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CAUSALITY ANALYSIS BETWEEN PUBLIC EXPENDITURE AND ECONOMIC GROWTH OF POLISH ECONOMY IN LAST DECADE

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Abstract

This paper investigates the causal links between different kinds of budgetary expenditure and the economic growth of Poland. The empirical analysis was based on both the linear and nonlinear Granger causality tests and the aim was to evaluate the applicability of Wagner's Law and contrasting theory formulated by Keynes. We based our research on aggregate and disaggregate quarterly data with the sub–division of public expenditure on human resources (HR), physical resources (PR), net interest payment (NIP) and other remaining budgetary expenditure (OTHER) for the period Q1 2000 to Q3 2008. Linear causality analysis showed that relation between total budgetary expenditure and economic growth is consistent with Keynesian theory. However, for the examined sub–categories of expenditure mixed results were reported supporting Keynesian theory (NIP), Wagner's Law (OTHER) or none of them (HR and PR). Results of nonlinear causality analysis performed for unfiltered data also provided some support for Keynesian theory (HR and OTHER). However, after GARCH(1,1)–filtration of data nonlinear causality was not reported in any case.

***Key words*: government expenditure, linear and nonlinear causality, bootstrap techniques.**

JEL Classification: G15, C32.

1. INTRODUCTION

In recent years one could observe rapid increase of government expenditure in both highly developed and emerging economies. This tendency was also reported in the case of transition countries e.g. Poland. Apart from last year, in Poland it was possible to observe a rise in government expenditure along with a high growth in GDP rate. It may be of interest for economists to answer the following question: which of the two variables – economic growth and government expenditure – is a causal factor for other one? The proper way to answer this question is the application of suitable causality analysis. In economics there are two main theories related to the interactions between public expenditure and economic growth. These contrasting propositions are known as Wagner's Law and Keynes's theory. Undoubtedly, the great achievement of Adolf Wagner was the establishment of a positive relationship between economic growth and public expenditure. An increase in economic activity reflected in economic growth leads to a rise in government activity, which in turn leads to public expenditure. This regularity is one of the best known explanations of Wagner's Law and leads to the further insight that government expenditure is an endogenous factor in economic growth. On the contrary, Keynes, claimed that public expenditure was an exogenous factor which could be used to influence economic growth. Further discussion and empirical investigations contained in this paper are dedicated to examining the applicability of these contrasting theories in the case of Polish economy.

This paper is organized as follows. In the next section we present the literature overview. Section 3 contains the formulation of the main research hypotheses to be tested by means of empirical analysis. Section 4 provides dataset description, which sets the context for the rest of the paper. In section 5 description of methodology of linear and nonlinear causality tests, details of the bootstrap technique as well as the results of some preliminary variable analysis are presented. Section 6 contains the outcomes of the causality analysis. The last section contains some final remarks.

2. LITERATURE OVERVIEW

The issue of examining causal links between public expenditure and economic growth has been a subject of number of papers in recent years. These studies dealt with both individual countries as well as groups of countries (applying panel datasets). The results vary significantly as for some countries the government expenditure was found to lead the economic growth, while for the others the opposite causal link was established. Naturally, for some countries there are papers reporting the existence of bidirectional causality or lack of causal link in any direction. The variety of conclusions depends surely on differences of the political and economic systems of the countries under study. At this place the sensitiveness of test results to sample size should also be mentioned. In this section various results of examination of GDP–expenditure links will be laid out. Alongside the total budgetary expenditure we shall also focus on its main sub–categories. Division of total public expenditure may be carried out in many ways. Researchers usually divide total expenditure on its main components, namely human resources expenditure, physical resources expenditure, net interest payment expenditure and other expenditure. However, there are also many studies which focus on the link between economic growth and one specific expenditure area e.g. education, national defence etc.

The examination of Wagner's Law for the economy of Taiwan was a subject of Pluta's (1979) contribution. This research provided no evidence in favour of this theory. 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. Similarly to the previously mentioned paper in this case the suitable analysis also contradicted Wagner's Law. Mixed results for the direction of causality between GDP and public expenditure were delivered by contributions by Sinha (1998) for Malaysian data (1952–1992) and by Jackson et al. (1998) for Northern Cyprus data (1977–1996). Some results support Wagner's Law, while others favour Keynesian theory. On the other hand, contributions by Park (1996) for Korean data, by Khan (1990) for Pakistani data and the results obtained by Nagarajan and Spears (1990) for Mexican data provided convincing basis for the acceptance of Wagner's Law for the examined economies.

One of the most extensive research projects about the linkage between public expenditure and economic growth was conducted by Anwar et al. (1996). The authors examined 88 countries using unit root and cointegration techniques (over the period 1960–1992) finding unidirectional causality in 23 cases and bidirectional causality in 8 cases. The main conclusion arising from this contribution is the fact that for the majority of analyzed countries the causality between GDP and public expenditure does not run in any direction.

Saunders (1985) performed an analysis of links between economic growth and public expenditure for OECD countries for the period 1960–1981. In general the results of this research provided evidence in favour of Keynesian theory, however some weak evidence of causality running in opposite direction was also reported.

Every paper discussed so far (except for Pluta's (1979) contribution) dealt with aggregate data. However, there are also studies which investigate the relationship between the growth of GDP and specific sub–categories of public expenditure. In further part of this section some of the most important papers on this subject, not necessarily conducted by means of causality analysis, will be briefly reviewed.

Our review will start with the relationships between GDP and human resources. At this point we cannot neglect the fact that the main factor which is believed to have an impact on human capital is the level of education. Many economists claim that education increases the quality of human resources because it improves people's productivity and therefore speeds up economic growth. According to the endogenous growth theory the creation of new products or ideas is a function of human capital. The latter is reflected in accumulated skills, training and general knowledge. One of the most popular explanations of the influence of human capital on economic growth is as follows. The rise in government expenditure on research and development causes growth in physical capital which in turn is a direct stimulus to economic growth.

The notion that causation may run in the opposite direction, that is from economic growth to human resources (i.e. to education), is also relatively common. Investment in capital stock may result in sufficient economic growth providing the surplus which is necessary for further investment in the education sector. Many economists (e.g. Easterly et al. 1994, Caselli 1999) claim that demand for highly qualified staff is stimulated by investment in capital stock and new technologies. Moreover, some studies support the thesis that human resources and new technologies are complementary. In some papers it is pointed out that higher education supports the tendency towards the reduction in the current earnings in favour of higher future economic growth. The analysis of causal links between human resources and economic growth has been the subject of numerous contributions. De Meulemeester and Rochat (1995) performed an analysis of causality between higher education and economic growth in six countries. This research included Sweden, the United Kingdom, Japan, France, Italy and Australia and was conducted over different time periods. The causality running from higher education to economic growth was established in the case of Sweden, the United Kingdom, Japan and France while for Italy and Australia no causality was reported. For all analyzed countries the null hypothesis of no cointegration could not be rejected.

The relationship under study was also examined by In and Doucouliagos (1997), Asteriou and Agiomirgianakis (2001) and by Narayan and Smyth (2006). The last paper concerns causal relations between higher education, real income and real investment. The final conclusion following from this paper is that an increase in the rate of graduation from higher education has a positive effect on real income growth and on real investment.

It is a well known fact that one of most important factors which have significant influence on human capital is the shape of heath care system. Recently, the relationship between gross domestic product and health care expenditure has also been the subject of number of contributions, e.g. Culyer (1990), Hitris and Posnett (1992), Hansen and King (1996, 1998), Blomqvist and Carter (1997), McCoskey and Seldon (1998) Roberts (1999. The main problem arising from the mentioned literature is the inconclusiveness of empirical results. Devlin and Hansen (2001) examined GDP–health care relationship for 20 OECD countries. It was reported in the literature that health care expenditure appeared to cause GDP in some cases. However, for some countries evidence of causality running in the opposite direction was also reported.

