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Taxation and Public Spending Efficiency: An International Comparison*

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Abstract

This paper evaluates the relevance of the taxation for public spending efficiency in a sample of OECD economies in the period 2003-2017. First, we compute the data envelopment analysis (DEA) scores and the Malmquist productivity index to measure the change in total factor productivity, the change in efficiency and the change in technology. Second, we explain these newly computed public efficiency scores with tax structures using a reduced-form panel data regression specification. Looking at the period between 2007 and 2017, our main findings are as follows: inputs could be theoretically lower by approximately 32-34%; the Malmquist indices show an overall decrease in technology and in TFP. Crucial for policymaking, we find that expenditure efficiency is negatively associated with taxation, more specifically direct and indirect taxes negatively affect government efficiency performance, and the same is true for social security contributions.

JEL: C14, C23, H11, H21, H50.
Keywords: government spending efficiency; public sector performance; tax structure; data envelopment analysis (DEA); Malmquist indices; non-parametric estimation; panel data; OECD

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1. Introduction

A country´s economic performance depends, inter alia, on the efficiency of its public sector. In fact, how governments raise and spend revenues affect both the economic and social development of countries. Even though governments have alternative sources of funding (e.g. transfers from the European Union (EU), in the case of the EU countries, social security contributions, and dividends from State Owned Firms), taxation is by far the main revenue source. According to ICTD/UNU-WIDER (2018), total tax revenues account for more than 80% of total government revenue in about half of the countries in the world, and more than 50% in almost every country. On the other hand, previous studies shows that government spending efficiency could be improved for OECD countries (see, for instance, Afonso et al., 2005, 2010, Adam et al., 2011, and Afonso and Kazemi, 2018). Importantly, one also needs to assess to what extent the specificities of a tax system can help, or not, the level of government spending efficiency. That is a topical issue that has been also receiving growing attention from academia and policymakers (see, notably, Afonso and Schuknecht, 2019).

In this study, we evaluate to what extent the structure and pattern of a country´s tax system are related to public spending efficiency in a sample of 36 advanced OECD economies in the period 2003-2017. To this end, we employ a two-stage methodology. In the first stage, we compute the Data Envelopment Analysis (DEA) scores and the Malmquist productivity indices to measure the change in total factor productivity, the change in efficiency and the change in technology. We use a set of metrics and construct composite indicators to relate outputs to inputs to measure government spending. In the second stage, we empirically evaluate whether the pattern and structure of taxes affect these input efficient scores obtained in the first stage, using a reduced-form panel data regression analysis.

Our results show that: i) input efficiency scores averaged 0.679 in 2003-2007, 0.665 in 2008-2012 and 0.667 in 2013-2017, implying that inputs could be theoretically lower by around 32-34%, keeping the same level of output; ii) between 2007 and 2017, there were efficiency gains for 47% of the countries; iii) between 2007 and 2017 there were some increases in efficiency, but the Malmquist indices show an overall decrease in technology and in TFP; iv) in the second step analysis, we find a negative effect of direct taxes on government performance; v) there is also a negative and significant effect on social security contributions with a magnitude similar to that of direct taxes or non-tax revenues; vi) a negative impact on efficiency from indirect taxes, with a higher magnitude than for the other tax items. These results have a direct implication for policy making, notably regarding the structure of taxation in place in a given country.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the methodology. Section 4 sets up the efficiency and productivity analysis. Section 5 reports the efficiency and tax structure analysis. The last section concludes.

2. Related Literature

The measurement of public sector efficiency and its determinants has been the subject of a growing literature, including key contributions by Afonso et al. (2005), Gupta and Verhoeven (2001) and Tanzi and Schuknecht (1997, 2000). These studies typically measured public sector efficiency by relating government expenditures to several socio-economic indicators usually targeted by public spending. To assess the efficiency of government spending, these studies estimated a non-parametrically production function frontier and derived efficiency scores based on the relative distances of inefficient observations from the frontier.[1] Although the majority of the

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[1] There are several parametric and non-parametric methodologies that have been used to compute technical efficiency. Parametric approaches include corrected ordinary least squares and stochastic frontier analysis (SFA). Among the non-

studies evaluated the overall efficiency of the services provided by the government, other focused on a particular public service, mostly education and health (see e.g. Afonso and Aubyn, 2006). Nevertheless, both streams of research suggest substantial efficiency differences between countries and possible spending savings for OECD and EU countries (see, notably, Adam at al., 2011, and Duti and Sicari, 2016, Afonso and Kazemi, 2017, and Antonelli and de Bonis, 2019) and Latin American and Caribbean countries (Afonso et al., 2013).

Recently, previous studies have begun examining the determinants of these cross-country efficiency differences. Since there are naturally exogenous and non-discretionary inputs that are contribute to each country's outputs, the literature several proposals a two-stage models to deal with this issue.[2] For example, Afonso et al. (2006) concluded that property right security, education, income level and civil service competence affect the public sector efficiency in new member states of the European Union; Hauner and Kyobe (2008) found that higher government efficiency tended to be associated with the income level, the share of transfers to local governments, with better governance and with the size of the total government expenditures; and Antonelli and de Bonis (2019) add that education, population size, welfare system and corruption affect government efficiency. Related to our topic, Chan et al. (2017) find that for a panel of more than 100 countries, value-added taxes (VAT) enhances the effect of efficient government spending on the economic growth. While the goal of the previous study was to evaluate how government spending efficiency affected economic growth, in our study we evaluate the extent to which taxes affect government spending efficiency.

