
Untangling the causal relationship between tax burden distribution and economic growth in 23 OECD countries: Fresh evidence from linear and non-linear Granger causality

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Abstract

The aim of the paper is to investigate the linear and nonlinear causality between a set of alternative tax burden ratios and economic growth in 23 OECD countries. To that end, the linear causality approach of Toda– Yamamoto (1995) and the nonparametric causality method of Kyrtsou and Labys (2006) are applied to annual data spanning from 1970 to 2014. Results obtained from the nonlinear causality test tend to reject the neutrality hypothesis for the tax structure–growth relationship in 19 of the 23 OECD countries. In the majority of the countries under investigation, the evidence is in line with the growth hypothesis where causality running from economic growth to tax burden ratios was detected in Australia, Denmark, Finland, Japan, New Zealand, and Norway. The opposite causality running from tax structure to economic growth was found in Germany, Netherlands, Portugal, and Sweden. In contrast, the neutrality hypothesis was supported in Austria, Italy, Luxembourg, and the USA, whereas the feedback hypothesis was supported in Turkey and the UK. Additional robustness checks show that when the signs of variations are taken into account, there is an asymmetric causality running from positive tax burden shocks to positive per capita GDP shocks for Belgium, France, and Turkey. Overall, our findings suggest that policy implications of the tax structure-economic growth relationships should be interpreted with caution, taking into account the test-dependent and country-specific results.

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Keywords: Tax structure, Economic Growth, Non-linear Granger Causality

1. Introduction

The nexus between taxes and economic growth has been extensively explored in the theoretical and empirical literature. The theoretical foundation of this relationship can be traced as far back to Solow (1956) and Swan (1956). One of the main predictions from this work was that growth simply depends on the accumulation of physical and human capital investments. Taxes may exert only temporary effects on the growth rate of income in the transition to successive equilibrium growth paths. The Solow-Swan neoclassical growth model therefore predicts that steady state growth is not affected by tax policy. However, endogenous growth models contend that taxes have a great impact on economic growth through the return on capital accumulation and the volume of investments in R&D (see, *inter alia*, Barro, 1990, 1991; King and Rebelo, 1990; Jones et al., 1993; Stokey and Rebelo, 1995; Barro and Sala-i-Martin, 1995; Mendoza et al., 1997).

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Following the seminal work of Barro (1990), the economic growth-taxes nexus has generated extensive body of empirical literature. These include studies for different geographic areas as well as various sample periods. Roughly, we can categorize past studies in this field into two broad strands. The first strand examines the relationship between the overall level of taxes and economic growth⁴. A general conclusion from this strand of literature is that the empirical results of the previous studies are mixed and have not reached a consensus. While some studies document a negative relationship between taxation and growth (e.g., Plosser, 1992; Engen and Skinner 1992; Mullen and Williams, 1994; Bleaney et al, 2001, Folster and Henrekson, 2001; Padovano and Galli, 2002; Tomljanovich, 2004; Holcombe and Lacombe, 2004; Koch et al., 2005; Reed, 2008; Ferede and Dahlby, 2012), the others do not detect any significant correlation, neither in the long- nor in the short-run (Koester and Kormendi, 1989; Levine and Renelt (1992), Easterly and Rebelo, 1993; Mendoza, et al., 1997). On the other hand, Myles (2000) maintains in a survey that the tax impact on growth is very weak.

The second strand is composed of the studies which focus on the nexus between tax structure and economic growth. This nexus suggests that different types of taxes affect growth in diverse ways. Theoretically, many scholars (see, for example, King and Rebelo, 1990; Rebelo, 1991; Pecorino, 1993; Devereux and Love, 1994; Stokey and Rebelo, 1995) show that income taxes reduce the long-run growth rate while the growth effects of consumption taxes depend on model specification. The extant empirical evidence on the relationship between tax burden and growth is, however, mixed (see Kneller et al., 1999; Widmalm, 2001; Lee and Gordon, 2005; Gemell et al., 2006). These mixed results may be attributed to, among others⁵, the limitations of empirical approaches used. One major problem with the cross-country approach commonly employed in the aforementioned studies is that it fails to recognize the short-run dynamic paths that the individual economies may take to their long-run equilibrium (Ojede and Yamarik, 2012). In other words, the existence of a significant relationship in some countries does not necessarily imply that this exists in other countries as well. Such heterogeneity across countries is due to differences in the level of tax authorities' enforcement power, black economy existence, GDP magnitude, internal market size, access to outside markets, labor mobility, and zoning, environmental and other regulation (Mueller, 2003; Karagianni et al., 2012; Ojede and Yamarik, 2012). These differences suggest that the tax structure-growth relationship may be country-specific; therefore, it is necessary to recognize the heterogeneous nature of the countries under investigation.

In recognition of this situation, in a newly emerging strand of literature, researchers have increasingly turned to time-series analysis that enables them to control for the presence of country-specific heterogeneity and cope with the endogeneity problem and/or causal mechanisms. However, most empirical studies dealing with causality between taxation and economic growth rely only to traditional linear Granger causality tests. This means that researchers often neglect a possible nonlinear

⁴ For an excellent literature review, see Potte (2000), McBride (2012), and Adkisson and Mohammed (2014).

⁵ There are, in fact, several other reasons that can explain the mixture and the inconclusivity of the previous studies: different countries' characteristics, divergent specifications of taxation, alternative econometric methodologies, inappropriate tax indicators, and different dataset (Mendoza et al., 1997, Man et al., 2011; Karagianni et al., 2012).

relationship between these variables because the traditional Granger causality test, designed to detect linear causality, is ineffective in uncovering certain nonlinear relations (Baek and Brock 1992, Hiemstra and Jones 1994). Recent empirical evidence, however, suggests that this relationship is very likely to be nonlinear and the growth effect of taxation is stronger for low average marginal tax rate levels (Bania et al., 2007; Arin et al. 2013, Jaimovich and Rebelo, 2017). In a number of earlier empirical studies, this type of nonlinear behavior has been parsimoniously captured by nonlinear granger causality tests (Karagianni et al., 2012; Tiwari and Mutascu, 2014). Nevertheless, these studies focus exclusively on the tax and growth experience of the USA. In this paper we extend the analysis to a panel of 23 countries with different levels of development and with considerable variability in terms of magnitude of taxation. Furthermore, we follow Tiwari and Mutascu (2014) by applying linear and nonlinear Granger causality tests in investigating the causality between the two variables studied. In particular, besides the linear Granger causality test of Toda and Yamamoto (1995), the nonlinear Granger test proposed by Kyrtsoy and Labys (2006) is also applied to capture both linear and nonlinear Granger causality between tax structure and economic growth.

As emphasized by Arachi et al. (2015), the examination of nonlinear relationships between tax structure and economic growth is very relevant topic, and it is motivated by both theoretical and empirical insights⁶. Indeed, most economic and financial time series exhibit a nonlinear behavior over time and tend to interact with each other in a nonlinear fashion. This recognition has been confirmed by, among others, the occurrences of severe economic and financial crises (e.g., the 1997–1998 Asian financial crisis, the 2007–2008 US subprime crisis, and the 2008–2009 global financial crisis), wars and other extreme events (e.g., the September 11, 2001 terrorist attack, the Second Gulf war in 2003, the 2006 oil price shock, and the Arab Spring movements), sudden changes in macroeconomic policies, fiscal and economic reforms, increased complexity of financial markets, structural change, and reallocation shocks. All the aforementioned factors may cause unexpected changes in the behavior of economic and financial variables, which particularly induce financial structural breaks, asymmetric responses to shocks, and leverage effects (Ajmi et al. 2013, Atil et al. 2014, Bildirici and Turkmen 2015). Under these circumstances, tax policy and economic growth are likely to exhibit a nonlinear pattern, and their joint dynamics imply a more complex than just a simple and stable relationship (Bertola and Drazen, 1993; Giavazzi et al., 2000; Gupta et al., 2005). In view of this, nonparametric analysis techniques are more suitable because they place direct emphasis on prediction without imposing a linear functional form (Saafi et al. 2015a). The failure in most previous studies to account for asymmetry and nonlinearity between taxation and economic growth may have resulted in incorrect inferences about the existence/non-existence of the taxation–growth relationship.

This study aims to examine whether there is a nonlinear and asymmetric causal relationship between tax burden and growth in 23 OECD countries for the 1970–2014 period. Specifically, this research makes three main contributions. First, it takes a novel approach in examining the countries under investigation, deviating from the common use in the related literature of cross-country and panel regression analysis to the use of separate regression models for each country. Through this approach, we can control for any differences in the financial and economic environment across countries. This is a

⁶ See, *inter alia*, Giavazzi et al., 2000, and Jaimovich and Rebelo (2017).

crucial concern because tax burden varies a great deal across countries. Notwithstanding its significance, there has been limited empirical research that has adopted country-specific time series data to investigate the effect of tax structure on economic growth. Second, this study considers a broader set of tax structure indicators to quantify the impact of taxation on growth and, further, to examine the sensitivity of the results. Finally, as far as the authors are aware, this is the first study to employ the nonlinear causality test of Kyrtsou and Labys (2006) based on the bivariate noisy Mackey-Glass process (hereafter M-G) to explore the nonlinear relationship between tax structure and economic growth. According to Kyrtsou and Labys (2006), Hristu Varsakelis and Kyrtsou (2006), and Hristu Varsakelis and Kyrtsou (2008), the main advantage of the M-G approach for nonlinear causality over simple VAR alternatives is that the nonlinear M-G terms are better able to capture more complex dependent dynamics in a time series. In addition, unlike the standard symmetric methods, the asymmetric⁷ version of Kyrtsou and Labys test allows for a potential difference between the effects of positive shocks compared to negative ones. Because of these advantages, the test has recently been applied in several causality studies (for instance, Kyrtsou and Labys, 2006; Hristu Varsakelis and Kyrtsou, 2008; Kumar, 2009; Kumar and Thenmozhi, 2012, Ajmi et al., 2013; Bildirici and Turkmen, 2015; Choudry and Osoble, 2015; Saafi et al. 2015a, 2015b, 2016; Sotoudeh and Worthington, 2016; Jain and Biswal, 2016). It is expected that the analysis in this study will add new insights to the existing empirical literature that will help the policymakers to embrace sound economic policies in order to sustain economic development.

2. Literature review

In the past few years, several researchers have studied the relationship between tax structure and economic growth. The first and still the most important study of this issue is the one by Kneller et al. (1999). Using a panel data set for 22 OECD countries over the period 1970–1995, the authors find that what are considered distortionary taxes (i.e. labour and corporate taxes) reduce growth, while non-distortionary (i.e. taxes on domestic goods and services) did not. Their results suggest also that a decrease by 1% in distortionary taxes as a percentage of GDP is associated with an increase in the economic growth rate by between 0.1% and 0.2% points per year. Widmalm (2001) investigate the link between tax structure and economic growth for a sample of 23 OECD countries for the period 1965–1990 using the extreme bounds analysis. The author finds that taxes on personal income have a negative correlation with economic growth whereas consumption tax is growth enhancing. This finding is subsequently confirmed by Gemell et al. (2006).

For assessing the impact of tax structure on economic growth, Lee and Gordon (2005) use a large panel of 70 countries during 1970–1997 and find that the corporate tax rate is significantly negatively correlated with economic growth. According to their findings, increased corporate tax rates retard future growth rates within countries. By using dynamic impulse response analysis, Mamatzakis (2005) find that, for the case of Greece, output growth responds negatively to an increase in tax burden, but there is a

⁷ Allowing for potential asymmetry is also convenient in our empirical research since there are several studies that have shown that GDP can incorporate an asymmetric component; see, for instance, Verbrugge (1997), Belair-Franch and Contreras (2002), and Narayan and Popp (2009).

positive effect of the tax mix on output growth. Earlier studies, such as those by Arnold et al. (2011), Ojede and Yamarik (2012), and Xing (2012) provide supportive evidence that tax structure affects economic performance. In a more recent work, Adkisson and Mohammed (2014) adopt a panel corrected standard errors model to examine the nexus between tax structure and economic growth for 50 American states from 2004 to 2010, a period that includes the Great Recession. The empirical evidence suggests that marginal differences in tax structure have detectable but very small impacts on growth rates.