The relationship between GDP and other sub–division expenditure has also been intensively examined in recent years. The paper by Benoit (1978) is believed to be the leading contribution concerning the effect of defence expenditure on economic growth. After some time, this relationship received a considerable attention and further research was performed by many economists (e.g. Smith 1980, Frederiksen and Looney 1982, Deger and Sen 1983, Lim 1983, Biswas and Ram 1986, 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). Each empirical study provided some basis for describing causal relationships between analyzed variables and was a trysail for answering a question whether defence expenditure is associated with higher or lower GDP growth rates. Some researchers claim that the net effect of defence expenditure on economic growth is positive (Chang et al. 2001) while others treat defence expenditure as a reason for reduced savings and investment which lead to reduced economic growth (see e.g. DeRouen 1995 and Landau 1996). Generally, in most of the papers the Keynesian theory is believed to be a proper pattern for description of this relationship. However, there are also studies (e.g. Joerding 1986, Kalyoncu and Yucel 2006) which provide evidence that causation runs from economic growth to defence expenditure (this was found for Turkey, but not for Greece). In the more recent contribution to the subject by Narayan and Singh (2007) the authors report that their findings are consistent with the Keynesian school of thought.

The association between economic growth and public expenditure in the United States of America was examined by Liu et al. (2008). In general, the results of this research (conducted for aggregated and disaggregated data) are in line with Keynesian theory. The authors also formulate some policy recommendation claiming that the US government should invest more money in human resources in order to stimulate GDP growth.

The literature overview presented above refers only to some part of research on GDP–public expenditure links. One can easily see that this literature presents various points of view. Taking them into account in the next section of this paper we will formulate our main research hypotheses which are to be tested by means of causality analysis.

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 selected sub–categories of public expenditure, namely human resources, physical resources, net interest payment and remaining expenditure. One important point that distinguishes our paper from other contributions on public expenditure and economic growth is that we did not use annual data but quarterly data. This is because the data covers only a few recent years due to the lack of previous years' data. Therefore, in order to get a sufficiently large data sample we chose quarterly data in spite of their high fluctuation. 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. Thus, it is of interest to test the following:

> *Hypothesis* 1: Total public expenditure in Poland is an endogenous factor in economic growth, i.e. Wagner's Law holds true for Poland.

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 to be justified:

> *Hypothesis* 2: Total public expenditure is an exogenous factor influencing the 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 more likely. Some authors report the existence of feedback between government expenditure and economic growth, i.e. that both Wagner's Law and Keynesian theory hold true. Therefore, 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 the main sub–categories of public expenditure, i.e. human resources, physical resources, net interest payment and remaining expenditure. Since most of the previous studies provided relatively convincing support for claiming that for GDP and expenditure on human resources (or expenditure on main components of human resources) Keynesian theory holds true, we shall test the following:

> *Hypothesis* 3: Spending on human resources Granger cause economic growth.

In the literature there are many quite conflicting results on the relation between expenditure on physical resources and economic growth. Some contributors claim that expenditure on physical resources has a positive effect on economic growth, while others claim that this effect is negative. Yet other contributors claim that economic growth is the source of expenditure growth on physical resources. The similar discussion is also ongoing in the case of the relationship between GDP and net interest payment. However, in some recent contributions the GDP–PR expenditure and GDP–NIP expenditure relationships are generally said to be in line with both the Keynesian theory and Wagner's Law. Therefore we formulate the next hypothesis for Poland:

> *Hypothesis* 4: Expenditure on physical resources (net interest payment) Granger causes economic growth. Causality runs in opposite direction too.

Recent papers provided relatively convincing support for claiming that expenditure on remaining budgetary areas (aggregated in variable denoted as OTHER) are caused by movements of GDP growth rate in advanced economies. It may be interesting to check this regularity in case of analyzed emerging economy. Thus, we shall consider testing the following hypothesis for Poland:

> *Hypothesis* 5: Economic growth Granger causes OTHER expenditure.

In order to check the size of the reaction of GDP growth rate on one s.d. shock we employed the Impulse Response Function technique. We formulate the next conjecture as follows:

> *Hypothesis* 6: GDP growth is sensitive to one s.d. shocks for the categories of expenditure under study.

Since most of previous studies dealt with standard linear Granger causality tests it may be interesting to check whether the nature of causal link between GDP and budgetary expenditure is indeed linear. This may have an important practical meaning for Polish policymakers in terms of transporting fluctuations of expenditure to economic growth or vice versa. Therefore, we formulate the last conjecture as follows:

> *Hypothesis* 7: All existing causal links between GDP and budgetary expenditure are strictly linear.

In the next section we describe the dataset applied.

4. DATASET OVERVIEW

In this section we present a brief description of the dataset used in further computations. At the moment we shall underline some important facts. Firstly, contrary to the most of previous contributions concerned with GDP–expenditure links our analysis is not limited only to one specific relationship. Beside total budgetary expenditure we examined four budgetary sections. Hence, the defined dataset includes quarterly data of real growth rates of GDP, total public expenditure as well as budgetary expenditure on four subcategories, namely human resources, physical resources, net interest payment and other remaining expenditure for the period Q1 2000 to Q3 2008. The dataset contains 35 observations. All growth rates are calculated in comparison to corresponding quarter of previous year. Secondly, the application of real growth rates gives us the opportunity to examine the links between the variables of interest which are not affected by movements of the inflation rate. We followed a simple procedure to calculate real growth rates for variables describing budgetary expenditure. We first calculated the GDP deflators for all quarters (with the help of nominal and real GDP) and then we applied these quantities to filter out the impact of inflation on time series of budgetary expenditure. The following formula was used to calculate real growth rate of budgetary expenditure (it is in line with the method of calculating the real GDP growth rate):

$$BE_t^r(x) := \frac{\dfrac{BE_t(x)}{deflator_t} - BE_{t-4}(x)}{BE_{t-4}(x)} \cdot 100\% \qquad (1)$$

where $BE_t^r(x)$ denotes the real growth rate of budgetary expenditure on x (i.e. one of five possibilities) in quarter t, $BE_t(x)$ denotes the value of budgetary expenditure on x in quarter t (expressed in current prices) and $deflator_t$ denotes the value of GDP deflator in quarter t ($deflator_t := GDP_t \cdot (GDP_t^c)^{-1}$, where GDP_t stands for GDP in quarter t expressed in current prices and GDP_t^c stands for GDP in quarter t expressed in constant prices of the previous year). It is easy to see that in order to construct all time series of real growth rates of budgetary expenditure for the period Q1 2000 to Q3 2008 the quarterly data of budgetary expenditure for the period Q1 1999 to Q3 2008 had to be used. The quarterly data describing GDP in Poland in the period under study was obtained from the Central Statistical Office in Poland, while time series of the budgetary expenditure (total and sub–categories) were collected from the Ministry of Finance of Poland.

Another important fact that distinguishes this paper from previous contributions concerned with similar topic is the application of quarterly data. Most of previous papers were based on applications of annual data. However the application of lower frequency data may not be adequate for testing for short–run Granger causality between chosen variables, as some important interactions may stay hidden (for more details see e.g.

Granger 2000). The data on GDP is published once a quarter, therefore the application of higher frequency data is not possible. In further parts of this paper we use abbreviations for all examined variables. Table 1 contains suitable information. Additionally, some short description of each variable is also presented:

Table 1. Abbreviations and short description of examined variables

Shortcut name	Description
GDP	Real GDP growth rate in Poland
BUDGET	Real growth rate of total budgetary expenditure in Poland
HR	Real growth rate of human resources expenditure in Poland (including education, health care, social security, sport, culture etc.)
PR	Real growth rate of physical resources expenditures in Poland (including manufacture, mining, construction of buildings, forestry, wholesale and retail trade, transport and communications, production and supply of energy, services, information technology etc.)
NIP	Real growth rate of net interest payment expenditure in Poland (including public debt service, subsidies for specific economic tasks, financial inflows from institutions and from individuals and connected spending etc.)
OTHER	Real growth rate of other expenditure in Poland (including science, public administration, public safety, national defence, justice administration, agriculture and fishing etc.)

