for which datasets of sufficient size are available. In transitional countries these analyses are restricted to much shorter time periods. There are, perforce, many unanswered questions about economic growth in such countries.

In order to reduce the problem of scarcity of data we applied quarterly data. In this paper we tested the applicability of two contrasting theories—Wagner's and Keynes's to the Polish economy. The results of computations performed by means of an asymptotic and a bootstrap-based TY procedure for total budgetary expenditure and economic growth are in favour of hypothesis 1 (above), i.e. they are in line with Keynesian theory. Similar results were obtained individually for the most important sub-categories of government expenditure.

The first part of hypothesis 2 (concerning health) must be clearly rejected. All tests show evidence of causality from health expenditure to economic growth. The second part of this conjecture cannot be rejected at a 5% but it is possible at a 10% significance level. Therefore, in the light of causality methodology one can conclude that there is a relatively uncertain association between economic growth and government administration expenditure.

Generally, we also found no significant evidence, at least in the short term, for the first part of hypothesis 3 (concerning defence). The tests themselves cannot be said to reject outright the hypothesis of no causality from national defence and public security expenditure to economic growth. However, in the long-run it is likely that just a causal relationship will be found to exist, in line with Keynesian theory. Furthermore, the application of asymptotic and bootstrap-based TY tests strongly supports the second part of hypothesis 3, i.e. the existence of a causal link in the direction from a growth rate in budgetary expenditure on education and science to the growth rate of GDP. This finding is in line with the widely accepted view that technological advances drive economic growth because nowadays the most important creators of technological progress are graduates such as mathematicians, scientists and IT experts. These findings were reported at the 5% significance level.

The results by impulse response function demonstrate the sensitivity of economic growth rate to one s.d. shocks imposed on government expenditure sub-categories and total budgetary expenditure. The peak of the economic growth response is located approximately in 5th or (in one case) in 9th quarter. In further quarters one s.d. shocks imply a drop in the economic growth rate. To summarise, in the case of the Polish economy Keynesian theory is much more appropriate than Wagner's Law. National defence and public security expenditure and government administration expenditure are shown to be of some help to economic growth in our causality models.

Some policy recommendations may be made based on the findings in this paper. In order to stimulate economic growth of Polish economy, the government should consider reallocating some of national defence and public security expenditure along with government administration expenditure to health care, social security, education and science expenditure. In contrast to widespread views in the literature, it follows

from our computations for Poland that health care expenditure is as important for economic growth as expenditures on education and science.

In addition, since the results of nonlinear tests for causality are not significant there is a strong argument, that a rise in growth rate of health care or education and science expenditure can be linearly transmitted to the economic growth rate. If this is so, it should give clear guidance to Polish policy makers and should receive considerable attention.

References

Anwar MS, Davies S, Sampath RK (1996) Causality between government expenditures and economic growth: an examination using cointegration techniques. Public Finance 51:166–184

Asteriou D, Argiomirgianakis GM (2001) Human capital and economic growth: time series evidence from Greece. J Policy Model 23:481–489

Baek E, Brock W (1992) A general test for Granger causality: bivariate model, Technical Report. Iowa State University and University of Wisconsin, Madison

Benoit E (1978) Growth and defence in developing countries. Econ Develop Cult Change 26:261–280

Blomqvist AG, Carter RAL (1997) Is health care really a luxury?. J Health Econom 16:2007–2029

Brock W (1991) Causality, chaos, explanation and prediction in economics and finance. In: Casti J, Karlqvist A (eds) Beyond belief: randomness, prediction and explanation in science. CRC Press, Boca Raton

Caselli F (1999) Technological revolutions. Am Econ Rev 89:78–102

Chang T, Fang W, Wen LF, Liu C (2001) Defense expenditure, economic growth and temporal causality: evidence from Taiwan and mainland China, 1952-1995. Appl Econ 33:1289–1299

Chen AS, Lin JW (2004) Cointegration and detectable linear and nonlinear causality: analysis using the London Metal Exchange lead contract. Appl Econ 36:1157–1167