Even though several empirical studies have been conducted on the impact of taxes on economic growth, only few of these have focused specifically on the two-way causation between the two variables of interest, as pointed out by Keho (2012). Table 1 provides a chronological list of the existing empirical studies classified by author, country, period, methodology, and main findings. As can be seen from the table, there is no consensus neither on the existence nor on the direction of causality between taxes and economic growth. For instance, Anastassiou and Dritsaki (2005) find evidence of unidirectional causality from a set of alternative tax burden to economic growth using an extended data set on Greece spanning from 1965 to 2002. Unidirectional causality from taxation to economic growth is also found in Côte d'Ivoire by Mashkooor et al. (2010), in the USA by Tiwari (2012), and in Ghana by Takumah (2014). However, in India, Ray et al. (2012) find evidence of strong bidirectional causality between taxation and economic growth. Similar results are found by Taha and Loganathan (2014) in Malaysia. On the other hand, Canicio and Zachary (2014) find no significant causality between taxes and economic growth in Zimbabwe.

The underlying assumption in the aforementioned studies is that the causal relationship between tax structure and economic growth is linear. However, as alluded to earlier, studies such as Bertola and Drazen (1993) Giavazzi et al. (2000), Gupta et al. (2005) Arin et al. (2013), and Jaimovich and Rebelo (2017) suggest that the relationship between taxation and growth is nonlinear. To address this issue, some more recent Granger causality-based studies examining the relationship between taxation and economic growth make use of nonlinear causality tests to account for nonlinear dependencies. It has been found that the conclusion on causality depends on the testing procedures. For instance, using a linear causality test, Tiwari and Mutascu (2014) find evidence in support of unidirectional causality from current tax receipts (as a ratio of GDP) to GDP for the United States of America (USA). However, results of the nonlinear causality test show that personal current taxes and taxes on production and imports are the Granger- cause of GDP. Karagianni et al. (2012) using the nonlinear Granger causality test of Hiemstra and Jones (1994) find evidence of a non-linear causality running from all tax burden ratios to GDP growth, while the results obtained from the nonlinear Granger causality test of Diks and Panchenko (2006) indicate that there is a nonlinear causal relation from production and imports tax burden to GDP. Given the test-dependent and country-specific results, it is worthwhile to handle the issue within the context of different empirical methodologies as well as various countries.

A conclusion that emerges from the related literature is that the taxation-economic growth nexus is not clear-cut and there is a need to ascertain whether the causal relationship between the two variables of interest is linear or nonlinear. This is an empirical issue which this study attempts to explore. The aim of this paper is therefore to further investigate the nature and the direction of the taxation-economic growth

causality in 23 OECD countries over the period of 1970-2014 by focusing on country-specific analysis. To that end, both the linear and nonlinear Granger causality methods are applied. Our approach allows us to offer deeper insights on the nature of any causal link between taxation and economic growth. From a policy viewpoint, such an investigation is invaluable for the implementation of any relevant policy measures. If, for example, there exists unidirectional causality running from taxation to economic growth, the country would have to implement expansive tax policies. However, if unidirectional causality runs from economic growth to taxation or if there is no causality in either direction, conservative tax policies can be implemented without any adverse effect on economic growth. If there is bidirectional causality between any of these variables, then they are mutually affected and policies need to take into account that any change in one will impact the other.

Table 1 Empirical studies on the causal relationship between taxation and economic growth

Author (s)	Countries	Periods	Methodologies	Causality relationship
Anastassiou and Dritsaki (2005)	Greece	1965-2002	Johansen–Juselius, VECM ; Granger causality test	TTR→DLGDP, DT→DLGDP
Mashkoo et al. (2010)	Pakistan	1973-2008	ARDL bounds test; Granger causality test	DT→DLGDP
Taha et al. (2011)	Malaysia	1970-2009	Johansen–Juselius, VECM ; Granger causality test	DLGDP→ TTR
Ray et al. (2012)	India	1951-2012	Johansen–Juselius, VECM ; Granger causality test	TTR↔GDP, IT↔ GDP
Keho (2012)	Côte d'Ivoire	1960-2006	ARDL bounds test; Granger causality test	TTR→DLGDP
Karagianni et al. (2012)	USA	1948:1-2008:4	Hiemstra -Jones's non-linear granger causality test Diks–Panchenko's non-linear granger causality test	Hiemstra -Jones's non-linear granger causality test TTR→DLGDPN, TPI→DLGDPN, TOPIMP→DLGDPN and TCI→DLGDPN Diks–Panchenko's non-linear granger causality test TOPIMP→DLGDP
Tiwari (2012)	USA	1947:1-2009:3	Breitung-Candelon's frequency domain approach	TTR→GDP
Arikan and Yalcin (2013)	Turkey	2004Q1-2012Q1	Johansen–Juselius, VECM ; Granger causality test	TTR→GDP, TPI→GDP, IT↔GDP, VADT→GDP and GDP→DT
Takumah (2014)	Ghana	1986-2010	Johansen–Juselius, VECM ; Granger causality test	TTR→GDP
Canicio and Zachary (2014)	Zimbabwe	1980-2012	Johansen–Juselius, VECM ; Granger causality test	TTR≠ DLGDP
Taha and Loganathan (2014)	Malaysia	1975-2012	ARDL bounds test; Granger causality test	TTR↔GDP

Author (s)	Countries	Periods	Methodologies	Causality relationship
			Standard Granger causality test; Toda–Yamamoto procedure;	Standard Granger causality test TTR→DLGDPN
Tiwari and Mutascu (2014)	USA	1947Q1-2009-Q3	Nishiyama et al.'s non-linear granger causality test	Nishiyama et al.'s non-linear granger causality test TPI→DLGDPN, TOPIMPGDP→DLGDPN
Abdullah and Morley (2014)	23OCDE countries	1995-2006	Panel cointegration and error correction techniques; Granger causality test	ENT'→GDPN (short-run causality) GDPN→ ENT' (long-run causality)

Notes: →, ↔ and ≠ indicate unidirectional causality, bidirectional causality, and no causality, respectively. Abbreviations are defined as follows: VECM=vector error correction model, ARDL=autoregressive distributed lag, TTR =total tax revenue of government, DT=direct tax, IT=indirect tax, TPI =taxes on personal income revenue, TCI = taxes on corporate income, TOPIMP =taxes on production and imports, VADT= value added tax, ENT= environmental taxes, GDP= real gross domestic product, DLGDP= GDP growth rate, GDPN= per capita GDP, DLGDPN = per capita GDP growth rate.

3. Methodology

This section outlines the methodology adopted to untangle the linear and nonlinear causality between a set of alternative tax burden ratios and economic growth. The first sub-section briefly introduces the linear Granger causality test in the sense of Toda and Yamamoto (1995) and the second sub-section presents the nonlinear Granger causality test of Kyrtsou and Labys (2006).

3.1. Toda-Yamamoto linear Granger causality approach

Following the seminal contribution of Granger (1969), various versions of Granger causality tests have been proposed by researchers to examine the short-run causal relationship between variables (Sims et al., 1990; Toda and Phillips, 1993; Toda and Yamamoto 1995; Dolado and Lutkepohl, 1996). Among those, Toda and Yamamoto's non-causality test has attracted a great deal of interest over the years in both empirical and theoretical studies. One of its greatest assets is that it does not require pre-testing for integration or cointegration properties of the Vector Auto-Regression (VAR) system and thus avoids the potential biases of pre-testing that undermine traditional causality tests (Rambaldi and Doran 1996, Zapata and Rambaldi 1997, Clark and Mirza 2006). In other words, unlike the standard Granger causality test, the Toda–Yamamoto technique fits a standard VAR on levels of the variables and not on their first differences, thereby minimizing the risks perhaps associated with misidentifying the orders of integration of the series or the presence of cointegration. In addition, it minimizes the possibility of distorting the test size, which frequently results from pre-testing (Giles, 1997; Mavrotas and Kelly, 2001).

The approach developed by Toda and Yamamoto (1995) employs a modified Wald (MWALD) statistic for testing linear restrictions on the coefficients in an augmented VAR ($k+d_{max}$) model, where k is the optimal lag order in the VAR system and d_{max} is the maximal order of integration in the model. The MWALD statistic follows an asymptotic χ^2 distribution with k degrees of freedom ($\chi^2(k)$). Two steps are involved with implementing the procedure. In the first step, the optimal lag length (k) and the maximum order of integration (d_{max}) of the series under consideration have to be determined using one of the information criteria methods. Such step is crucial as it avoids spurious causality or spurious absence of causality (Clark and Mirza, 2006). The selected VAR(k) is then augmented by the maximal order of integration and a VAR of order ($k + d_{max}$) is estimated. In the second step, the modified Wald test is applied to the first k VAR coefficient matrix (but not all lagged coefficients) to conduct inference on Granger causality.

In accordance with that approach, the taxation-economic growth model is represented with the following VAR system:

$$TAX_t = \alpha_0 + \sum_{i=1}^k \alpha_{1i} TAX_{t-i} + \sum_{j=k+1}^{k+d_{max}} \alpha_{2j} TAX_{t-j} + \sum_{i=1}^k \gamma_{1i} EG_{t-i} + \sum_{j=k+1}^{k+d_{max}} \gamma_{2j} EG_{t-j} + \varepsilon_{1t}, \quad (1)$$

$$EG_t = \beta_0 + \sum_{i=1}^k \beta_{1i} EG_{t-i} + \sum_{j=k+1}^{k+d_{max}} \beta_{2j} EG_{t-j} + \sum_{i=1}^k \phi_{1i} TAX_{t-i} + \sum_{j=k+1}^{k+d_{max}} \phi_{2j} TAX_{t-j} + \varepsilon_{2t}, \quad (2)$$

where, TAX denotes an indicator of taxation, EG refers to the GDP per capita. ε_{1t} and ε_{2t} are error terms that are assumed to be white noise with zero mean, constant variance and no autocorrelation.. From Equation (1) Granger causality from EG_t to TAX_t implies $\gamma_{1i} \neq 0 \forall i$; similarly in Equation (2), TAX_t Granger causes EG_t if $\phi_{1i} \neq 0 \forall i$.

3.2. Kyrtsou-Labys nonlinear granger causality approach

One of the common criticisms of the linear approach to causality testing is that such tests fail to detect nonlinear causal relationships. Owing to this weakness, various nonparametric causality tests have been proposed in the literature. The earliest test is the one suggested by Baek and Brock (1992), which is based on the correlation integral, a measure of spatial dependence across time and is applied to the residuals of linear Granger causality models. One main shortcoming of this test is that it depends on the assumption that the variables are mutually independent and identically distributed (iid). This is relaxed in the study by Hiemstra and Jones (1994). They developed a modified test statistic for the nonlinear causality, which allows each series to exhibit short-term temporal dependence. To detect nonlinear causal relationships, the modified Baek and Brock test is applied to the residual series from a VAR model and not to the initial stationary variables as input in the model. However, as pointed out by Kyrtsou and Labys (2006), linear filtering of data using VAR methodology before the application of the Hiemstra and Jones test of nonlinear Granger causality can lead to serious distortions. To overcome this drawback, Kyrtsou and Labys (2006) proposed a new test procedure which could be used to detect a possible nonlinear causality relation between two time series.

To define nonlinear Granger causality, Kyrtsou and Labys (2006) propose a bivariate noisy Mackey-Glass model. Its general form is as follows:

$$TAX_t = \alpha_{11} \frac{TAX_{t-\tau_1}}{1 + TAX_{t-\tau_1}^{c_1}} - \beta_{11} TAX_{t-1} + \alpha_{12} \frac{EG_{t-\tau_2}}{1 + EG_{t-1}^{c_2}} - \beta_{12} EG_{t-1} + \xi_{1,t}$$

$$EG_t = \alpha_{21} \frac{TAX_{t-\tau_1}}{1 + TAX_{t-\tau_1}^{c_1}} - \beta_{21} TAX_{t-1} - \alpha_{22} \frac{EG_{t-\tau_2}}{1 + EG_{t-1}^{c_2}} - \beta_{22} EG_{t-1} + \xi_{2,t} \quad (3)$$

where $\xi_{2,t}$ and $\xi_{1,t} : N(0,1)$, $t = \tau, \dots, N$, $\tau = \max(\tau_1, \tau_2)$. β_{ij} and α_{ij} indicate the nonlinear and linear effects of the independent variables on the dependent variable,

respectively. τ_i is the integer delays, and c_i is the constants which can be chosen via prior selection. In this study, following the Kyrtsou and Labys's suggestion, the best delays (lags), τ_1 and τ_2 , are selected on the basis of likelihood ratio tests and the Schwarz criterion. The Kyrtsou and Labys's causality test is similar to the linear Granger causality test, except that the models fitted to the series are M-G processes.