In order to provide basic information about our dataset we present some descriptive statistics of all examined variables. For each time series some typical quantities were calculated. The following table contains suitable results:

Table 2. Descriptive statistic of examined variables

Quantity \ Variable	GDP [%]	BUDGET [%]	HR [%]	PR [%]	NIP [%]	OTHER [%]
Minimum	0.50	–4.84	–18.65	–44.87	–13.54	–7.37
1st quartile	2.40	–0.47	–3.73	–11.65	–3.07	1.27
Median	4.40	4.36	2.78	4.66	5.16	5.04
3rd quartile	6.20	9.52	11.90	38.76	8.56	9.11
Maximum	7.50	20.63	32.44	219.32	18.34	37.32
Mean	4.25	4.98	4.70	19.97	3.66	6.43
Std. Deviation	2.09	6.82	11.75	51.33	6.79	9.90
Skewness	–0.30	0.42	0.26	2.14	–0.31	1.32
Excess kurtosis	–1.16	–0.62	–0.41	5.29	–0.02	1.94

We can remark some interesting information directly from this table. Firstly, we can see that in the period under study relatively stable development could be observed in Polish economy, since the real GDP growth rate was positive in each quarter. Moreover, periods of rapid development (GDP growth at the level of 7.50%) as well as stages characterized by relatively slow growth rate (at the level of 0.50%) were also perceived. In each quarter the total public expenditure was on average almost 5% greater than in the corresponding quarter of previous year. Also one can easily note that the values of real growth rates of budgetary expenditure are much more varied than GDP growth. The biggest drop in expenditure (in comparison to corresponding quarter of previous year) was reported for physical resources expenditure time series and reached the value of

44.87%. The highest growth was also reported for PR series (219.32%, this huge value was reported for first quarter of 2001 when expenditure on sub–category under study reached value of over 3 million PLN in comparison to just one million PLN in corresponding quarter of previous year). Furthermore, we shall note that the standard deviations of all time series are relatively large (except for GDP growth rate). All these facts together seem to prove that in the period under study the growth rates of expenditure on the chosen budgetary sections have evolved dynamically. This phenomenon could be interpreted as the effect of whole gamut of system transformation for the financing of the crucial budgetary sections which took place in Poland in recent years.

5. METHODOLOGY AND PRELIMINARY ANALYSIS

In this article we use both the linear and nonlinear Granger causality tests to explore the short–run dynamic relationships between real growth rates of GDP, expenditure on major budgetary sections and total public expenditure in Poland. The main goal of our analysis is to investigate which one of the theories presented in the introductory section, namely the Wagner's approach or Keynes's theory, seems to be more adequate for the case of Polish economy.

The definition of causality used in this paper is due to Granger (1969). One stationary time series, say *X*, is said to strictly Granger cause another stationary one, say *Y*, if past and current values of series *X* are helpful in predicting future values of time series *Y*. The definition of causality was intentionally formulated for stationary time series. As it was shown through empirical (Granger and Newbold 1974) and theoretical (Phillips 1986) deliberations, if the time series under study are indeed nonstationary then the results of typical linear causality tests may lead to spurious conclusions. Thus, testing the chosen time series for stationarity and identifying their order of integration is the initial part of standard causality analysis. In the first step we conducted Augmented Dickey–Fuller (ADF) unit root test. Table 3 contains results of ADF test with deterministic term including either constant or constant with linear trend. Before conducting the test we had set up the maximal lag length equal to 6 and then we used AIC information criterion to choose optimal lag length from the set {0, 1, …, 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
HR	–1.68 (0.43)	2	–1.58 (0.80)	2
PR	–2.73 (0.07)	3	–2.79 (0.20)	3
NIP	–5.38 (0.00)	0	–5.70 (0.00)	0
OTHER	–4.38 (0.00)	0	–5.45 (0.00)	0

From table 3 one can easily notice that only GDP, HR and PR time series were found to be nonstationary (at 5% significance level), regardless the form of deterministic term. However, at this place we should underline few important facts. Firstly, the results of ADF test are relatively sensitive to the incorrect establishment of lag parameter. Secondly, as it was shown in some papers this test tends to under–reject the null hypothesis pointing too often at nonstationarity. The low power against stationary alternatives was frequently reported (see e.g. Agiakoglu and Newbold (1992)). Therefore, the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test was additionally conducted to check the results of ADF tests. Results of KPSS test are presented in table 4:

Table 4. Results of KPSS test of examined variables (levels)

Variable	with constant (test statistic*)	with constant and linear trend (test statistic**)
GDP	0.54	0.08
BUDGET	0.32	0.13
HR	0.22	0.14
PR	0.13	0.12
NIP	0.24	0.09
OTHER	0.55	0.04

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

As we can see results presented in table 4 lead to relatively different conclusions than the outcomes contained in table 3. This time only GDP and OTHER time series were found to be nonstationary (at 5% significance level). However, when time component was additionally included then the test pointed at stationarity (trend stationarity) of variables under study (also at 5% significance level).

The relatively different results of both tests forced us to use third test, namely the Phillips–Perron (PP) test. This test is based on nonparametric method of controlling for serial correlation when testing for a unit root. The initial point of this procedure is the equation of non–augmented DF test with lag parameter equal to zero. Then special modification of *t*–ratios is applied to avoid the influence of serial correlation on asymptotic distribution of test statistic (for more details see Phillips and Perron (1988)). We shall note that the null hypothesis refers to nonstationarity. The results of PP test are presented in following table:

Table 5. Results of PP test of examined variables (levels)

Variable	Only constant (*p*–value):	Constant and linear trend (*p*–value):
GDP	0.38	0.18
BUDGET	0.00	0.00
HR	0.00	0.00
PR	0.00	0.00
NIP	0.00	0.00
OTHER	0.00	0.00

After analyzing outcomes presented in table 5 one can easily see that all time series except for GDP were found to be stationary at reasonable significance levels. In order to make the final decision about orders of integration of all variables we re–run all applied tests for their first differences. Of course, this was performed only in those cases for which the results of test conducted for the variables in their levels pointed at nonstationarity. Suitable outcomes are presented in the following table (Δ denotes differencing operator):

Table 6. Results of tests of stationarity of examined variables (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
ΔHR	–9.69 (0.00)	1	–4.87 (0.00)	1
ΔPR	–3.83 (0.002)	4	–4.57 (0.001)	5
Variable	KPSS with constant (test statistic)		KPSS with constant and linear trend (test statistic)	
ΔGDP	0.14		0.11	
ΔOTHER	0.06		0.03	
Variable	PP with constant (p–value)		PP with constant and linear trend (p–value)	
ΔGDP	0.001		0.01	

The main conclusion arising from the analysis of outcomes presented in table 6 is the fact that the order of integration of all variables is no greater than one (assuming no deterministic trend). Taking into consideration all results presented in tables 3–6 we may state that only GDP time series is indeed integrated of order one (around constant). The nonstationarity of GDP was found in the results of all conducted tests while for other variables at least two of three conducted tests have pointed at stationarity. This final conclusion will be crucial for our further analysis as it is initial point of causality testing.

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 while dealing with nonstationary variables. Another issue worth underlying is the fact that this method is useful for testing for causality between variables which are characterized by different orders of integration (which is true for most cases analyzed in this paper). In such cases the linear causality analysis cannot be performed by the application of suitable VEC model (as variables are characterized by different orders of integration).