Chen CH (1993) Causality between defence spending and economic growth: the case of mainland China. J Econ Stud 26:37–43

Cheng JC, Taylor LW, Weng W (2006) Exchange rates and prices: revisiting Granger causality tests. J Post Keynesian Econ 29:259–283

Chou PH, Zhou G (2006) Using bootstrap to test portfolio efficiency. Ann Econ Finance 2:217–249

Ciarreta A, Zarraga A (2007) Electricity consumption and economic growth: evidence from Spain. Working Paper. Dept. of Applied Economics III (Econometrics and Statistics), University of the Basque Country

Davison AC, Hinkley DV (1999) Bootstrap methods and their application. Cambridge University Press, Cambridge

De Meulemeester J-L, Rochat D (1995) A causality analysis of the link between higher education and development. Econ Educ Rev 14:351–361

Demirbas S (1999) Cointegration analysis-causality testing and Wagner's Law: The Case of Turkey, 1950–1990. http://www.econturk.org/safaaabi.pdf

DeRouen KR (1995) Arab-Israeli defence spending and economic growth. Conflict Manage Peace Sci 14:25–47

Devlin N, Hansen P (2001) Health care spending and economic output: Granger causality. Appl Econ Lett 8:561–564

Diks CGH, DeGoede J (2001) A general nonparametric bootstrap test for Granger causality. In: Broer HW, Krauskopf W, Vegter G (eds) Global analysis of dynamical systems. Institute of Physics Publishing, Bristol

Diks CGH, Panchenko V (2005) A note on the Hiemstra-Jones test for Granger non-causality. Stud Nonlinear Dyn Econometr 9(2, Article 4)

Diks CGH, Panchenko V (2006) A new statistic and practical guidelines for nonparametric Granger causality testing. J Econ Dyn Control 30:1647–1669

Dolado JJ, Lütkepohl H (1996) Making Wald tests work for cointegrated VAR systems. Econometr Rev 15:369–386

Dunne JP, Smith RP, Willenbockel D (2005) Models of military expenditure and growth: a critical review. Defence Peace Econ 16:449–461

Easterly W, King R, Levine R, Rebelo S (1994) Policy, technology adoption and growth. In: Pasinetti L, Solow R (eds) Economic growth and the structure of long-term development. St Martins Press, New York

Engle RF, Granger CWJ (1987) Cointegration and error-correction: representation, estimation, and testing. Econometrica 55:251–276

Granger CWJ (1969) Investigating causal relations by econometric models and cross–spectral methods. Econometrica 37:424–438

Granger CWJ (1988) Some recent developments in the concept of causality. J Econometr 39:199–211

Granger CWJ, Newbold P (1974) Spurious regression in econometrics. J Econometr 2:111–120

Granger CWJ, Huang B, Yang C (2000) A bivariate causality between stock prices and exchange rates: evidence from recent Asian Flu. Q Rev Econ Finance 40:337–354

Grobar L, Porter R (1989) Benoit revisited: defence spending and economic growth in less developed countries. J Conflict Resolut 33:318–345

Hacker RS, Hatemi JA (2006) Tests for causality between integrated variables using asymptotic and bootstrap distributions: theory and application. Appl Econ 38:1489–1500

Hamilton JD (1994) Time series analysis. Princeton University Press, Princeton

Hansen P, King A (1996) The determinants of health care expenditure: a cointegration approach. J Health Econ 15:127–137

Hansen P, King A (1998) Health care expenditure and GDP: panel data unit root test results-comment. J Health Econ 17:377–381

Heo U, Eger RJ (2005) The security-prosperity dilemma in the United States. J Conflict Resolut 49:699–708

Hiemstra C, Jones JD (1994) Testing for linear and nonlinear Granger causality in the stock price-volume relation. J Finance 49:1639–1664

Hitris T, Posnett J (1992) The determinants and effects of health expenditure in developed countries. J Health Econ 11:173–181