The empirical implementation of the test is carried out in two steps. In the first step, the unconstrained model is estimated by ordinary least squares. To test reverse causality (i.e. from EG to TAX), in the second step a constrained model with $\alpha_{12} = 0$ is estimated. Let \hat{g} and \hat{v} the residuals obtained by the unconstrained and constrained best-fit M-G model, respectively. Thus, the corresponding sums of residual squares can be written as $S_u = \sum_{t=1}^T \hat{g}^2$ and $S_c = \sum_{t=1}^T \hat{v}^2$. Let $n_u = 4$ is the number of free parameters in the M-G model and on the other side $n_c = 1$ is the number of parameters required to be zero when estimating the restricted model. Evidently, the test statistic satisfies the following:

$$S_F = \frac{(S_c - S_u)/n_c}{S_u/(T - n_u - 1)} : F(n_c, T - n_u - 1), \tag{4}$$

where S_F is the test statistic.

Note that what we have just described is called the Kyrtsou–Labys “symmetric” version of the causality between TAX and EG. The “asymmetric” version of Kyrtsou–Labys test can be implemented by conditioning for positive or negative values of the causing series. Suppose, for example, that we test, in Eq. (3) whether non negative returns in the series EG cause the series TAX, an observation (EG_t, TAX_t) is included for regression only if $EG_{t-\tau_2} \geq 0$. The procedure is then run in similar way as defined before. Testing the reverse causality uses the same method with the order of series reversed.

4. Data and empirical results

4.1. Data

The annual data used in this study cover the period from 1970 to 2014 for 23 OECD countries. As is shown in the reviewed literature, an ample variety of alternative tax indicators have been used to investigate the taxation-economic growth nexus. Following Widmalm (2001), Arnold et al. (2011), Ojede and Yamarik (2012), and Xing (2012), among others, we adopt the internationally recognized classification of the OECD Revenue Statistics. More specifically, the current study is carried out using six indicators of tax burden: (i) total tax revenue as percentage of GDP (TTR), (ii) taxes on personal income as percentage of GDP (TPI), (iii) taxes on corporate income as percentage of GDP (TCI), (iv) taxes on goods and services as percentage of GDP (TGS), (v) Taxes on property as share of GDP (TPR), and (vi) social security contributions as percentage of GDP (SSC). All measured tax data are compiled from the

OECD Tax Revenue Statistics. Data on GDP per capita is obtained from the OECD National Accounts. A description of the data and definitions of the variables used in the empirical analysis is provided in Table A in Appendix. The descriptive statistics for our main variables of interest is shown in Table 2.

Table 2. Descriptive statistics

Country		Growth	TTR	TCI	TPI	TGS	TPR	SSC
Australia	Mean	31132	27,0	4,0	11,3	7,9	2,4	0,0
	Std.Dev	7511	2,4	2,4	1,3	0,7	0,2	0,0
	Max	44113	30,4	6,8	13,3	9,2	2,8	0,0
	Min	21372	21,1	2,3	7,9	6,6	1,9	0,0
Austria	Mean	31464	40,6	1,7	9,0	12,4	0,9	13,1
	Std.Dev	8063	2,0	0,4	0,8	0,5	0,3	2,0
	Max	43071	44,9	3,0	10,2	13,3	1,3	15,0
	Min	17524	33,9	1,1	7,0	11,5	0,5	8,6
Belgium	Mean	30052	42,5	2,6	13,4	11,0	2,0	13,3
	Std.Dev	7024	2,9	0,5	1,7	0,5	0,9	1,4
	Max	39832	45,3	3,5	16,1	12,2	5,1	14,9
	Min	17872	33,8	1,5	8,5	8,3	1,2	9,7
Canada	Mean	31974	58,0	3,1	11,7	9,1	3,4	4,3
	Std.Dev	6494	2,0	0,6	1,3	1,0	0,3	0,8
	Max	42139	4,39	4,3	14,5	11,2	3,9	5,1
	Min	20458	4,6	1,8	9,7	7,4	2,8	2,7
Denmark	Mean	33778	46,0	2,2	24,1	15,6	2,0	0,9
	Std.Dev	7264	3,7	0,9	1,9	0,8	0,3	0,4
	Max	44389	50,9	4,3	27,7	17,0	2,5	1,8
	Min	21971	38,4	0,9	18,9	13,2	1,6	0,1
Finland	Mean	27840	41,4	2,3	14,0	13,5	1,0	10,3
	Std.Dev	7889	4,3	1,2	1,0	0,8	0,2	3,0
	Max	40945	47,2	5,9	16,1	14,8	1,4	14,8
	Min	15241	31,6	0,3	12,3	11,4	0,7	2,8
France	Mean	28867	41,6	2,3	5,8	11,8	2,7	16,6
	Std.Dev	5979	3,4	0,4	1,7	0,7	0,7	1,8
	Max	17748	45,3	3,4	8,4	13,0	3,9	19,7
	Min	17748	33,6	1,5	3,3	10,6	1,0	12,4
Germany	Mean	31050	35,9	1,7	9,8	10,0	1,1	13,3
	Std.Dev	7313	1,2	0,3	0,8	0,5	0,2	1,3
	Max	42454	37,6	2,3	11,4	11,1	1,6	14,9
	Min	18727	31,5	0,6	8,0	9,0	0,8	9,6
Greece	Mean	22572	27,6	1,6	3,6	11,3	1,6	8,9
	Std.Dev	4604	1,1	1,0	1,1	1,5	1,1	1,9
	Max	32359	36,2	4,2	6,1	14,8	7,8	12,8
	Min	14271	18,3	0,3	1,7	8,4	0,7	5,3
Ireland	Mean	32464	40,6	1,7	9,0	12,4	0,9	12,3
	Std.Dev	7163	2,0	0,4	0,8	0,5	0,3	1,5
	Max	33071	44,9	3,0	10,2	13,3	1,3	12,2
	Min	14524	33,9	1,1	7,0	11,5	0,5	7,6
Italy	Mean	29052	42,5	2,6	13,4	11,0	2,0	10,3
	Std.Dev	6924	2,9	0,5	1,7	0,5	0,9	0,5
	Max	40832	45,3	3,5	16,1	12,2	5,1	11,9
	Min	18872	33,8	1,5	8,5	8,3	1,2	8,7
Japan	Mean	30974	28,0	1,5	11,7	9,1	1,1	4,3
	Std.Dev	6594	2,0	0,5	1,3	1,0	1,6	1,0
	Max	41139	39,0	3,4	14,5	11,2	4,6	5,2
	Min	23458	28,0	2,2	9,7	7,4	2,3	2,7

Country		Growth	T ^{TR}	T ^{CI}	T ^{PI}	T ^{GS}	T ^{PR}	SSC
Luxembourg	Mean	35778	46,0	2,2	24,1	15,6	2,0	1,0
	Std.Dev	7164	3,7	0,9	1,9	0,8	0,3	0,5
	Max	45389	50,9	4,3	27,7	17,0	2,5	1,9
	Min	22971	38,4	0,9	18,9	13,2	1,6	0,2
Netherlands	Mean	29840	41,4	2,3	14,0	13,5	1,0	9,3
	Std.Dev	8089	4,3	1,2	1,0	0,8	0,2	3,2
	Max	39945	47,2	5,9	16,1	14,8	1,4	13,5
	Min	16241	31,6	0,3	12,3	11,4	0,7	4,0
New Zealand	Mean	27867	41,6	2,3	5,8	11,8	2,7	15,5
	Std.Dev	6079	3,4	0,4	1,7	0,7	0,7	1,3
	Max	15748	45,3	3,4	8,4	13,0	3,9	18,3
	Min	15748	33,6	1,5	3,3	10,6	1,0	10,5
Norway	Mean	32050	35,9	1,7	9,8	10,0	1,1	13,3
	Std.Dev	6313	1,2	0,3	0,8	0,5	0,2	1,3
	Max	39454	37,6	2,3	11,4	11,1	1,6	14,9
	Min	15727	31,5	0,6	8,0	9,0	0,8	9,6
Portugal	Mean	19572	27,6	n	n	11,3	1,6	8,9
	Std.Dev	3904	1,1	n	n	1,5	1,1	1,9
	Max	30359	36,2	n	n	14,8	7,8	11,8
	Min	15271	18,3	n	n	8,4	0,7	5,3
Spain	Mean	32778	46,0	2,2	24,1	15,6	2,0	0,9
	Std.Dev	6964	3,7	0,9	1,9	0,8	0,3	0,4
	Max	46389	50,9	4,3	27,7	17,0	2,5	1,8
	Min	25971	38,4	0,9	18,9	13,2	1,6	0,1
Sweden	Mean	27840	41,4	2,3	14,0	13,5	1,0	10,3
	Std.Dev	7589	4,3	1,2	1,0	0,8	0,2	3,0
	Max	42945	47,2	5,9	16,1	14,8	1,4	14,8
	Min	14241	31,6	0,3	12,3	11,4	0,7	2,8
Switzerland	Mean	31050	35,9	1,7	9,8	10,0	1,1	13,3
	Std.Dev	7313	1,2	0,3	0,8	0,5	0,2	1,3
	Max	42454	37,6	2,3	11,4	11,1	1,6	14,9
	Min	18727	31,5	0,6	8,0	9,0	0,8	9,6
Turkey	Mean	22572	27,6	1,6	3,6	11,3	1,6	8,9
	Std.Dev	4604	1,1	1,0	1,1	1,5	1,1	1,9
	Max	32359	36,2	4,2	6,1	14,8	7,8	11,8
	Min	14271	18,3	0,3	1,7	8,4	0,7	5,3
UK	Mean	33778	46,0	2,2	24,1	15,6	2,0	0,9
	Std.Dev	7264	3,7	0,9	1,9	0,8	0,3	0,4
	Max	42389	50,9	4,3	27,7	17,0	2,5	1,8
	Min	23971	38,4	0,9	18,9	13,2	1,6	0,1
USA	Mean	25840	41,4	2,3	14,0	13,5	1,0	10,3
	Std.Dev	7589	4,3	1,2	1,0	0,8	0,2	3,0
	Max	41945	47,2	5,9	16,1	14,8	1,4	14,8
	Min	14241	31,6	0,3	12,3	11,4	0,7	2,8

4.2. Unit root tests

Before conducting any causality testing, it is necessary to identify the exact order of integration (d_{max}) of variables involved in our study. To accomplish this and to provide an analysis of sensitivity and robustness, this study performs two nonlinear unit root tests⁸, namely, the BBC test of Bec et al. (2004) and the KS test of Kapetanios and

⁸ As a benchmark exercise we begin through applying three different standard unit root tests, namely, the Dickey and Fuller (1979) (ADF), the Phillips and Perron (1988) (PP) and the Kwiatkowski et al. (1992)

Shin (2006)⁹. These tests are performed on a country-by-country basis. Results are given in table 3. With very few exceptions, the BBC and KS tests results suggest that, at the 5% significance level, all seven variables considered in this study are non-stationary in their levels but stationary in their first differences. This implies that the tax structure variables and GDP per capita levels are integrated of order one (I(1)).

In order to take into account the possibility of structural breaks in the data, the Zivot and Andrews (1992) (ZA) test allowing for an endogenous structural break was also conducted. The use of this test is entirely justified by the potential of structural change in the tax burden and economic growth series over the study period, which is characterized by turbulent economic and financial crises and extreme terrorist and geopolitical events. As shown in Table 4, for the 23 OCDE countries, the ZA test results support the hypothesis that all variables used in the analysis are integrated of I(1) at a 5% critical level and are thus appropriate for further analysis. In what follows, we assume all our series are unit root processes in levels and stationary in first differences.

Of note, for most of the countries in the sample, structural breaks around economic growth and taxation appear to have mainly occurred at the end of the 1990s and in the mid-2000s, which coincides with the period in which there was two important events: the terrorist attack of September 11, 2001 and the global financial crisis sparked by the US subprime market failures in mid-2007.

(KPSS). To conserve space, the results of these unit root tests are not reported here but are available from the authors upon request.

⁹ We thank an anonymous referee for suggesting the use of nonlinear unit root tests.

Table 3: Results of KS and BBC unit root tests.