In order to understand the idea of Toda–Yamamoto approach for causality testing consider the following n–dimensional VAR(p) process:

$$y_t = c + \sum_{i=1}^{p} A_i y_{t-i} + \varepsilon_t \tag{2}$$

where $y_t=(y_t^1,\ldots,y_t^n)^{tr}$, $c=(c_1,\ldots,c_n)^{tr}$ and $\varepsilon_t=(\varepsilon_{1,t},\ldots,\varepsilon_{n,t})^{tr}$ are n–dimensional vectors (tr denotes transpose operator) and $\{A_i\}_{i=1}^{p}$ is a set of $n\times n$ matrices of parameters for appropriate lags. The order p of the process is assumed to be known. If this value is unknown then it may be established with the help of some standard statistical methods (like application of consistent model selection criterion, for more details see e.g. Paulsen (1984)). The Toda–Yamamoto (1995) idea of testing for causal effects is based on estimating the augmented VAR($p+d$) model:

$$y_t = c' + \sum_{i=1}^{p+d} A_i' y_{t-i} + \varepsilon_t' \qquad (3)$$

In order to use Toda–Yamamoto approach we shall assume that the error vector ε' is an independent white noise process with nonsingular covariance matrix $\Sigma_{\varepsilon'}$ (whose elements are assumed to be constant over time). Additionally, we shall also assume that the condition $E\left|\varepsilon_{k,t}'\right|^{2+s} < \infty$ holds true for all $k=1,\ldots,n$ and some $s>0$. The value of parameter d is equal to the maximum order of integration of variables $y^1,\ldots,y^n$. According to Toda and Yamamoto (1995) the number of extra lags (parameter d) is an unrestricted variable since its role is to guarantee the use of asymptotic theory. We say that the k–th element of y_t does not Granger–cause the j–th element of y_t ($k,j \in \{1,\ldots,n\}$) if there is no reason for the rejection of following hypothesis:

$$\mathrm{H}_0\!: \ a_{jk}^{s} = 0 \quad \text{for } s=1, \ldots, p, \qquad (4)$$

where $A_s = \left[a_{pq}^{s}\right]_{p,q=1,\ldots,n}$ for $s=1$, ..., p (note that the considered hypothesis of non–causality refers to non–augmented VAR model (i.e. model (2)). In order to present the test statistic we shall make use of the following compact notation (T denotes the sample size, circumflex indicates the OLS estimator):

Table 7. Compact notation used to formulate TY test statistic

Object	Description
$Y := (y_1,\ldots,y_T)$	$n\times T$ matrix
$\hat{D} := (\hat{c},\hat{A}_1,\ldots,\hat{A}_p,\ldots,\hat{A}_{p+d})$	$n\times(1+n(p+d))$ matrix
$Z_t := \begin{bmatrix} 1 \\ y_t \\ y_{t-1} \\ \ldots \\ y_{t-p-d+1} \end{bmatrix}$	$(1+n(p+d))\times 1$ matrix, $t=1,\ldots,T$
$Z := (Z_0,\ldots,Z_{T-1})$	$(1+n(p+d))\times T$ matrix
$\hat{\delta} := (\varepsilon_1',\ldots,\varepsilon_T')$	$n\times T$ matrix

The initial step of TY procedure is the calculation of $S_U := \frac{\hat{\delta}\hat{\delta}^{tr}}{T}$ — the variance–covariance matrix of residuals from unrestricted augmented VAR model (i.e. model (3)). Then one may define $\beta := vec(c, A_1,\ldots,A_p, 0_{n\times nd})$ and $\hat{\beta} := vec(\hat{c},\hat{A}_1,\ldots,\hat{A}_p,\ldots,\hat{A}_{p+d})$ where $vec(\cdot)$ denotes column stacking operator and $0_{n\times nd}$ stands for $n\times nd$ matrix filled with zeros. Using this notation one can write the Toda–Yamamoto test statistic for testing causal effects between variables in y_t in the following form:

$$\mathrm{TY} := \left(C\hat{\beta}\right)^{tr} \left(C\left(\left(ZZ^{tr}\right)^{-1} \otimes S_U\right) C^{tr}\right)^{-1} \left(C\hat{\beta}\right) \qquad (5)$$

where $\otimes$ denotes Kronecker product and C is the matrix of suitable linear restrictions. In our case (i.e. testing for causality from one variable in y_t to another) C is $p\times(1+n(p+d))$ matrix which elements take only the value of zero or one. Each of p rows of matrix C corresponds to restriction of one parameter in β. The value of every element in each row of C is one if the associated parameter in β is zero under the null hypothesis, otherwise it is zero. There is no association between matrix C and last n^2d elements in β. This approach allows us to formulate the null hypothesis of Granger non–causality in the following form:

$$\mathrm{H}_0\colon C\beta^{tr}=0\,. \tag{6}$$

Finally we shall note that the TY test statistic is asymptotically χ^2 distributed (which holds true if previously mentioned assumptions like properties of error term, etc. are fulfilled) with the number of degrees of freedom equal to number of restrictions to be tested (in our case this value is equal to p). In other words TY test is just a standard Wald test applied for first p lags obtained from augmented VAR(p+d) model.

As we have already mentioned the application of Toda–Yamamoto method requires some specific modelling assumptions. If these assumptions are fulfilled then the test statistic is asymptotically chi–square distributed. At this place we should mention some drawbacks of this method of testing for Granger causality. Firstly, if the error term of augmented VAR model is not a white noise (e.g. heteroscedastic) then the application of asymptotic theory may lead to spurious results. Secondly, even if modelling assumptions are generally fulfilled the distribution of TY test statistic may be significantly different from chi–square while dealing with extremely small samples. In order to avoid these problems we have decided to use bootstrap technique additionally. This method is used for estimating the distribution of test statistic by resampling data. At this point we shall also underline some important facts. Firstly, the estimated distribution depends only on available dataset, therefore it may be reasonable to expect that none of the assumptions required for parametric methods has to be fulfilled for proper application of bootstrap technique. Secondly, the size and power properties of causality test based on bootstrap techniques remain relatively good even in cases of nonstationarity and various schemes of error term structure including heteroscedasticity etc. (for more details see Dolado and Lütkepohl (1996), Mantalos (2000), Hacker and Hatemi (2006), Lach (2010)). However, we may not forget that bootstrap methods have some drawbacks too and hence they 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 second thought (see e.g. Horowitz (1995), Chou and Zhou (2006)).

Every bootstrap simulation conducted for the use of this article is based on resampling leveraged residuals. We have decided to use leverages as this is just a simple modification of regression raw residuals which supports stabilization of their variance (more details on leverages may be found in Davison and Hinkley (1999)). For every pair of variables we estimated non–augmented bivariate VAR model through OLS methodology with the assumed null hypothesis that one variable does not Granger cause the other one. In fact this means that some elements of coefficient matrices were restricted to zero. In the next step we used leverages to transform regression raw residuals (vector of residuals modified by this transformation will be denoted as $\{\hat{\varepsilon}_i^m\}_{i=v_0,\dots,T}$, T

stands for sample size, v_0 is equal to VAR lag length plus one). Finally, the following algorithm was conducted:

- Drawing randomly with replacement (all points have equal probability $p_0=\frac{1}{T-v_0+1}$) from the set $\{\hat{\varepsilon}_i^m\}_{i=v_0,...,T}$ (as a result the set $\{\hat{\varepsilon}_i^{**}\}_{i=v_0,...,T}$ was obtained);
- Subtracting the mean in order to guarantee the mean of bootstrap residuals is zero (this way we create the set $\{\hat{\varepsilon}_i^{*}\}_{i=v_0,...,T}$, such that $\hat{\varepsilon}_{k,i}^{*}=\hat{\varepsilon}_{k,i}^{**}-\frac{\sum_{j=v_0}^{T}\hat{\varepsilon}_{k,j}^{**}}{T-v_0+1},\ i=v_0,...,T,\quad k=1,2$);
- Generating the simulated data through the use of original data, coefficient estimates from the regression of restricted non–augmented VAR model and the bootstrap residuals $\{\hat{\varepsilon}_i^{*}\}_{i=v_0,...,T}$;
- Perform the TY procedure (for simulated data).