Horowitz JL (1995) Advances in economics and econometrics: theory and applications, chapter 7: bootstrap methods in econometrics: theory and numerical performance. Cambridge University Press, Cambridge

In F, Doucouliagos C (1997) Human capital formation and US economic growth: a causality analysis. Appl Econ Lett 4:329–331

Jackson PM, Meryem DF, Sami F (1998) Cointegration, causality, and Wagner's Law: a test for Northern Cyprus. http://www.le.ac.uk/economics/research/RePEc/lec/lpserc99-2.pdf

Joerding W (1986) Economic growth and defense spending: Granger causality. J Dev Econ 21:35–40

Johansen S (1988) Statistical analysis of cointegrating vectors. J Econ Dyn Control 12:231–254

Kalyoncu H, Yucel F (2006) An analytical approach on defense and expenditure and economic growth. The case of Turkey and Greece. J Econ Stud 33:336–343

Khan AH (1990) Wagner's Law and the developing economy: a time series evidence from Pakistan. Indian Econ J 38:115–123

Kollias C (1994) The economic effects of defense spending in Greece 1963-90: some preliminary econometric findings. Spoudai 44:114–130

Lai C-N, Huang B-N, Yang C-W (2005) Defense spending and economic growth the Taiwan straits: a threshold regression model. Defence Peace Econ 16:45–57

Landau D (1996) Is one of the "peace dividends" negative? Military expenditure and economic growth in the wealthy OECD countries. Q Rev Econ Finance 36:183–195

Liu LC, Hsu CE, Younis MZ (2008) The association between government expenditure and economic growth: Granger causality test of US data, 1947-2002. J Public Budget Financ Manage 20:537–553

Lütkepohl H (1993) Introduction to multiple time series analysis, 2nd edn. Springer, New York

Mantalos P (2000) A graphical investigation of the size and power of the Granger-Causality tests in integrated-cointegrated VAR systems. Stud Nonlinear Dyn Econometr 4 (1, Article no. 2)

McCoskey SK, Seldon TM (1998) Health care expenditures and GDP: panel data unit root test results. J Polit Econ 70:129–157

Nagarajan P, Spears A (1990) An econometric test of Wagner's Law for Mexico: a re-examination. Public Finance 45:165–168

Narayan PK, Singh B (2007) Modelling the relationship between defense spending and economic growth for the Fiji islands. Defence Peace Econ 18:391–401

Narayan PK, Smyth R (2006) Higher education, real income and real investment in China: evidence from Granger causality. Educ Econ 14:107–125

Park WK (1996) Wagner's Law vs. Keynesian Paradigm: The Korean experience. Public Finance 51:71–91

Paulsen J (1984) Order determination of multivariate autoregressive time series with unit roots. J Time Ser Anal 5:115–127

Phillips PCB (1986) Understanding the spurious regression in econometrics. J Econometr 33:311–340

Phillips PCB, Perron P (1988) Testing for a unit root in time series regressions. Biometrika 75:335–346

Pluta JE (1979) Wagner's Law, public sector patterns, and growth of public enterprises in Taiwan. Public Finance Q 7:25–46

Reitschuler G, Loening JL (2005) Modeling the defense-growth nexus. World Dev 33:513–526

Roberts J (1999) Sensitivity of elasticity estimates for OECD health care spending analysis of a dynamic heterogenous data field. Health Econ 8:459–472

Saunders P (1985) Public expenditure and economic performance in OECD countries. J Public Policy 5:1–21

Sinha D (1998) Government expenditure and economic growth in Malaysia. J Econ Dev 23:265–283

Skaug HJ, Tjøstheim D (1993) Nonparametric tests of serial independence. In: Subba Rao T (ed) Developments in time series analysis. Chapman and Hall, London

Toda HY, Yamamoto T (1995) Statistical inference in vector autoregressions with possibly integrated processes. J Econometr 66:225–250

Wolde-Rufael Y (2006) Electricity consumption and economic growth: a time series experience for 17 African countries. Energy Policy 34:1106–1114