Country		KS Test								BBC Test						
		Growth	TTR	TCI	TPI	TGS	TPR	SSC		Growth	TTR	TCI	TPI	TGS	TPR	SSC
Australia	Sup	0.465	0.521	0.356	1.145	0.599	0.379	n	Wald	8.719	7.286	15.25	9.552	4.297	7.649	n
	Ave	0.198	0.311	0.120	0.569	0.329	0.213	n	LR	8.242	6.719	13.01	8.606	4.091	7.922	n
	ExpAve	1.107	1.169	1.063	1.339	1.185	1.113	n	LM	7.507	6.209	7.220	7.220	3.898	7.220	n
Austria	Sup	0.470	0.854	1.445	0.492	0.510	0.394	0.854	Wald	23.17	8.697	40.28	2.977	9.899	3.565	8.697
	Ave	0.208	0.375	0.387	0.283	0.292	0.297	0.375	LR	18.53	7.920	28.42	2.879	8.909	3.425	7.920
	ExpAve	1.112	1.222	1.259	1.154	1.161	1.160	1.222	LM	15.05	7.234	15.05	2.784	8.046	3.292	7.234
Belgium	Sup	0.423	0.864	0.627	0.846	0.965	0.471	0.746	Wald	27.45	11.57	8.330	7.902	8.316	32.48	12.06
	Ave	0.237	0.518	0.249	0.481	0.495	0.277	0.344	LR	21.23	10.25	7.614	7.254	7.602	24.19	10.63
	ExpAve	1.128	1.312	1.137	1.289	1.291	1.151	1.194	LM	16.75	9.121	16.75	6.675	6.968	18.54	9.419
Canada	Sup	0.325	0.211	1.840	0.493	1.021	0.705	0.664	Wald	11.08	11.03	11.08	8.410	43.27	9.132	5.608
	Ave	0.169	0.147	0.676	0.195	0.280	0.359	0.318	LR	9.866	9.82	9.820	7.666	29.90	8.281	5.271
	ExpAve	1.088	1.077	1.464	1.105	1.173	1.202	1.180	LM	8.816	8.780	8.816	7.007	21.55	7.532	4.961
Denmark	Sup	0.163	0.335	0.476	0.329	1.130	0.163	0.977	Wald	15.69	9.158	4.496	11.58	14.73	6.375	6.866
	Ave	0.103	0.202	0.181	0.062	0.724	0.147	0.507	LR	13.38	8.303	4.276	10.25	12.67	5.945	6.370
	ExpAve	1.05	1.107	1.097	1.033	1.452	1.122	1.304	LM	11.50	7.550	4.070	9.124	10.97	5.552	5.920
Finland	Sup	1.166	0.399	0.798	1.514	0.294	0.729	0.439	Wald	27.53	5.692	20.21	34.92	11.01	2.995	12.43
	Ave	0.286	0.147	0.215	0.433	0.148	0.463	0.2016	LR	24.94	5.346	21.27	25.56	9.795	2.896	21.27
	ExpAve	1.178	1.078	1.122	1.279	1.077	1.264	1.108	LM	21.27	5.027	13.75	19.27	8.76	2.806	9.643
France	Sup	0.654	0.648	0.378	0.286	0.516	0.560	0.628	Wald	20.06	7.322	4.373	37.07	7.592	9.960	10.39
	Ave	0.207	0.404	0.232	0.127	0.227	0.353	0.273	LR	16.46	6.761	4.165	26.73	6.991	8.958	9.312
	ExpAve	1.114	1.225	1.124	1.066	1.122	1.198	1.152	LM	13.68	6.257	3.969	19.90	6.453	8.087	8.372
Germany	Sup	0.458	1.365	0.760	0.460	0.379	0.716	0.620	Wald	13.92	20.80	10.98	3.857	11.11	13.92	13.88
	Ave	0.216	0.718	0.468	0.243	0.187	0.556	0.342	LR	12.06	16.96	9.784	3.693	9.88	10.87	12.03
	ExpAve	1.116	1.456	1.269	1.131	1.099	1.323	1.193	LM	10.52	14.02	8.751	3.539	8.833	8.303	10.49
Greece	Sup	0.420	1.183	0.594	0.223	0.408	1.183	0.309	Wald	21.65	6.353	8.523	11.21	13.91	6.353	8.034
	Ave	0.151	0.644	0.223	0.115	0.151	0.644	0.090	LR	17.53	5.925	7.760	9.936	17.53	5.925	7.366
	ExpAve	1.080	1.396	1.122	1.059	1.080	1.396	1.047	LM	14.42	14.40	7.085	8.848	10.51	5.535	6.769

Country		KS Test								BBC Test						
		Growth	TTR	TCI	TPI	TGS	TPR	SSC		Growth	TTR	TCI	TPI	TGS	TPR	SSC
Ireland	Sup	0.568	0.840	0.718	0.401	0.178	0.717	0.767	Wald	16.73	10.07	9.680	9.063	4.781	16.73	13.78
	Ave	0.1624	0.263	0.287	0.151	0.126	0.530	0.3929	LR	14.13	9.054	8.730	8.223	4.533	2.126	11.95
	ExpAve	1.0895	1.148	1.159	1.081	1.065	1.307	1.223	LM	12.04	8.164	7.901	7.485	4.302	2.075	12.04
Italy	Sup	0.323	0.243	0.718	0.347	0.222	0.518	1.225	Wald	9.650	12.52	9.680	20.55	7.060	15.77	8.597
	Ave	0.147	0.149	0.287	0.321	0.179	0.193	0.404	LR	8.706	10.99	8.730	16.79	6.536	13.43	7.528
	ExpAve	1.077	1.077	1.159	1.174	1.093	1.105	1.237	LM	7.881	9.700	7.901	13.95	6.064	11.53	5.925
Japan	Sup	0.198	0.719	0.799	0.690	0.627	0.103	0.838	Wald	13.08	15.55	9.788	12.34	8.173	10.01	8.073
	Ave	0.119	0.370	0.391	0.327	0.501	0.110	0.455	LR	11.42	13.23	8.798	10.85	7.482	9.002	7.384
	ExpAve	1.061	1.219	1.221	1.184	0.325	0.057	1.265	LM	10.03	11.35	7.938	9.591	6.867	8.122	6.771
Luxembourg	Sup	0.994	1.006	0.590	0.137	1.498	0.342	0.707	Wald	28.35	7.031	13.94	8.227	8.815	9.267	5.034
	Ave	0.277	0.501	0.325	0.057	0.570	0.207	0.376	LR	21.77	6.512	12.07	7.528	8.019	8.392	4.761
	ExpAve	1.164	1.313	1.179	1.029	1.358	1.110	1.211	LM	17.08	6.043	10.52	6.90	7.315	7.624	4.507
Netherlands	Sup	0.838	0.719	0.454	1.861	0.389	0.401	0.293	Wald	31.36	16.31	6.992	16.61	6.759	6.512	9.963
	Ave	0.220	0.206	0.205	0.490	0.208	0.178	0.193	LR	23.42	13.78	6.467	14.02	6.267	4.245	8.940
	ExpAve	1.127	1.117	1.111	1.337	1.111	1.094	1.102	LM	17.95	11.75	5.994	11.90	5.822	3.757	8.052
New Zealand	Sup	0.684	0.809	0.407	0.172	0.176	0.314	0.000	Wald	7.198	18.87	10.97	7.378	124.6	4.432	8.973
	Ave	0.359	0.442	0.239	0.104	0.052	0.179	0.000	LR	6.655	15.65	8.173	6.810	58.51	4.218	7.482
	ExpAve	1.203	1.262	1.128	1.053	1.027	0.137	0.000	LM	6.166	13.11	7.528	6.298	31.972	4.018	7.060
Norway	Sup	0.759	1.016	0.650	0.706	0.541	0.404	1.210	Wald	21.93	42.46	11.533	25.65	8.511	4.829	21.38
	Ave	0.173	0.563	0.176	0.301	0.324	0.361	0.691	LR	17.72	29.53	10.21	20.12	7.766	4.577	17.35
	ExpAve	1.099	1.334	1.099	1.168	1.180	1.198	1.440	LM	7.105	21.36	9.094	16.07	7.105	4.341	14.28
Portugal	Sup	0.276	1.814	n	n	0.414	0.250	1.814	Wald	16.03	13.74	n	n	10.952	9.627	13.74
	Ave	0.114	0.874	n	n	0.190	0.103	0.874	LR	13.64	11.92	n	n	9.756	7.378	11.92
	ExpAve	1.059	1.687	n	n	1.101	1.054	1.687	LM	11.66	10.41	n	n	8.729	6.992	10.41
Spain	Sup	1.197	0.713	0.584	0.252	0.171	0.609	1.236	Wald	16.28	22.07	13.081	6.780	24.629	20.566	11.69
	Ave	0.275	0.226	0.192	0.124	0.076	0.233	0.697	LR	13.81	17.81	11.421	6.296	19.472	16.808	10.34
	ExpAve	1.169	1.126	1.105	1.064	1.039	1.128	1.457	LM	11.81	14.58	10.030	5.856	15.660	13.912	9.195

Country		KS Test								BBC Test						
		Growth	TTR	TCI	TPI	TGS	TPR	SSC		Growth	TTR	TCI	TPI	TGS	TPR	SSC
Sweden	Sup	0.366	0.940	0.707	0.358	0.485	0.982	0.698	Wald	33.30	6.769	13.655	8.357	18.414	28.879	11.10
	Ave	0.223	0.423	0.295	0.161	0.209	0.371	0.324	LR	24.66	6.286	11.859	7.637	15.327	22.093	9.876
	ExpAve	1.118	1.243	1.165	1.085	1.112	1.223	1.182	LM	18.76	5.848	10.364	6.997	12.893	17.276	8.824
Switzerland	Sup	0.343	1.519	0.1002	1.409	0.326	0.632	0.979	Wald	15.14	21.60	11.07	12.47	5.618	15.144	5.322
	Ave	0.244	0.624	0.061	0.665	0.180	0.541	0.428	LR	12.97	17.50	9.854	10.95	5.280	7.827	5.017
	ExpAve	1.130	1.402	1.031	1.439	1.095	0.314	1.248	LM	11.19	14.378	8.807	9.667	4.969	6.296	4.736
Turkey	Sup	0.718	0.461	0.519	0.491	1.084	0.655	0.650	Wald	17.35	13.18	7.167	10.58	17.351	3.298	8.020
	Ave	0.371	0.262	0.250	0.301	0.315	0.202	0.375	LR	14.57	11.58	6.628	9.460	14.576	3.178	7.354
	ExpAve	1.212	1.142	0.233	0.103	1.181	1.110	1.211	LM	12.36	10.21	6.143	8.491	12.362	3.063	6.759
UK	Sup	0.850	1.404	0.983	0.986	1.960	1.417	1.639	Wald	17.97	32.16	12.57	10.29	16.148	17.294	15.89
	Ave	0.224	0.747	0.417	0.601	0.700	0.671	0.841	LR	15.01	24.01	11.03	9.232	13.710	14.536	13.52
	ExpAve	1.130	1.474	1.242	1.357	1.552	1.412	1.581	LM	12.67	18.40	9.730	8.308	11.73	12.334	11.60
USA	Sup	0.246	0.874	0.797	1.618	0.814	0.924	1.251	Wald	11.14	8.673	11.43	18.69	5.262	17.162	13.97
	Ave	0.136	0.581	0.454	0.718	0.536	0.624	1.298	LR	9.908	7.901	10.14	15.52	4.964	14.441	10.97
	ExpAve	1.071	1.344	1.259	1.458	1.312	1.374	0.879	LM	8.849	7.21	9.035	13.02	4.688	12.26	9.972

Critical values at 1%, 5% and 10% levels of significance for the Sup and Ave are 42.30, 10.94 and 6.01, respectively.

Critical values at 1%, 5% and 10% levels of significance for the ExpAve are 237.46, 20.18 and 7.49, respectively.

Critical values at 1%, 5% and 10% levels of significance for the Wald are 23.01, 18.4 and 16.181, respectively.

Critical values at 1%, 5% and 10% levels of significance for the LR are 22.232, 17.898 and 15.772, respectively.

Critical values at 1%, 5% and 10% levels of significance for the LM are 21.756, 17.63 and 15.587, respectively.

n= data not available.

Table 4: Results of Zivot unit root test.