After repeating this procedure *N* times it was possible to create the empirical distribution of TY test statistic and get empirical critical values (bootstrap critical values) next. In order to take part in academic discussion on how the number of bootstrap replications (parameter *N*) may affect performance of bootstrap techniques we examined several possibilities for this parameter. The suitable procedure written in Gretl is available from the authors upon request.

As a complacement of standard linear Granger causality tests we applied impulse response (IR) analysis additionally. The standard Granger causality analysis provides an opportunity to the establishment of direction of causal link between variables, however it does not tell anything about signs of this relationship. In order to examine the reaction of effect variable to the shock in the cause variable (which is transmitted through the dynamic structure of VAR model) we applied impulse response function based on orthogonal residuals (established through the application of Cholesky decomposition). In order to save the space we do not present all technical details (like definition and properties of Wold decomposition etc.) and results of suitable preliminary analysis (like analysis of Wold instantaneous causality etc.) which should be performed before applying orthogonal IR functions. The reader may find the theoretical background of this method in Lütkepohl (1993) and Hamilton (1994). Furthermore, complete results of all mentioned preliminary tests conducted before application of the IR techniques are available from authors upon request.

Beside the bootstrap–based linear causality test and IR analysis the 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), Gurgul and Lach (2009)). Secondly, since the traditional linear approach is based on testing the statistical significance of suitable parameters only in mean equation the causality in higher–order structure (for example causality in variance etc.) cannot be explored (Diks and DeGoede (2001)). The application of nonlinear approach may be a solution to this problem as it allows exploring complex dynamic links between variables of interest.

The idea of nonlinear procedure comes from Baek and Brock (1992). Their findings were thereafter modified by Hiemstra and Jones (1994). Diks and Panchenko (2005) found the testing procedure proposed by Hiemstra and Jones (HJ test) mostly improper for testing for Granger causality. They managed to prove that the hypothesis examined by Hiemstra and Jones is in general not equivalent to the null hypothesis of Granger non–causality. Furthermore, their research led to the establishment of exact conditions under which the HJ test is a useful tool for causality analysis. They managed to bypass the above mentioned problem of testing for an incorrect hypothesis and provided detailed description of the asymptotic theory of their modified test statistic.

In this article we use nonlinear causality test proposed by Diks and Panchenko (2006). In our research we decided to use some typical values of bandwidth parameter, setting it at the level of 0.5, 1 and 1.5 for all conducted tests. These values were commonly used in previous papers (see e.g. Hiemstra and Jones (1994), Diks and Panchenko (2005) and (2006)). We have also decided to use the same lags for every pair of time series being analyzed establishing this lag at the order of 1 and 2. More details about meaning of technical parameters and the form of applied test statistic 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. Since the structure of linear dependences had been filtered out with application of suitable VAR models and TY procedure, 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 standardized, thus they shared a common scale parameter. Finally we must note that we used one–side test rejecting whenever calculated test statistic was significantly large. There are at least two main reasons justifying this choice. Firstly, in practice one–sided test is often found to have larger power than a two–sided one (see e.g. Skaug and Tjøstheim (1993)). Secondly, although significant negative values of test statistic also provide basis for rejection of the null hypothesis of Granger non–causality, they additionally indicate that the knowledge of past values of one time series may aggravate the prediction of another one. In contrast, the causality analysis is usually conducted to judge whether this knowledge is helpful (not aggravating) for prediction issues or not.

Finally we shall note that the former research provided solid basis for claiming that the nonlinear causality test tends to over–reject in cases of presence of heteroscedastic structures in analyzed time series. (see e.g. Diks and Panchenko (2006)). Thus, we have decided to test all residual time series additionally for the presence of GARCH structures. Since we found significant proof of the presence of conditional heteroscedasticity in residuals of most VAR models, we decided to re–run nonlinear causality test for filtered series of residuals. Complete results of heteroscedasticity tests are available from authors upon request. At this point we shall also note that GARCH filtering shall be carried out carefully as it sometimes may lead to loss of power of the test, which derives from possible misspecification of conditional heteroscedasticity model. This of course may simply lead to spurious results of the test (Diks and Panchenko (2006)).

6. Analysis of Empirical Results

In this section the results of short–run 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 dynamic links between real GDP growth and crucial budgetary expenditure categories in Poland in the period under study. One may expect these outcomes to provide basis for judging which of two main concepts described in previous sections, namely Wagner's Law or Keynesian's theory, seems to be more adequate for Polish economy. We shall start the presentation of results of our research with the outcomes obtained from analysis of linear Granger causality. Tables 8–12 contain *p*–values obtained while testing for linear Granger causality through the application of bootstrap–based Toda–Yamamoto procedure. Numbers in brackets denote corresponding *p*–values obtained with the help of standard (chi–square) distribution of modified Wald test statistic. The value of *N* parameter denotes number of bootstrap replications used to construct the distribution of TY test statistic. For every pair of variables we first established the number of lags (parameter *p*) in non–augmented two–dimensional VAR model. For this purpose we followed a simple procedure. We set up maximal possible lag length at the level of 6 and then we used several information criteria (namely, AIC, BIC, HQ and SIC) to choose the optimal lag length. For all VAR models the optimal lag was always one of the elements of following set {1, 4, 5}. 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 that lag parameter for which the significant autocorrelation of error vector was reported. If all possibilities were rejected then we set up the lag parameter at the level of 4. This value was established arbitrarily and seemed to be a proper choice for quarterly data. This procedure (arbitrary establishment of lag parameter) is an alternative method to application of popular model selection criteria and it was commonly used in previous papers (e.g. see Granger (2000)). Significant autocorrelation may prove that the established lag length was too small and some important lagged parameters have been omitted in construction of VAR model. This may in turn affect both the causality tests (linear and nonlinear) as well as the IR analysis. One may expect that autocorrelation of error term should not be a serious problem for the application of bootstrap methods. However, in practical research it may significantly worsen performance of this approach. We shall note once again that since the GDP time series was found to be I(1), parameter *d* was set up to one in case of all examined pairs of variables. Whenever test results indicated the existence of causal link in certain direction (at 10% significance level) the shading was used to mark this finding.

The following table contains results computed by VAR model constructed for GDP and BUDGET time series:

Table 8. 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*=1000
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)

As we can see test results strongly support hypothesis that BUDGET Granger causes GDP (at 10% significance level). Furthermore, test results provided no basis to claim that linear Granger causality runs in the opposite direction. It should be also noted that both these findings were reported by results of asymptotic– and bootstrap–based TY procedure (despite value of parameter *N*). The next table contains results computed by VAR model constructed for GDP and HR time series:

Table 9. Results of Toda–Yamamoto test for linear Granger causality between GDP and HR (set of lag lengths indicated by information criteria: {1, 5}, final lag length: *p*=5)

Null hypothesis	*p*–value		
	N=100	*N*=500	*N*=1000
GDP does not Granger cause HR	0.64 (0.52)	0.67 (0.52)	0.54 (0.52)
HR does not Granger cause GDP	0.32 (0.21)	0.41 (0.21)	0.39 (0.21)

After analyzing outcomes presented in table 9 one can easily see that the results of Toda–Yamamoto test provided no basis to claim that linear Granger causality runs in any direction for real growth rate of human resources expenditure and GDP growth variables. We shall underline that this finding was reported for both types of test statistic distribution, namely the $\chi^2(5)$ distribution and bootstrap–based distribution. It is worth mentioning that this phenomenon was reported for all used numbers of bootstrap replications.

The following table contains results gained after analysis of VAR model constructed for GDP and PR time series:

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

Null hypothesis	*p*–value		
	N=100	*N*=500	*N*=1000
GDP does not Granger cause PR	0.71 (0.65)	0.63 (0.65)	0.67 (0.65)
PR does not Granger cause GDP	0.38 (0.41)	0.44 (0.41)	0.39 (0.41)

Similarly to previous case, also for these two variables both variants of Toda–Yamamoto procedure indicated that there is no linear Granger causality running in any direction. Therefore, neither Keynesian approach nor Wagner's Law was found to be a proper pattern for dynamic relationship between GDP and PR. It is worth mentioning that this finding was obtained regardless of the number of bootstrap replications used.

The following table contains results gained after analysis of VAR model constructed for GDP and NIP time series:

Table 11. Results of Toda–Yamamoto test for linear Granger causality between GDP and NIP (set of lag lengths indicated by information criteria: {1}, final lag length: *p*=4)

Null hypothesis	*p*–value		
	N=100	*N*=500	*N*=1000
GDP does not Granger cause NIP	0.72 (0.67)	0.65 (0.67)	0.72 (0.67)
NIP does not Granger cause GDP	0.08 (0.02)	0.04 (0.02)	0.06 (0.02)

The outcomes presented in table 11 provided solid basis for claiming that there is no linear Granger causality running from GDP to NIP. This result was reported in both asymptotic– and bootstrap–based (once again nonetheless value of parameter *N*) variant of TY procedure. On the other hand, results of linear causality analysis provided relatively convincing arguments for the existence of causal link running from the real growth rate of budgetary expenditure on net interest payment to the real GDP growth rate. All these facts are in line with Keynes's approach to expenditure–GDP relationship.

The last VAR model was constructed for GDP and OTHER variables. The following table contains results of suitable causality analysis:

Table 12. Results of Toda–Yamamoto test for linear Granger causality between GDP and OTHER (set of lag lengths indicated by information criteria: {1}, final lag length: *p*=4)

Null hypothesis	*p*–value		
	N=100	*N*=500	*N*=1000
GDP does not Granger cause OTHER	0.03 (0.01)	0.04 (0.01)	0.05 (0.01)
OTHER does not Granger cause GDP	0.61 (0.59)	0.67 (0.59)	0.51 (0.59)

The Toda–Yamamoto procedure based on asymptotic distribution theory provided no support for claiming that OTHER Granger causes GDP. The application of bootstrap–based distribution provided similar results (suitable *p*–value no less than 0.50). On the other hand, both variants of TY procedure strongly point at the existence of causal link in the direction from real GDP growth rate to growth rate of budgetary expenditure on examined category (OTHER variable). Unlike the previous case, this time the Wagner's Law was found as the suitable explanation of the GDP–expenditure relationship. It is worth mentioning that both these findings were obtained despite the number of bootstrap replications used. This robustness to technical parameters of bootstrap approach makes results of performed causality analysis even more convincing. At this place we shall underline that for other pairs of variables results of asymptotic– and bootstrap–based tests were also relatively similar.

After analyzing outcomes presented in tables 8–12 one can easily see that for Polish economy the total public expenditure was found as a causal factor for movements of real growth rate of GDP. This is how the principals of Keynesian economy were found as the set of suitable rules for describing the relationship between GDP and total budgetary expenditure in Poland in the period under study. On the other hand, the causality analysis performed for expenditure sub–categories provided relatively mixed results. For HR and PR variables no recognizable pattern was found, while for NIP and OTHER categories results supporting competitive theories were reported.

However, the analysis of linear Granger causality in terms of TY procedure may not provide the complete information about the dynamic interactions between chosen variables. Therefore, the impulse response analysis was performed additionally. Every IR function illustrates the response of one variable (found as a caused variable through application of TY procedure) to one s.d. shock in time series of other variable (found as a causal factor in TY procedure). As we have already mentioned the complete results of preliminary analysis are available from authors upon request. The following figure contains illustration of all responses:

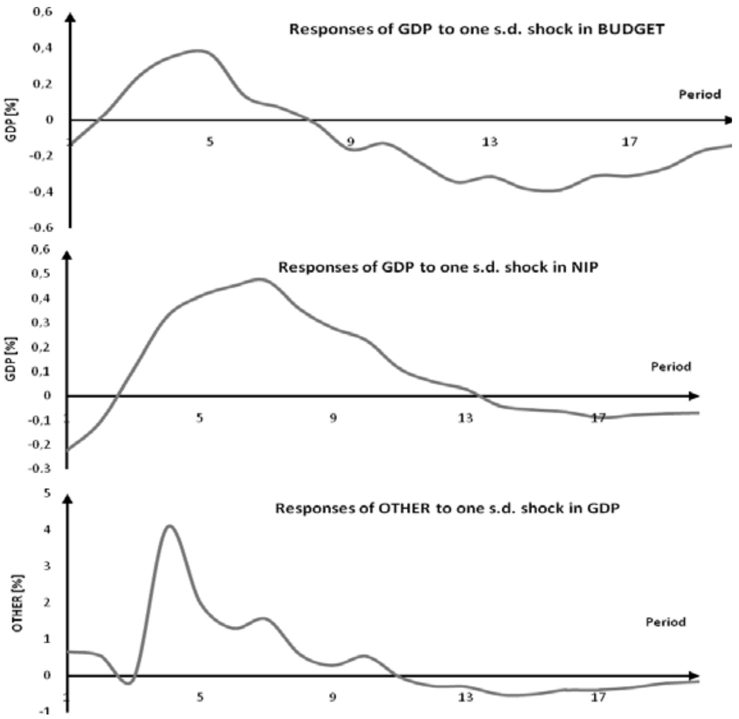

Figure 1. Impulse responses of caused variables to one s.d. shocks in time series of causal factors

The one s.d. (6.82%) shock from BUDGET causes negative (–0.13%) response of GDP in the first quarter. However, the positive responses were reported in quarters 2 to 7. The highest positive response was reported for the fifth period and reached the value of 0.36%. Starting from eight period negative responses occur. The biggest drop in GDP was found for quarter 14 and reached the value of –0.37%.

The one s.d. (6.79%) shock from NIP causes negative responses of GDP in the first two quarters. However, in quarters 3 to 13 the positive responses were indicated. The highest positive response was reported for seventh period and reached the value of 0.47%. Starting from quarter 14 negative responses occur. However, these drops are relatively slight and do not exceed the value of 0.09%.

The one s.d. (2.09%) shock in GDP time series caused positive responses of OTHER variable in the first 10 quarters (except for slight negative response reported in third quarter). The highest positive response was reported for fourth period and reached the value of 4.07%. Starting from eleventh quarter negative responses had occurred, however they were not as significant as positive ones (drops no greater than 0.50%).

In addition to linear causality tests and impulse response analysis the nonlinear Granger causality tests were conducted as well. Results obtained for unfiltered residual time series are presented in the following table:

Table 13. Results of tests for nonlinear Granger causality between examined variables (unfiltered data)

Null hypothesis	p–value			
	ε=0.5	ε=1	ε=1.5	l
GDP does not Granger cause BUDGET	0.81	0.81	0.77	1
	0.77	0.71	0.45	2
BUDGET does not Granger cause GDP	0.96	0.91	0.92	1
	0.82	0.85	0.93	2
GDP does not Granger cause HR	0.40	0.38	0.31	1
	0.72	0.92	0.54	2
HR does not Granger cause GDP	0.23	0.21	0.17	1
	0.18	0.08	0.27	2
GDP does not Granger cause PR	0.39	0.27	0.67	1
	0.52	0.61	0.92	2
PR does not Granger cause GDP	0.24	0.33	0.78	1
	0.64	0.42	0.68	2
GDP does not Granger cause NIP	0.90	0.81	0.45	1
	0.86	0.62	0.67	2
NIP does not Granger cause GDP	0.95	0.88	0.85	1
	0.76	0.67	0.92	2
GDP does not Granger cause OTHER	0.82	0.82	0.42	1
	0.71	0.72	0.87	2
OTHER does not Granger cause GDP	0.20	0.27	0.08	1
	0.18	0.23	0.09	2

As we can see the test results provided solid evidence to claim that in most cases under study nonlinear Granger causality does not run in any direction. Some evidence of existence of causal link was found only for HR and OTHER variables. In both mentioned cases the direction of causal link was in line with fundamentals of Keynes's theory.