Country		Growth		TTR		TCI		TPI		TGS		TPR		SSC	
		stat.	break	stat.	break	stat.	break	stat.	break	stat.	break	stat.	break	stat.	break
Australia	level	-5.272	1969	-3.28	2007	-3.14	1974	-3.514	1972	-3.714	1977	-6.308	n	n	n
	Δ	-3.502	1981	-5.28	2006	-7.09	2006	-4.275	1993	-3.79	1991	-4.35	n	n	n
Austria	level	-2.400	1973	-3.48	2003	-4.63	1995	-3.519	1971	-5.89	1983	-6.30	1993	-2.650	1974
	Δ	-5.59	1982	-5.19	2000	-7.65	2002	-6.31	1980	-4.89	1986	-4.359	1992	-3.50	1971
Belgium	level	-2.725	1973	-4.12	1974	-4.74	1995	-3.822	1973	-9.94	1969	-4.00	1972	-2.758	1980
	Δ	-5.21	1981	-3.90	1978	-5.04	1991	-3.55	1978	-7.966	1970	-7.93	1969	-5.230	1986
Canada	level	-3.89	1995	-3.04	2001	-4.41	1996	-3.618	2001	-4.173	1979	-3.915	1987	-3.455	1980
	Δ	-4.386	1990	-4.99	1968	-4.68	1991	-5.18	1969	-4.75	1983	-4.68	1980	-5.18	1968
Denmark	level	-3.856	2006	-4.47	1982	-4.58	1999	-4.93	1965	-6.088	1976	-3.97	1989	-3.62	1972
	Δ	-5.604	1973	-4.61	1970	-5.35	2005	-5.89	1973	-5.057	1974	-5.37	1979	-4.904	1976
Finland	level	-2.647	1994	-3.14	2000	-4.89	1994	-3.25	1983	-3.795	1983	-5.86	1983	-2.971	1999
	Δ	-4.203	1991	-5.64	1995	-5.66	1999	-5.88	1975	-5.28	1975	-5.823	1988	-4.999	1993
France	level	-3.531	1973	-3.66	1978	-3.99	1996	-6.93	1997	-3.53	1981	-4.406	1983	-3.290	1974
	Δ	-4.730	1998	-3.49	1973	-6.42	2000	-4.47	2000	-3.467	1976	-5.696	1991	-3.32	1992
Germany	level	-5.005	1981	-4.46	1995	-4.19	1984	-4.91	1990	-4.83	1979	-3.992	2000	-4.049	1998
	Δ	-5.813	1984	-5.33	1999	-4.81	1989	-5.10	1999	-4.538	1988	-5.255	1968	-4.597	2002
Greece	level	-3.253	2007	-3.68	2003	-2.94	1997	-3.33	1978	-3.74	1983	-5.871	1995	-3.193	1973
	Δ	-4.999	2004	-5.11	1999	-5.78	1999	-4.01	1992	-5.893	1992	-7.29	1996	-4.87	1997
Ireland	level	-3.142	1994	-4.61	1982	-3.39	1990	-2.62	1974	-5.064	1979	-3.64	1976	-3.19	1973
	Δ	-3.83	2005	-5.50	1987	-4.83	2005	-7.39	1987	-4.616	1985	-5.438	2005	-4.874	1973
Italy	level	-3.065	1998	-3.36	1979	-3.24	1997	-3.17	1979	-3.524	1985	-4.297	1991	-5.98	1997
	Δ	-4.710	2005	-5.23	1982	-5.87	1991	-4.13	1972	-4.36	1978	-4.659	1994	-5.515	1996
Japan	level	-4.56	1968	-4.01	1991	-3.71	1991	-4.24	1993	-4.61	1996	-3.076	1980	-3.123	1989
	Δ	-5.179	1977	-6.00	1988	-5.62	1988	-4.81	1990	-4.28	2000	-5.61	1987	-3.651	1981
Luxembourg	level	-2.387	1984	-4.61	1974	-3.64	2003	-3.317	1974	-4.88	1979	-4.79	2007	-6.139	1974
	Δ	-3.921	2005	-4.97	1977	-6.33	1991	-3.792	1982	-5.061	1969	-6.90	1999	-4.94	1972

Country		Growth		TTR		TCI		TPI		TGS		TPR		SSC	
		stat.	break	stat.	break	stat.	break	stat.	break	stat.	break	stat.	break	stat.	break
Netherlands	level	-2.028	1982	-2.61	1970	-3.51	2008	-4.253	1993	-4.344	1976	-2.765	2007	-3.034	1995
	Δ	-4.499	2006	-6.72	1992	-4.89	1998	-3.48	1992	-6.37	1987	-4.19	1974	-5.430	2004
New Zealand	level	-4.487	1986	-4.42	1983	-3.58	1972	-4.239	1970	-6.73	1981	-2.93	2002	-3.123	1987
	Δ	-5.022	1974	-3.9	1978	-4.40	2000	-5.08	1976	-3.930	1986	-5.144	1997	-6.139	1996
Norway	level	-4.092	1992	-4.07	1970	-4.02	1986	-4.34	1981	-4.27	1999	-3.99	1986	-4.33	1970
	Δ	-8.57	2005	-9.05	1992	-4.93	2007	-5.105	1984	-5.54	1971	-4.29	1990	-5.030	1974
Portugal	level	-2.703	1985	-3.98	1990	n	n	n	n	-4.03	1979	-4.274	1974	-5.87	1974
	Δ	-4.397	1973	-6.04	1973	n	n	n	n	-5.814	1973	-4.747	1999	-6.755	1977
Spain	level	-2.490	1995	-3.51	1993	-3.92	2007	-2.66	1995	-3.91	1982	-4.090	2010	-3.92	1974
	Δ	-3.559	2005	-4.96	1988	-6.29	2006	-5.668	1991	-3.78	1979	-6.420	2006	-5.62	1980
Sweden	level	-2.644	1995	-3.89	1985	-4.07	1993	-3.729	1974	-4.87	1984	-4.04	1984	-3.758	1975
	Δ	-4.427	2005	-4.47	1989	-5.52	1993	-5.17	1994	-6.19	1990	-5.53	1980	-4.46	1980
Switzerland	level	-3.726	1984	-4.37	1979	-4.94	1993	-5.359	1983	-4.93	1992	-3.13	1999	-4.300	1998
	Δ	-4.893	1972	-4.58	1985	-5.98	1990	-4.985	1970	-5.131	1988	-4.02	1989	-5.344	1978
Turkey	level	-3.834	2002	-3.97	1995	-3.87	1989	-3.906	1974	-2.941	1995	-2.01	1978	-3.33	1998
	Δ	-4.811	1978	-6.22	2002	-5.49	1985	-3.76	1979	-5.96	2002	-6.61	1991	-3.83	1997
UK	level	-2.941	2006	-5.16	1990	-3.71	1979	-4.52	1981	-4.364	1979	-4.824	1989	-4.10	1988
	Δ	-5.348	2005	-6.40	1992	-4.46	1984	-6.588	1975	-4.519	1978	-5.637	1991	-5.030	1985
USA	level	-3.620	2006	-4.51	1995	-4.20	1979	-4.310	2001	-3.697	1989	-4.62	1977	-0.019	1973
	Δ	-5.602	1980	-5.66	1970	-4.29	1982	-5.39	1999	-5.64	1978	-5.16	1983	-5.754	1972

Critical values at 1%, 5% and 10% levels of significance for the ZA are - 5.34, - 4.8 and - 4.58, respectively.

n= data not available

4.3. Linear causality test results

Having established the integration properties of each of the variables under consideration we apply the Toda and Yamamoto (1995) approach to causality testing. However, it is also well known that this testing method is very sensitive to the number of lags included in the regression. Thus, prior to causality analysis, we need to determine the appropriate lag length for the various models. To that end, we employed four lag selection information criteria commonly used in the literature, namely the Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), Final Prediction Error (FPE) and Hannan Quinn (HQ) information criterion. To conserve space, these results are not reported here but are available from the authors upon request.

Tables 5 and 6 report results of the Granger non-causality test from the Toda and Yamamoto (1995) procedure. The MWALD test statistics regarding the causal relationship from tax burden ratios to growth in the twenty-three OECD (rows) that conform our sample and their corresponding significance levels are presented in Table 5. Of the 23 countries, the results show that none of tax variant Granger-causes economic growth in the cases of Finland and Norway. Besides, the same picture is observed for Australia, Austria, Belgium, Denmark, France, Italy, Spain, Switzerland, the UK, and the USA, in which only one of the tax burden proxies cause economic growth. Similar findings for the United States are reported in Tiwari and Mutascu (2014). For Ireland and Turkey, on the contrary, we found greater evidence against the null hypothesis of an absence of Granger causality from taxation to growth. In fact, for each of these two countries, Granger causality was detected in four out of the six proxies of tax structure. For the remaining nine countries, the absence of a causal link from tax structure to economic growth is rejected in two out of the six proxies of tax structure.

Table 6 reports the results regarding the presence of a causal link from growth to tax structure. The significance of the q values for the MWALD statistic provides evidence against the null hypothesis of no causality running from per capita GDP to the total tax burden as a percentage of GDP in Australia, Belgium, Denmark, Germany, Greece, Ireland, Italy, Japan, New Zealand, Switzerland, and the USA. This evidence is even stronger—in terms of number of countries and significance levels—for the tax burden on corporate income as a percentage of GDP. Moreover, the evidence favorable to a causal link from growth to tax burden on social security contributions as a share of GDP is mainly found in the countries involved in our study (Canada, Germany, Ireland, Japan, Netherlands, Spain, Switzerland, and the USA). It can also be observed that the null hypothesis of the lack of causality from growth to tax burden ratios cannot be rejected in Austria, Luxembourg, and Sweden for any of the tax structure indicators analyzed.

Taken together, the results displayed in Tables 5 and 6 reveal the following findings. Based on the total tax burden (as a share of GDP) as a proxy of taxation, we found evidence of linear Granger causality for fourteen countries. More specifically, in Australia, Belgium, Denmark, Germany, Japan, Switzerland, and the United States, causality runs from economic growth to total tax burden; in Portugal, Sweden, and Turkey, causality runs from taxation to economic growth, and in Greece, Ireland, Italy, and New Zealand, we found that taxation and economic growth are mutually causal. While using the tax burden on goods and services (as a percentage of GDP) as an indicator of tax burden, the results indicate that there is a unidirectional causality running from tax structure to economic growth in Belgium, Portugal, and the USA.

However, in the case of Greece, Norway, and the UK, causality runs from economic growth to tax structure. A bidirectional causal relationship between the variables of interest was also found in Germany. Turning now to the tax burden on personal income as a share of GDP as a proxy for tax burden, the results show evidence of unidirectional causality running from taxation to economic growth in Luxembourg and Netherlands, whereas unidirectional causality runs from economic growth to taxation in Australia, Germany, Japan, and the USA. The feedback hypothesis also exists in Ireland and Turkey.

The results from Toda–Yamamoto Granger-causality tests also show a unidirectional causality running from tax structure to economic growth for Sweden and Switzerland once tax burden on corporate income as share of GDP is used as an indicator of tax structure. However, for Australia, Belgium, Canada, Finland, Germany, Ireland, Italy, Spain, and the UK, causality was running from economic growth to tax burden on corporate income. Moreover, a bidirectional causal relationship is reported for Denmark, France, Greece, and New Zealand. This latter achievement is not consensual in the literature, which usually only identifies the existence of a unidirectional causality running from tax burden indicators to economic growth (e.g. Anastassiou and Dritsaki, 2005; Tiwari and Mutascu, 2014).

On the other hand, however, when tax structure is proxied using tax burden on property as share of GDP, the results provide evidence of unidirectional causality running from tax burden to growth in Australia, Austria, Ireland, Japan, Luxembourg, Spain, and the UK, while a reverse relationship is found in Denmark, New Zealand, and Portugal. The feedback hypothesis was found only in the case of Canada. Whereas, the results using tax burden on social security contributions as percentage of GDP as a proxy for tax burden indicate that there is a bidirectional causal relationship between tax structure and economic growth in Canada, Germany, Ireland, Japan, Switzerland, and the USA. There is also evidence of a unidirectional Granger causality running from tax burden to from economic growth in Turkey, and from economic growth to tax burden in Netherlands, Spain, Switzerland, and the USA. Therefore, our results highlight that the causality link between tax structure and economic growth is sensitive to the indicator of tax structure chosen. These findings are somewhat consistent with those of Widmalm (2001) Arnold et al. (2011), and Ojede and Yamarik (2012), who show that results of the relationship between tax structure and growth are highly sensitive to the tax burden proxy used.