Finally, taking into consideration the fact that Diks and Panchenko's test was found to be sensitive to presence of heteroscedasticity in analyzed time series, we had performed GARCH(1,1)–filtration of suitable time series of residuals and then we re–ran nonlinear causality analysis. It is worth underlying that for almost every analyzed case the GARCH(1,1) structure was significantly present in residual time series. In order to save the space we do not present the results of these tests in this paper, however they are of course available from the authors upon request. The nonlinear causality was not found at reasonable significance levels for any analyzed pair of filtered variables. Therefore, for HR and OTHER variables applicability of Keynesian approach seems a bit uncertain. This phenomenon may somehow prove that nonlinear causality analysis is indeed sensitive to the presence of heteroscedastic structures in examined data which is in line with the outcomes presented in previous papers (e.g. Diks and Panchenko (2006)). However, we cannot forget that possible misspecification of heteroscedasticity model could be the reason for relatively different indications of tests conducted for unfiltered and filtered data.

7. Final remarks

Economists around the world make efforts to find sources of economic growth. Technically, it seems that conducting this type of research for developed economy is not a serious problem since necessary data is quite reachable. For countries like Poland, where economy is still in transitory phase, the problem of insufficient datasets occurs, which in turn causes that many questions concerning economic growth cannot be answered.

In this paper we reached out to this problem as we decided to use quarterly data. This way the dataset of highest possible frequency was applied. Our goal was to test the applicability of two contrasting theories, namely Wagner's Law and Keynesian's theory, for the Polish economy. The application of TY procedure in both variants (asymptotic– and bootstrap–based) provided solid basis for claiming that for total budgetary expenditure and economic growth hypothesis 1 is false, but hypothesis 2 is true, which means that in this case Keynesian's theory applies. It is also worth mentioning that since results of nonlinear causality analysis provided no evidence of existence of causal link between examined variables in any direction then the relationship between GDP and total budgetary expenditure was found to have a strict linear nature.

Relatively mixed results were obtained for all four analyzed sub–division expenditure. Results of linear causality analysis provided relatively convincing support for rejection of hypothesis 3. Both the asymptotic– and bootstrap–based (regardless value of parameter *N*) variants of TY procedure show evidence that linear causality does not run in any direction between HR and economic growth. However, nonlinear causality analysis provided weak support claiming that for this pair of variables the Keynesian theory applies. Since the later was reported only for unfiltered data this result may be due to the sensitivity of Diks and Panchenko's test to the presence of heteroscedastic structures which causes over–rejection. Therefore, applicability of Keynesian theory to HR and GDP variables seems quite doubtful and hypothesis 3 should rather be rejected.

We have also found relatively weak evidence in favour of hypothesis 4. Although the conducted tests do not allow to reject hypothesis of no linear causality between PR and economic growth, we found significant evidence of the unidirectional linear causal relation existence in the sense of Keynesian's theory for NIP and GDP variables. The application of nonlinear methods (for unfiltered and GARCH(1,1)–filtered data) provided no evidence of existence of causal link for PR and GDP as well as for NIP and GDP variables in any direction.

The application of asymptotic– and bootstrap–based TY tests strongly supports hypothesis 5, i.e. the existence of causal link in the direction from real GDP growth rate to real growth rate of budgetary expenditure on sub–categories included in OTHER variable. This finding supports the view that economic growth is driving public expenditure on science, national defence and public security. These results were reported at 5% significance level. Although for unfiltered data the nonlinear causality analysis provided relatively weak support for claiming that for GDP and OTHER variables Keynesian theory is also applicable, the GARCH(1,1)–filtration of time series led to different conclusion (no causality in any direction). As in GDP–HR case this phenomenon may provide some support for the hypothesis that nonlinear approach is indeed sensitive to presence of heteroscedasticity in analyzed time series.

The results by Impulse Response Function demonstrate sensitivity of economic growth rate to one s.d. shocks imposed on budgetary expenditure on NIP and total budgetary expenditure. The peak of economic growth response is located in 5–th (BUDGET) or in 7–th quarter (NIP). In further quarters the one s.d. shocks implies drop in economic growth rate. This is in favour of hypothesis 6. On the other hand, a one s.d. shock imposed on GDP time series causes significant positive responses of OTHER variable in first quarters. In this case negative responses have also occurred, but they were not as significant as positive ones.

To summarise, in the case of Polish economy Keynesian's theory is in general more appropriate than Wagner's Law. This statement is mostly based on the results of linear causality analysis, as results of nonlinear tests, although providing some weak support, also seem to suffer due to uncertainty occurring in case of heteroscedasticity problems. Furthermore, one can claim, that rise in NIP growth rate can be linearly transmitted to GDP growth rate. This finding seems to be an interesting advice for Polish policy makers and should gain a considerable attention.

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REFERENCES

AGIAKOGLU, C. & NEWBOLD, P., 1992, Empirical Evidence on Dickey–Fuller Type Tests, *Journal of Time Series Analysis*, 13, pp. 471–483.

ANWAR, M.S., DAVIES, S. & SAMPATH, R.K., 1996, Causality between Government Expenditures and Economic Growth: An Examination Using Cointegration Techniques, *Public Finance*, 51, pp. 166–184.

ASTERIOU, D. & ARGIOMIRGIANAKIS, G.M., 2001, Human capital and economic growth: time series evidence from Greece, *Journal of Policy Modeling*, 23, pp. 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, *Economic Development and Cultural Change*, 26, pp. 261–280.

BISWAS, B. & RAM, R., 1986, Military expenditures and economic growth in less developed countries: an augmented model and further evidence, *Economic Development and Cultural Change*, 34, pp.361–372.

BLOMQVIST, A.G. & CARTER, R.A.L., 1997, Is health care really a luxury?, *Journal of Health Economics*, 16, pp. 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, Fla.

CASELLI, F., 1999, Technological revolutions, *American Economic Review*, 89, pp. 78–102.

CHANG, T., FANG, W., WEN, L.F. & LIU, C., 2001, Defense expenditure, economic growth and temporal causality: evidence from Taiwan and mainland China, 1952–1995, *Applied Economics*, 33, pp. 1289–1299.

CHEN, A.S. & LIN, J.W., 2004, Cointegration and detectable linear and nonlinear causality: analysis using the London Metal Exchange lead contract, *Applied Economics*, Vol. 36, pp. 1157–1167.

CHEN, C.H., 1993, Causality between defence spending and economic growth: the case of mainland China, *Journal of Economic Studies*, 26, pp. 37–43.

CHOU, P.H. & ZHOU, G., 2006, Using Bootstrap to Test Portfolio Efficiency, *Annals of economics and finance*, 2, pp. 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.

CULYER, A.J., 1990, Cost containment in Europe, Health Care Systems in Transition, OECD, Paris.

DAVISON, A.C. & HINKLEY, D.V., 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, *Economics of Education Review*, 14, pp. 351–361.

DEGER, S. & SEN, S., 1983, Military expenditures, spin–off and economic development, *Journal of Development Economics*, 13, pp. 68–83.

DEMIRBAS, S., 1999, Cointegration Analysis–Causality Testing and Wagner's Law: The Case of Turkey, 1950–1990, Available at: http://www.econturk.org/safaaabi.pdf.

DEROUEN, K.R., 1995, Arab–Israeli defence spending and economic growth, *Conflict Management and Peace Science*, 14, pp. 25–47.

DEVLIN, N. & HANSEN, P., 2001, Health care spending and economic output: Granger causality, *Applied Economics Letters*, 8, pp. 561–564.

DIKS, C.G.H. & DEGOEDE, J., 2001, A general nonparametric bootstrap test for Granger causality, In: Broer H.W., Krauskopf W., Vegter G. (eds.), *Global analysis of dynamical systems*, Institute of Physics Publishing, Bristol, United Kingdom.

DIKS, C.G.H. & PANCHENKO, V., 2005, A note on the Hiemstra–Jones test for Granger non–causality, *Studies in Nonlinear Dynamics and Econometrics*, 9, No. 2, Article 4.

DIKS, C.G.H. & PANCHENKO, V., 2006, A new statistic and practical guidelines for nonparametric Granger causality testing, *Journal of Economic Dynamics & Control*, 30, pp. 1647–1669.

DOLADO, J.J. & LÜTKEPOHL, H., 1996, Making Wald tests work for cointegrated VAR systems, *Econometrics Reviews,* 15, pp. 369–386.

DUNNE, J.P., SMITH, R.P. & WILLENBOCKEL, D., 2005, Models of military expenditure and growth: a critical review, *Defence and Peace Economics*, 16, No. 6, pp. 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.

FREDERIKSEN, P.C. & LOONEY, R.E., 1982, Defence expenditures and economic growth in development countries: some further empirical evidence, *Journal of Economic Development*, 7, pp. 113–125.

GRANGER, C.W.J., 1969, Investigating causal relations by econometric models and cross–spectral methods, *Econometrica*, 37, pp. 424–438.

GRANGER, C.W.J. & NEWBOLD, P., 1974, Spurious regression in econometrics, *Journal of Econometrics*, 2, pp. 111–120.

GRANGER, C.W.J., HUANG, B. & YANG, C., 2000, A bivariate causality between stock prices and exchange rates: evidence from recent Asian Flu, *The Quarterly Review of Economics and Finance*, 40, pp. 337–354.

GROBAR, L. & PORTER, R., 1989, Benoit revisited: defence spending and economic growth in less developed countries, *Journal of Conflict Resolution*, 33, pp. 318–345.

GURGUL, H. & LACH, Ł., 2009, Linear versus nonlinear causality of DAX companies, *Operations Research and Decisions*, 3, pp. 27–46.

HACKER, R.S. & HATEMI–J, A., 2006, Tests for causality between integrated variables using asymptotic and bootstrap distributions: theory and application, *Applied Economics*, pp. 1489–1500.

HAMILTON, J.D., 1994, *Time Series Analysis,* Princeton University Press, Princeton.

HANSEN, P. & KING, A., 1996, The determinants of health care expenditure: a cointegration approach, *Journal of Health Economics*, pp. 127–137.

HANSEN, P. & KING, A., 1998, Health care expenditure and GDP: panel data unit root test results–comment, *Journal of Health Economics*, 17, pp. 377–381.

HEO, U. & EGER, R.J., 2005, The security–prosperity dilemma in the United States, *Journal of Conflict Resolution*, 49, pp. 699–708.

HIEMSTRA, C. & JONES, J.D., 1994, Testing for linear and nonlinear Granger causality in the stock price–volume relation, *Journal of Finance*, 49, pp. 1639–1664.

HITRIS, T. & POSNETT, J., 1992, The determinants and effects of health expenditure in developed countries, *Journal of Health Economics*, 11, pp. 173–181.

HOROWITZ, J.L., 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, *Applied Economics Letters*, 4, pp. 329–331.

JACKSON, P.M., MERYEM, D.F. & SAMI, F., 1998, Conitegration, Causality, and Wagner's Law: A test for Northern Cyprus, Available at http://www.le.ac.uk/economics/research/RePEc/lec/lpserc99–2.pdf.

JOERDING, W., 1986, Economic growth and defense spending, *Economics*, 21, pp. 35–40.

KALYONCU, H. & YUCEL, F., 2006, An analytical approach on defense and expenditure and economic growth. The case of Turkey and Greece, *Journal of Economic Studies*, 33, pp. 336–343.

KHAN, A.H., 1990, Wagner's Law and the Developing Economy: A Time Series Evidence from Pakistan, *Indian Economic Journal*, 38, pp. 115–123.

KOLLIAS, C., 1994, The economic effects of defense spending in Greece 1963–90: some preliminary econometric findings, *Spoudai*, 44, pp. 114–130.

LACH, Ł., 2010, Application of bootstrap methods in investigation of size of the Granger causality test for integrated VAR systems, to appear in *Managing Global Transition.*

LAI, C–N., HUANG, B–N. & YANG, C–W., 2005, Defense spending and economic growth the Taiwan straits: a threshold regression model, *Defence and Peace Economics,* 16, pp. 45–57.

LANDAU, D., 1996, Is one of the "peace dividends" negative? Military expenditure and economic growth in the wealthy OECD countries, *The Quarterly Review of Economic and Finance*, 36, pp. 183–195.

LIM, D., 1983, Another look at growth and defense in developed countries, *Economic Development and Cultural Change*, 31, pp. 377–384.

LIU, L.C., HSU, C.E. & YOUNIS, M.Z., 2008, The association between government expenditure and economic growth: Granger causality test of US data, 1947–2002, *Journal of Public Budgeting & Financial Management*, 20, pp. 537–553.

LÜTKEPOHL, H., 1993, *Introduction to Multiple Time Series Analysis,* 2nd ed., Springer–Verlag, New York.

MANTALOS, P., 2000, A Graphical Investigation of the Size and Power of the Granger–Causality Tests in Integrated–Cointegrated VAR Systems, *Studies in Nonlinear Dynamics & Econometrics*, 4, Issue 1, Article no. 2

MCCOSKEY, S.K. & SELDON, T.M., 1998, Health care expenditures and GDP: panel data unit root test results, *Journal of Political Economy*, 70, pp. 129–157.

NAGARAJAN, P. & SPEARS, A., 1990, An Econometric Test of Wagner's Law for Mexico: A Re–Examination, *Public Finance*, 45, pp. 165–168.

NARAYAN, P.K. & SINGH, B., 2007, Modelling the relationship between defence spending and economic growth for the Fiji islands, *Defence and Peace Economics*, 18, pp. 391–401.

NARAYAN, P.K. & SMYTH, R., 2006, Higher Education, Real Income and Real Investment in China: Evidence from Granger Causality, *Education Economics*, 14, pp. 107–125.

PARK, W.K., 1996, Wagner's Law vs. Keynesian Paradigm: The Korean Experience, *Public Finance*, 51, pp.71–91.

PAULSEN, J., 1984, Order determination of multivariate autoregressive time series with unit roots, *Journal of time series analysis*, 5, pp. 115–127.

PHILLIPS, P.C.B., 1986, Understanding the spurious regression in econometrics, *Journal of Econometrics*, 33, pp. 311–340.

PHILLIPS, P.C.B. & PERRON, P., 1988, Testing for a Unit Root in Time Series Regressions, *Biometrika,* 75, pp. 335–346.

PLUTA, J.E., 1979, Wagner's Law, Public Sector Patterns, and Growth of Public Enterprises in Taiwan, *Public Finance Quarterly*, 7, pp. 25–46.

REITSCHULER, G. & LOENING, J.L., 2005, Modeling the defense–growth nexus, *World Development*, 33, pp. 513–526.

ROBERTS, J., 1999, Sensitivity of elasticity estimates for OECD health care spending analysis of a dynamic heterogenous data field, *Health Economics*, 8, pp. 459–472.

SAUNDERS, P., 1985, Public Expenditure and Economic Performance in OECD Countries, *Journal of Public Policy*, 5, pp. 1–21.

SINHA, D., 1998, Government Expenditure and Economic Growth in Malaysia, *Journal of Economic Development*, 23, pp. 265–283.

SKAUG, H.J. & TJØSTHEIM, D., 1993, Nonparametric tests of serial independence, In: Subba Rao T. (ed.), *Developments in time series analysis*, Chapman and Hall, London.

SMITH, R., 1980, ME and investment in OECD countries, 1954–1973, *Journal of Comparative Economics*, 4, pp. 19–32.

TODA, H.Y. & YAMAMOTO, T., 1995, Statistical inference in vector autoregressions with possibly integrated processes*, Journal of Econometrics*, 66, pp. 225–250.

WOLDE–RUFAEL, Y., 2006, Electricity consumption and economic growth: a time series experience for 17 African countries*, Energy Policy,* 34, pp. 1106–1114.