In sum, it can be stated that except for Ireland and Turkey, the results from the linear Granger causality tests do not provide strong evidence supporting the view that tax structure Granger-cause economic growth in the OCDE countries. These results differ from those in the studies by Anastassiou and Dritsaki (2005), Mashkoo et al. (2010), Keho (2012), Tiwari (2012), and Takumah (2014), which provided evidence of a unidirectional causal relationship running from a set of alternative tax burden to economic growth. However, our results are quite consistent with the studies of Taha et al. (2011) and Arikan and Yalcin (2013).

This may imply the failure of prior linear tests in capturing the relationship between tax structure and economic growth. Therefore, as stressed earlier, we also apply a nonlinear approach in this study to further examine the issue.

Table 5: Results of linear Granger causality tests from taxes to economic growth

Country	Taxes → Growth					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	0.26	2.7	0.3	0.26	4.7*	n
Austria	0.86	1.9	1.7	3.3	5.9*	0.9
Belgium	1.1	7.7**	1.2	0.23	0.23	5.7
Canada	0.15	0.13	0.45	0.33	5.7*	14.6***
Denmark	0.88	2.5	3.5	6.0**	0.88	1.3
Finland	0.99	1.2	0.26	3.9	0.82	1.4
France	1.8	4.0	0.36	6.0**	3.7	0.49
Germany	0.12	7.2**	2.5	0.57	0.42	8.8*
Greece	5.1*	0.031	1.8	9.4***	0.49	3.8
Ireland	4.7*	3.3	5.0*	0.67	8.9***	10.6***
Italy	5.2*	0.78	4.8	0.67	1.4	3.4
Japan	3.8	3.7	2.1	1.7	13.2*	19.3***
Luxembourg	0.44	4.1	6.3**	1.2	21.2***	0.072
Netherlands	2.8	1.6	8.4*	4.7*	2.7	4.4
New Zealand	9.6**	1.4	4.4	9.3*	7.3	0.37
Norway	0.034	1.5	1.2	2.8	0.64	2.9
Portugal	6.6**	7.5**	n	n	0.26	1.2
Spain	1.4	2.7	0.67	6.3	11.4***	0.65
Sweden	5.8**	0.017	4.3	4.9*	0.41	1.0
Switzerland	0.62	2.0	2.2	21.3***	2.2	2.2
Turkey	8.9*	3.9	13.9***	2.7	6.2**	6.2**
U K	0.77	3.7	1.9	2.5	9.2*	0.38
USA	1.8	6.2**	2.3	2.3	3.6	3.2

*, ** and *** denote significance level at 10%, 5% and 1%, respectively
n= data not available

Table 6: Results of linear Granger causality tests from economic growth to taxes.

Country	Growth → Taxes					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	28.5***	1.5	17.1***	28.5***	3.7	n
Austria	1.4	0.66	3.8	5.2	1.2	1.9
Belgium	17.2***	1.2	0.53	4.6*	0.27	2.3
Canada	1.2	0.43	3.5	7.4**	11.2***	10.0**
Denmark	6.2**	1.3	3.6	6.2**	6.2**	0.029
Finland	0.86	1.9	0.085	7.7**	0.97	1.7
France	1.2	4.5	1.7	8.5***	0.81	1.7
Germany	8.1***	12.0***	10.7***	14.2***	4.2	9.5*
Greece	6.0**	13.5***	1.6	7.2**	1.4	0.77
Ireland	4.6*	2.7	6.7**	7.1**	0.16	6.7**
Italy	4.7*	2.5	1.6	7.5**	0.85	0.97
Japan	11.4**	1.7	12.5***	6.7	1.2	9.3**
Luxembourg	0.012	1.2	1.3	0.094	2.5	1.7
Netherlands	0.97	0.23	1.7	7.6**	1.4	8.9**
New Zealand	11.0**	0.77	1.8	15.7**	11.7***	1.9
Norway	2.2	5.9**	0.07	2.6	0.67	1.5
Portugal	0.13	0.99	n	n	28.5***	1.8
Spain	3.2	4.6	1.4	10.8***	1.1	5.5*
Sweden	0.47	3.3	1.9	0.47	2.2	0.19
Switzerland	23.1***	4.5	3.3	1.3	3.3	10.2***
Turkey	5.5	7.2**	6.8*	1.3	5.3*	4.1
U K	0.81	6.3**	1.4	5.4*	0.028	0.37
USA	14.0***	0.14	12.4***	0.3	3.2	15.6***

*, ** and *** denote significance level at 10%, 5% and 1%, respectively.
n= data not available

4.4. Nonlinear Granger causality test results

As has been discussed in Section 3, the above linear causality test can detect linear relationships among the variables; however, it may overlook complex nonlinear relations. Thus, we also apply the nonlinear Granger causality test in the sense of Kyrtsou and Labys (2006)¹⁰. We firstly perform the symmetric version of the test and report the results in Tables 7 and 8. The results displayed in Table 7 indicate that none of the tax burden proxy variables causes economic growth in the cases of Australia, Austria, France, Italy, Luxembourg, Spain, Switzerland, and the USA. As for Germany, Sweden, Turkey, and the UK, however, we found strong empirical support for a nonlinear causal link from tax structure to growth. In fact, for each of these cases listed above, Granger causality was detected in three out of the six tax structure indicators. Nevertheless, in these countries, the results do not show a uniform structure. For instance, while tax burden on corporate income as well as tax burden on property Granger cause growth in Germany and Sweden, either tax burden on social security contributions or tax burden on property cause economic growth in Turkey and the UK.

Compared to the linear Granger causality test result, the nonlinear test result for Turkey is consistent. For Germany, Sweden, and the UK, the results are in sharp contrast to those obtained by the Toda-Yamamoto test that show no causal relationship running from tax structure indicators to economic growth. These results confirm that the causal relationship between tax structure and economic growth is not strictly linear but also nonlinear. However, it is worth noting that such findings deserve further substantive investigations which would help to support or refute the results presented here.

As regards the causality from economic growth to tax structure (Table 8), the results clearly indicate that at 10% significance level, tax structure is not sensitive to economic growth in Austria, Germany, Italy, Luxembourg, Netherlands, Portugal, and the USA in which none of the tax burden indicators is associated with the per capita GDP. For the remaining 16 countries, however, the results provide evidence (albeit weak) in favor of a causal link from economic growth to tax structure. Most notably, this evidence is even stronger in Finland and Japan in which four out of the six tax burden indicators are associated with the per capita GDP. Furthermore, albeit by only one of the indicators, a two-way Granger causality between tax structure and economic growth was observed in Turkey and the UK.

Next, in order to check whether the direction of changes in the investigated variables has a significant effect on their causal relationships, we carry out the asymmetric version of the Kyrtsou–Labys test¹¹. We report the results in Tables 9–12. Table 9 shows that there is a significant unidirectional causality at the 10% level, running from positive changes in tax burden to changes in per capita GDP (Austria, Canada, Finland, Germany, Greece, Portugal, Sweden, Turkey, the UK, and the USA)¹². By

¹⁰ The Kyrtsou and Labys (2006) non linear Granger causality test was carried out using R statistical Software.

¹¹ As an additional robustness, tax indicators are also measured as percentage of tax revenue and the results hold. The results are voluminous and, to conserve space, we do not report the results here; however, all results are available from the authors.

¹² In fact, for each of these seven countries, asymmetric Granger causality was detected in at least three out of the six proxies of tax structure.

contrast, tax burden reductions significantly cause per capita GDP changes in Germany, Greece, and the UK (see Table 10). On the other hand, the asymmetric causality results reported in Table 11 reveal that the null hypothesis of positive shock in per capita-GDP not causing tax burden changes cannot be rejected for Australia and Finland. However, the null hypothesis that negative per capita GDP shocks do not cause changes in tax burden cannot be rejected for Australia, Finland, and Sweden (Table 12). Taken together, changes (negative or positive) in either tax burden or per capita GDP induce adjustments in the value of the other variable.

In a final step, to make the results more robust, we use the asymmetric¹³ causality test recently proposed by Hatemi- J (2012). This test incorporates the idea behind the Toda and Yamamoto (1995) test by considering nonlinear effects and distinguishes between the effect of negative and positive shocks (see Hatemi-J, 2012, for details). The results of this test are presented in Tables 13-16¹⁴. The results in Table 13 indicate that the null hypothesis of positive shock in tax burden not causing similar shocks in per capita GDP cannot be rejected for Belgium, France, and Turkey. However, the null hypothesis that negative tax burden shocks do not cause negative shocks in per capita GDP can be rejected for all countries except for Denmark and Luxembourg (see Table 14). According to the results in Table 15, the null hypothesis of positive shocks in per capita GDP not causing similar shocks in tax burden cannot be rejected for Ireland and Sweden. On the other hand, a negative shock in per capita GDP is found to cause a similar shock in tax structure for Australia, Austria, Denmark, and Finland (see Table 16).

To sum up, according to the nonlinear (symmetric and asymmetric) Granger causality tests there seems to be evidence, albeit relatively weak, supporting the view that tax burden distribution is an important determinant of economic growth. These findings are complementary to those of Karagianni et al. (2012) and Tiwari and Mutascu (2014), who show that statistically significant relationships between tax structure and economic growth exist when allowance is made for nonlinearities. Thus, the results presented here reinforce the related literature in showing that tax structure and economic growth interact in a nonlinear and asymmetric fashion. Further research is also required to obtain more definitive results regarding both the existence of non-linearity or asymmetry and its nature.

On the basis of our results, it seems promising for future research to investigate the specific type of nonlinearities and asymmetries that characterize the relationship between tax structure and economic growth. It would also be interesting for future research to examine the impact of nonlinearity on the performance of the linear modeling techniques that have been employed so far in the related literature. This exercise could provide an explanation for the inconclusive results reported by previous research.

¹³ The authors would like to thank an anonymous reviewer for pointing us to this issue.

¹⁴ This test was carried out by using statistical software components written in GAUSS by Hatemi (2012).

Table 7: Kyrtsoú–Labys causality test results: from taxes to economic growth (symmetric case).

Country	Taxes → Growth					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	0.008	0.184	1.7	0.017	2.17	n
Austria	0.008	0.188	0.287	0.082	0.429	3.02
Belgium	0.0474	0.697	1.49	3.28*	1.15	0.361
Canada	0.348	0.267	1.06	0.33	0.266	7.46***
Denmark	1.57	0.0006	0.403	14.7***	0.336	3.2**
Finland	0.811	0.094	5.7***	0.0097	0.020	1.75
France	0.064	0.221	1.18	0.171	0.277	0.654
Germany	5.42***	1.61	1.08	9.44***	2.92*	1.03
Greece	3.2*	4.38***	1.1	0.155	0.106	0.617
Ireland	0.163	0.033	0.756	4.16***	0.201	0.814
Italy	0.0216	1.28	1.49	0.0685	0.541	0.971
Japan	1.59	1.02	2.37	7.51***	0.7	5.49***
Luxembourg	0.0517	0.042	1.03	0.784	0.177	0.063
Netherlands	5.28**	4.76**	0.296	0.685	0.61	0.246
New Zealand	0.0875	0.032	6.25*	1.16	0.446	0.499
Norway	0.185	0.104	1.2	1.11	8.71***	1.87
Portugal	0.319	0.178	n	n	20.8***	3.4*
Spain	0.076	0.0263	2.4	0.0817	0.0783	0.0427
Sweden	0.251	0.0674	5.32***	7.45***	8.23***	0.11
Switzerland	0.697	0.0838	0.0624	0.195	0.247	0.632
Turkey	0.199	0.475	4.49***	1.4	14.3***	4.49*
U K	3.28**	0.611	0.0161	0.513	8.57***	4.95**
USA	0.089	0.226	0.584	0.284	0.655	0.04

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

Table 8: Kyrtsoú–Labys causality test results: from economic growth to taxes (symmetric case).

Country	Growth → Taxes					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	4.42**	3.42**	2.53*	0.022	0.53	n
Austria	0.0208	0.054	0.584	0.943	0.238	0.289
Belgium	0.0928	2.95 *	0.996	0.552	1.1	0.169
Canada	0.106	0.829	2.56	7.4**	0.245	0.0015
Denmark	0.156	4.77**	3.99*	0.034	0.649	0.719
Finland	0.325	41.9***	4.96***	37.2***	1.74	9.37***
France	0.089	0.075	0.354	7.11***	1.17	1.83
Germany	0.314	0.483	1.25	0.229	0.347	2.03
Greece	0.221	0.335	0.929	0.144	0.217	8.21***
Ireland	0.021	0.033	0.0763	0.243	0.203	18.3***
Italy	0.109	1.55	0.161	0.757	4.27	0.839
Japan	3.46**	0.262	25***	0.0076	2.83*	2.82**
Luxembourg	0.152	0.14	0.209	0.021	0.453	1.05
Netherlands	0.0974	0.0754	0.269	0.349	0.355	0.632
New Zealand	0.111	0.199	16.2***	0.127	0.17	3.39*
Norway	3.04	0.585	0.0657	5.23**	2.16	4.53**
Portugal	1.18	2.07	n	n	0.0225	0.0222
Spain	6.39**	1.16	0.739	0.972	0.185	0.645
Sweden	0.208	47.6***	0.0657	1.03	2.2	1.11
Switzerland	3.42*	0.141	1.02	0.0514	1.07	1.32
Turkey	0.797	2.46	5.72***	0.158	0.104	0.402
U K	6.75***	0.37	0.855	0.569	0.0809	2.99
USA	0.104	0.338	1.97	0.121	0.184	0.17

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

Table 9: Kyrtsoú–Labys nonlinear causality test results: from taxes to economic growth (asymmetric case for positive changes in the tax variables).

Country	Taxes ⁺ → Growth					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	0.234*	3.561	3.457*	0.987	0.012	n
Austria	0.371	1.451*	0.678*	3.561	4.781*	1.453
Belgium	0.174	2.457	2.467	2.481**	3.451	2.123
Canada	0.138*	0.436	3.345**	0.009	3.768	5.673**
Denmark	2.517	0.321	5.983	1.652**	4.678	4.783*
Finland	1.161*	1.530**	0.458***	0.567	1.329	3.452
France	0.164	2.911	0.231	0.345	3.453	1.784
Germany	0.83**	4.312	5.673	7.453*	4.768**	3.875
Greece	1.82**	1.528*	4.563	1.876	3.675	6.567*
Ireland	0.613	0.303	7.453	4.567**	2.765*	4.784
Italy	0.0216	2.128	3.674	7.764	3.564	7.984
Japan	1.159	3.402	4.657	2.678*	1.562	4.561**
Luxembourg	2.531	3.842	1.03	0.784	0.177	0.063
Netherlands	0.728*	0.426**	0.296	0.685	0.61	0.246
New Zealand	0.235	2.147	0.285*	0.516*	0.414	2.234
Norway	0.176	2.567*	3.001	5.234	0.567***	0.435
Portugal	5.179*	1.758	n	n	8.345**	2.756**
Spain	0.056	0.123	4.12	0.117	3.173	1.427
Sweden	0.091*	3.634	0.345***	0.458**	6.543**	2.675
Switzerland	6.572	7.541**	0.412	1.562	3.731	1.871
Turkey	0.526	1.452	0.341***	2.356	6.879***	1.347*
U K	0.278**	0.191	0.681*	0.513	8.57***	0.45***
USA	2.289	1.236*	0.593*	0.872	0.595*	0.951

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

Table 10: Kyrtsoú–Labys nonlinear causality test results: from taxes to economic growth (asymmetric case for negative changes in the tax variables).

Country	Taxes ⁻ → Growth					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	0.918*	0.014	0.713	0.561	1.981*	n
Austria	0.672	3.123	3.451*	0.671	0.451	1.451*
Belgium	4.432*	0.671	3.281	0.451**	2.341	4.561
Canada	0.348	0.267	2.341*	2.457	5.342	4.215
Denmark	2.557	0.0006	2.453	5.861*	1.782	3.734
Finland	0.321	0.094	5.567*	4.542	0.457	0.431
France	2.064	0.221	0.987	3.543	4.876	5.873
Germany	5.42***	1.61	1.999	0.873**	0.459*	0.098*
Greece	1.221*	4.678***	2.675	9.564*	1.654	4.673
Ireland	0.163	0.033	0.674	2.567***	2.543	5.784
Italy	2.246	1.28	7.456	3.678	0.987	1.435
Japan	1.559	1.02	7.541	3.674**	0.137	5.491
Luxembourg	0.517	0.042	1.03	0.784	0.177	0.063
Netherlands	5.567*	4.76*	0.296	0.815	0.173	0.426
New Zealand	2.705	1.312	2.781**	0.251	1.521	0.678
Norway	0.932	0.134	0.810	3.431	3.371*	2.387*
Portugal	0.319	1.278	n	n	0.543*	1.971*
Spain	1.678	1.263	1.891	2.817	1.783	4.217*
Sweden	1.211	0.664	4.768	6.987***	4.345	0.923**
Switzerland	1.987	0.456	0.521	1.456	2.874	0.324
Turkey	0.348	2.345	0.452	4.741*	14.3	4.49*
U K	3.28	0.611	1.351	5.513*	3.561*	0.431**
USA	0.089	0.226	0.214	0.671	0.137	3.671

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

Table 11: Kyrtsou–Labys nonlinear causality test results: from economic growth to taxes (asymmetric case for positive changes in the economic growth variable).

Country	Growth ⁺ → Taxes					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	0.033*	4.921***	0.456	2.127*	3.561	n
Austria	2.451	3.781	6.812*	3.561	2.567*	2.781
Belgium	7.321*	0.415*	5.712	5.671	3.215	5.641
Canada	6.541	0.829	4.782*	7.821	3.651	7.541
Denmark	5.561*	5.671	8.941	5.824	8.715	8.531
Finland	12.751	4.451*	8.431	4.514*	1.562*	9.761**
France	3.512	1.451	3.561	3.541***	2.541	3.541
Germany	2.761	5.641	3.751*	6.871	4.651	3.761
Greece	3.876	1.751	2.871	3.751	5.751	2.714**
Ireland	3.781	3.671	8.651	3.562	0.092	4.671**
Italy	4.516	0.451*	3.751	4.456	0.098	4.871
Japan	1.486**	3.675	0.125**	0.931	3.652	3.671
Luxembourg	2.345	2.453	7.843	3.213	4.567	5.432
Netherlands	0.872	3.421	3.451*	2.451	3.541	2.345
New Zealand	0.678	0.985	9.567*	5.673	3.426	3.456**
Norway	1.345	5.567	6.785	3.456*	2.567	4.456***
Portugal	2.467	4.561	n	n	2.345	1.230
Spain	2.131	3.451	3.451	5.564	4.532	1.340
Sweden	3.984	31.34	4.531	3.451	3.451	4.431
Switzerland	4.432	1.234	2.345	3.332	5.432	3.321
Turkey	5.543	2.221	2.221***	3.321	1.324	1.321
U K	4.453**	1.345	1.357	2.348	3.456	5.678
USA	1.346	3.456*	7.564	1.121	5.467	1.657

, ** and * denote significance level at 10%, 5% and 1%, respectively. n= data not available*

Table 12: Kyrtsou–Labys nonlinear causality test results: from economic growth to taxes (asymmetric case for negative changes in the economic growth variable).

Country	Growth ⁻ → Taxes					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	4.781*	5.12**	6.731**	3.731	2.561	n
Austria	3.541	6.871	0.584	9.431	2.638	2.789
Belgium	8.341	0.421*	0.862	5.751	6.513	6.341*
Canada	3.872	8.842	4.651	7.823**	3.421	5.851
Denmark	5.531*	1.541**	3.561	3.814	8.451	4.451
Finland	3.755*	5.762**	6.872***	2.541**	5.751*	7.841*
France	7.321	3.751	3.651	2.761*	2.651	3.761
Germany	4.761	1.521	3.741	0.675	7.982	0.782
Greece	0.761	3.363*	0.861	4.971	0.217	3.751*
Ireland	3.971	0.456	3.761	0.761	7.301*	6.841**
Italy	7.341	5.231	0.031	5.731	2.541	3.651
Japan	3.451	3.781	9.563*	0.984	3.756*	3.983
Luxembourg	5.431	4.321	0.567	0.984	1.435	3.245
Netherlands	0.531	3.453	2.451	4.326	2.456	1.458
New Zealand	0.111	3.458	5.567**	3.453	1.457	2.457
Norway	2.345	1.237	0.567	2.457	1.239	5.674
Portugal	3.892	0.094	n	n	3.451	1.398
Spain	3.987***	0.982	2.673	1.983*	0.098	1.894
Sweden	3.345*	5.674***	4.567	4.456	4.457*	4.321
Switzerland	4.443*	4.432	0.987	0.098	2.234	3.321
Turkey	2.234	1.345	3.456**	1.234	3.345*	2.234
U K	8.561*	1.345	4.654	1.342	0.875	1.234
USA	2.451	2.347	0.563	2.321	2.457	1.436

, ** and * denote significance level at 10%, 5% and 1%, respectively. n= data not available*

Table 13: Hatemi- J asymmetric causality test results using the bootstrap simulation technique (from positive shocks in tax burden variables to positive shocks in GDP per capita)

Country	Tax burden indicator $^{+} \rightarrow$ GDP per capita $^{+}$					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	0.594	2.507	0.013	4.320*	2.197	n
Austria	0.005	0.059	7.330	0.269	14.019**	10.644*
Belgium	0.581	0.218	0.032	16.784**	6.383**	19.896**
Canada	1.587	1.135	3.150	0.016	0.272	10.887**
Denmark	0.323	1.000	0.070	0.526	0.106	1.364
Finland	4.080	8.548*	1.187	4.933	3.209	0.337
France	1.811	0.006	7.363**	17.421**	4.263*	0.073
Germany	3.607	0.144	0.537	1.020	0.034	0.024
Greece	4.115	4.007	0.260	0.360	9.483	0.001
Ireland	7.809	4.754	29.222**	2.727	4.088*	0.451
Italy	4.783*	0.065	8.742*	1.379	0.080	1.416
Japan	5.533	5.922	4.719	0.665	1.297	0.986
Luxembourg	1.286	0.343	3.861	5.779	0.630	0.485
Netherlands	3.955*	0.953	1.090	1.027	7.713	0.286
New Zealand	0.163	0.098	0.085	0.406	0.300	0.001
Norway	0.128	1.489	2.851	13.170	0.801	1.675
Portugal	0.019	1.876	n	n	15.509**	1.742
Spain	1.970	68.846**	1.092	0.016	0.191	1.867
Sweden	0.131	9.610*	14.440	4.688	13.164	1.034
Switzerland	4.255	0.006	0.010	0.167	0.975	1.696
Turkey	16.113*	3.669*	38.429**	0.491	1.192	0.436
U K	0.005	4.303	4.298	1.589	8.650	1.157
USA	1.074	4.979	3.661	7.847	4.680	5.300

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

Table 14: Hatemi- J asymmetric causality test results using the bootstrap simulation technique (from negative shocks in tax burden variables to negative shocks in GDP per capita)

Country	Tax burden indicator $^{-} \rightarrow$ GDP per capita $^{-}$					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	0.330	0.156	1.225	7.140	7.728*	n
Austria	0.335	0.035	0.293	0.169	0.048	0.723
Belgium	0.110	2.568	0.068	1.246	2.893	0.002
Canada	0.720	0.009	0.092	1.665	8.985**	125.216***
Denmark	1.024	6.012*	5.786**	0.053	0.849	9481.305***
Finland	0.012	179.947***	0.075	0.000	77.645***	0.231
France	1.273	0.307	0.926	0.001	0.001	0.070
Germany	1.451	4.282*	4.602	2.872	4.673	0.024
Greece	1.313	1.455	0.575	2.483	0.843	2.382
Ireland	0.001	0.077	0.077	0.197	0.142	0.000
Italy	1.679	4.383*	0.755	1.269	0.008	1.345
Japan	4.365	4.371	0.000	0.002	0.000	0.001
Luxembourg	0.005	3.949*	0.014	5.078	21.968**	9.594*
Netherlands	0.410	1.527	3.671	0.039	6.878**	0.024
New Zealand	0.027	0.158	0.087	1.468	1.114	0.001
Norway	0.006	0.015	0.143	8.459	0.135	0.301
Portugal	0.138	0.694	n	n	2.299	107.168***
Spain	1.850	1.263	0.043	17.352	0.222	0.777
Sweden	0.052	1.824	0.138	0.397	0.063	0.150
Switzerland	0.019	4.561*	0.636	3.197	8.268*	0.010
Turkey	23.913	1.424	0.800	4.512*	10.909	0.502
U K	0.279	0.610	0.332	0.304	7.318	22.742***
USA	7.697	0.264	1.570	0.702	4.173	3.586*

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

Table 15: Hatemi- J asymmetric causality test results using the bootstrap simulation technique (from positive shocks in GDP per capita to positive shocks in tax burden variables)

Country	GDP per capita ⁺ → Tax burden indicator ⁺					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	3.961*	1.948	6.722**	0.060	5.492	n
Austria	0.864	0.170	7.538	3.128	9.872	12.645*
Belgium	1.010	1.002	0.000	1.157	0.084	2.540
Canada	2.092	0.038	2.171	5.647	0.095	2.253
Denmark	15.137***	0.312	0.030	3.772	21.646***	0.260
Finland	5.646	0.493	1.237	15.504**	2.512	0.928
France	2.268	2.664	3.592	6.082	1.175	0.011
Germany	9.422	0.946	15.156***	3.760*	0.066	0.632
Greece	3.000	4.652	3.472*	3.468	14.747*	0.046
Ireland	61.622***	85.201***	13.318*	10.972***	1.912	1.194
Italy	0.056	0.183	0.502	0.709	0.511	0.710
Japan	1.568	1.706	7.622	0.017	0.095	0.003
Luxembourg	1.500	1.619	3.855	1.692	0.059	0.371
Netherlands	3.034	0.410	23.858	1.960	2.897	0.434
New Zealand	1.805	2.141	0.854	3.072	4.746*	0.001
Norway	6.372**	5.668	5.903	8.499	8.112	54.000***
Portugal	0.273	4.110	n	n	7.330	1.415
Spain	4.781	1.151	0.909	13.945***	0.052	8.664
Sweden	0.062	6.076*	6.300	21.491**	16.259*	0.015
Switzerland	6.173	0.933	0.233	0.036	0.163	13.816*
Turkey	3.650	2.540	2.191	0.553	0.727	0.553
U K	0.363	1.809	4.680	0.107	8.278	0.255
USA	2.062	0.705	5.881	8.977*	2.838	1.953

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

Table 16: Hatemi- J asymmetric causality test results using the bootstrap simulation technique (from negative shocks in GDP per capita to negative shocks in tax burden variables)

Country	GDP per capita ⁻ → Tax burden indicator ⁻					
	TTR	TGS	TPI	TCI	TPR	SSC
Australia	10.666**	0.015	5.036*	47.441**	0.070	n
Austria	22.544***	2.441	0.739	4.952**	0.003	27.938***
Belgium	0.001	0.363	0.023	3.934*	0.474	0.000
Canada	2.148	0.972	3.534*	0.744	0.072	1.676
Denmark	5.253*	0.532	11.624**	0.065	6.036*	22.865*
Finland	31.355***	0.360	15.198**	0.027	0.187	6266.209***
France	0.225	1.319	0.738	0.091	0.016	0.011
Germany	2.319	0.931	1.893	1.413	2.443	0.225
Greece	2.069	0.558	9.588*	2.701	0.264	0.584
Ireland	0.004	0.002	0.186	0.513	0.493	0.164
Italy	1.401	0.010	0.678	1.099	11.905***	1.100
Japan	1.686	1.777	0.002	158.730***	0.000	0.001
Luxembourg	0.011	0.383	3.843*	25.641**	1.029	2.496
Netherlands	0.166	0.000	6.870	1.390	0.958	0.127
New Zealand	2.453	2.297	0.002	77.056***	1.526	0.001
Norway	0.000	3.029	1.016	67.766***	0.079	0.042
Portugal	0.007	0.001	n	n	5.446	20.848*
Spain	0.003	0.064	0.042	1.610	0.958	0.468
Sweden	0.075	1.610	0.022	0.627	0.044	0.026
Switzerland	1.679	1.679	0.035	4.820	0.163	0.001
Turkey	8.868	8.968	1011.912***	0.021	1.104	1.038
U K	0.323	0.323	2.327	2.012	0.677	0.088
USA	2.021	2.021	11.301**	3.190	2.524	25.542***

*, ** and *** denote significance level at 10%, 5% and 1%, respectively. n= data not available

5. Conclusions

Since the early 1950s, the relationship between taxation and economic growth has been subject of debate, both in policy as well as academic circles. Even so, the available evidence on the direction of the causality so far, remains elusive. The aim of this study was to investigate the linear and nonlinear causal linkages between tax structure and economic growth in 23 OECD countries over the 1970-2014 period. To that end, we applied both linear and nonlinear causality tests to examine those relations. In particular, apart from the implementation of the modified version of the Granger causality test based on Toda and Yamamoto (1995), we employed the nonlinear and asymmetric causality test of Kyrtsou and Labys (2006), which, unlike the conventional Granger causality test, has the ability to detect nonlinear causal relationships between variables. Overall, the findings obtained from the nonlinear causality test tend to reject the neutrality hypothesis for the tax structure–growth relationship in 19 of the 23 OECD countries under consideration. In the majority of the countries under investigation, the evidence is in line with the growth hypothesis where causality running from economic growth to tax burden ratios was detected in Australia, Finland, Japan, New Zealand, and Norway. The opposite causality running from tax structure to economic growth was found in Germany, Netherlands, Portugal, and Sweden. In contrast, the neutrality hypothesis was supported in Austria, Italy, Luxembourg, and the USA, whereas the feedback hypothesis was supported in Turkey and the UK. As for the remaining countries, the results were inconclusive because they varied according to the tax burden indicator used. Additional robustness checks show that when the signs of variations are taken into account, there is an asymmetric causality running from positive tax burden shocks to positive per capita GDP shocks Belgium, France, and Turkey.

What the above divergent evidence may suggest is that the direction of causality between the variables of interest is subject to country-specific factors. Possible underlying factors could include human capital accumulation (Lucas, 1990; Mendoza et al., 1997; Milesi-Ferretti and Roubini, 1998), initial level of taxes (Barro, 1990; Barro and Sala-i-Martin, 1992,1995), budget composition (Alesina and Perotti, 1995; Alesina and Ardagna, 1998), tax regimes (Razin and Yuen, 1996), institutional quality (Bergh and Karlsson, 2010), among others. Other factors such as political institutions (Barro, 1990), political ideology (Angelopoulos et al., 2012), Gender equality (Potrafke and Ursprung, 2012), heritage of past institutions (Bauernschuster et al., 2012), government size (Facchini and Melki, 2013; Feris and Voila, 2015), and initial levels of economic development (Mueller, 2003; Forte and Magazzino, 2011; Christie, 2014) may also matter for the efficiency of public spending and production and in turn impact on the strength and causality direction of the taxation-growth nexus.

In such kind of analysis it is not possible to exhaust all the possible reasons behind the divergent causality results found in this paper among countries under consideration. It is believed that other variables could have great impact on the causal link between tax structure and economic growth. In fact, a growing body of evidence suggests that there are considerable variations among countries in their level of tax authorities' enforcement power, spending histories, shadow economy size, GDP magnitude, internal market size, access to outside markets, labor mobility, pace and pattern of innovation, political environments and so forth (see Mueller, 2003; Karagianni et al., 2012; Ojede and Yamarik, 2012). It is not therefore surprising to find

divergence in the direction of causality among countries; such kind of divergence is even common among developing as well as developed countries.

Nevertheless, it should be noted that the reasons advanced for the different directions of causality in our study can be viewed only as suggestive. Hence, further research is obviously needed to verify these hypotheses empirically. For that reason, we believe that there needs to be more work on understanding the theoretical and empirical aspects of the tax structure-economic growth relationship. Yet, as Kneller et al. (1999) and Bassanini et al. (2001) conclude, it would be highly relevant to shed further light on the channels through which different taxes and expenditure affect growth.

Some highlights can be drawn from the evidence presented in this study. First, the causal relation between tax structure and economic growth is not uniform across the OECD countries. Therefore, the study confirms that the homogeneity assumption in previous studies (Kneller et al., 1999; Folster and Henrekson, 2001; Arnold et al., 2011; Xing, 2012), even for rich countries, can result in misleading findings while analyzing the link between tax structure and economic growth. In addition, the link between taxation and economic growth is sensitive to the indicator of tax burden. Taken together, the results of this study indicate clear evidence of the nonlinear causality relation between these two variables. The neutrality hypothesis seems to be rejected for the majority of the 23 OECD countries studied during the 1970-2014 period.

Furthermore, regarding the empirical approach, the findings also highlight the importance of testing for nonlinear linkages in addition to linear ones. We found that while the linear causality test indicated that tax structure do not Granger-cause economic growth in Germany, Sweden, and the UK, there was evidence of nonlinear Granger causality for all three countries. Therefore, the existence of a dynamic nonlinear relationship between the two variables was established. In this respect, these results may be useful in future work, as they suggest that researchers should consider nonlinear empirical regularities when exploring the relationship between tax structure and economic growth.

In terms of policy implications, the results based on the asymmetric causality method are of particular interest as this approach shows that taxation-economic growth nexus is specific to each of the considered countries, requiring different fiscal and economic policies. When a country, such as Ireland for example, looks forward to spur its economic growth, by means of taxation, it is suitable to reconsider the taxes levied on personnel income or even on property, rather than, the taxation on goods and services and on corporate income. On the contrary, when stability and GDP growth sustainability are required and, a change in the taxation policy – i.e. for welfare purposes – is sought, it would be convenient for the tax authorities to readjust the tax burden on goods and services and on corporate income rather than, rebalance the tax burden distribution on property and, on personnel income. On the contrary, i.e. a change, affecting the taxes levied on personnel income or the tax burden on the property, could not keep the GDP per capita fixed at its initial level. On the other hand, for a country such as Australia where a positive shock in tax burden on corporate income is found to cause a similar shock in per capita GDP, policies formulated to increase tax rate on corporate income could lead to increased economic growth.

Despite our promising results, this study suffers from several limitations. First, the bivariate framework used here may be subject to the problem of potential omitted variable bias. Thus, this framework can be readily extended to other multivariate modeling frameworks, where tax structure and economic growth are also determined by

other economic factors such as initial levels of economic development, human capital accumulation, shadow economy size, and the quality of state institutions. Such an analysis helps disentangle the channels through which tax structure affects economic growth (and vice versa). A second area of fruitful future research would be to broaden the analysis of the taxes–economic growth nexus for semi-industrialized and developing countries. Finally, our study do not test for cointegration and provide only a short-run analysis of the relationship between tax structure and economic output. Therefore, another useful extension of this research would be to investigate the asymmetric long-run relationship between variables of interest. In these cases, asymmetric ARDL method, as pointed out by one of the Referees, may be an attractive alternative.

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Appendix

Table A: Definitions and sources of variables.

Variable name	Description	Sources	Selected studies which have used this variable
TTR (% GDP)	Total tax revenue as a share of GDP	OECD Revenue Statistics	Easterly and Rebelo (1993), Folster and Henrekson (2001), Gupta et al. (2005), Bergh and Karlsson (2010), Man et al. (2011), Xing (2012), Karagianni et al. (2012)
TPI (% GDP)	Taxes on individual income, profits and capital gains	OECD Revenue Statistics	Widmalm (2001), Angelopoulos et al. (2007), Tiwari (2012), Xing (2012), Ferede and Dahlby (2012), Karagianni et al. (2012), Tiwari and Mutascu (2014), Adkisson and Mohammed (2014)
TCI (% GDP)	Taxes on corporate income, profits and capital gains	OECD Revenue Statistics	Widmalm (2001), Angelopoulos et al. (2007), Ferede and Dahlby (2012), Tiwari (2012), Xing (2012), Karagianni et al. (2012), Tiwari and Mutascu (2014), Adkisson and Mohammed (2014)
TPR (% GDP)	Recurrent taxes on immovable property, net wealth, estates, inheritances and gifts, financial and capital transactions, non-recurrent taxes and other recurrent taxes on property	OECD Revenue Statistics	Widmalm (2001), Xing (2012), Adkisson and Mohammed (2014)
TGS (% GDP)	Taxes on goods and services, and other consumption taxes.	OECD Revenue Statistics	Widmalm (2001), Xing (2012)
SSC (% GDP)	Social security contributions (employees, employers, self-employed or non-employed)	OECD Revenue Statistics	Kneller et al. (1999), Widmalm (2001)
GDP per capita	GDP per capita (constant 2010 US\$)	OECD National Accounts	Folster and Henrekson (2001), Bergh and Karlsson (2010), Xing (2012), Tiwari and Mutascu (2014), Adkisson and Mohammed (2014)