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parametric techniques data envelopment analysis (DEA) and free disposal hull (FDH) have been widely applied in the literature.

[2] For instance, Ruggiero (2004) and Simar and Wilson (2007) provide an overview on this issue.

3. Methodology

3.1 DEA

DEA is a non-parametric technique,[3] which computes the production frontier for each Decision Management Units (DMUs). Therefore, each observation can be compared with an optimal outcome. For each DMU, in our case each country i, we consider the following function:

$$Y_i = f(X_i),\ i = 1, \dots, n \tag{1}$$

where Y is the composite output measure and X is the composite input measure, namely government spending to GDP ratio.

If $Y_i < f(X_i)$, it is said that country *i* exhibits inefficiency. For the observed input levels, the actual output is smaller than the best attainable one and inefficiency is measured by computing the distance to the theoretical efficiency frontier.

Considering, for the sake of illustration, an input orientation and assuming variable-returns to scale (VRS), the efficient scores are computed through the following linear programming problem: [4]

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ &s.t.\ -y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &I1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \tag{2}$$

[3] DEA is a non-parametric frontier methodology, which draws from Farrell's (1957) seminal work and that was further developed by Charnes et al. (1978). Coelli et al. (2002) and Thanassoulis (2001) offer introductions to DEA.
[4] This is the equivalent envelopment form (see Charnes et al., 1978), using the duality property of the multiplier form of the original model.

where y_i is a column vector of outputs, x_i is a column vector of inputs, θ is the efficient scores, λ is a vector of constants, $I1'$ is a vector of ones, X is the input matrix and Y is the output matrix.. In this linear problem, we have k inputs to produce m outputs for n DMUs.

In equation (2), θ is a scalar (that satisfies $0 \leq \theta \leq 1$) and measures the technical efficiency, the distance between a country and the efficiency frontier, defined as a linear combination of the best practice observations. With $\theta < 1$, the country is inside the frontier, it is inefficient, while $\theta = 1$ implies that the country is on the frontier and it is efficient. The vector λ measures the weights used to compute the location of an inefficient country if it were to become efficient, hence, maximizes productivity. The inefficient country can theoretically be on the production frontier as a linear combination of those weights, related to the country-peers of the inefficient country. The peers are other DMUs that are more efficient, and used as references for the inefficient country.

The restriction $I1'\lambda = 1$ imposes convexity of the frontier, accounting for VRS. Not using this restriction would amount to admit that returns to scale were constant and that all countries are operated at the optimal scale. VRS scores take into account the fact that countries might not operate at the optimal scale.

3.2 Malmquist TFPI

The production frontier and the efficiency scores usually change over time. Therefore, it is important to decompose that variation into changes attributed to efficiency and to the frontier changes. The output Malmquist total factor productivity index (Malmquist, 1953), *TFP,* allows this decomposition in an intuitive way.[5] For a given country, it is defined as follows:

[5] See Coelli et al. (1998) for a more detailed explanation of Malmquist TFPI

$$TFP_{t+1}(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{d_o^t(y_{t+1}, x_{t+1})}{d_o^t(y_t, x_t)} \times \frac{d_o^{t+1}(y_{t+1}, x_{t+1})}{d_o^{t+1}(y_t, x_t)} \right]^{1/2}, \tag{3}$$

where $d_o^t(y_s, x_s)$ is the output distance score using the frontier at year *t* and inputs and outputs related to year *s*. *TFP* may also be written as:

$$TFP_{t+1}(y_t, x_t, y_{t+1}, x_{t+1}) = \frac{d_o^{t+1}(y_{t+1}, x_{t+1})}{d_o^t(y_t, x_t)} \times \left[\frac{d_o^t(y_{t+1}, x_{t+1})}{d_o^{t+1}(y_{t+1}, x_{t+1})} \times \frac{d_o^t(y_t, x_t)}{d_o^{t+1}(y_t, x_t)} \right]^{1/2}, \tag{4}$$

or, equivalently,

$$TFP_{t+1} = EC_{t+1} \times TC_{t+1}, \tag{5}$$

where $EC_{t+1} = \frac{d_o^{t+1}(y_{t+1}, x_{t+1})}{d_o^t(y_t, x_t)}$ is the efficiency change index and $TC_{t+1} = \left[\frac{d_o^t(y_{t+1}, x_{t+1})}{d_o^{t+1}(y_{t+1}, x_{t+1})} \times \frac{d_o^t(y_t, x_t)}{d_o^{t+1}(y_t, x_t)} \right]^{1/2}$ is the technology change index. In a variable returns to scale framework as ours, the efficiency change index can be further decomposed into a scale effect and a pure efficiency effect.

Figure 1 illustrates the concept of Malmquist total factor productivity index. Consider that we are evaluating a DMU, a country in our analysis, in two points in time t and t+1. In both periods, the DMU production is less than feasible under each production frontier. The Malmquist index indicates the potential rise in productivity as the frontier shifts from period t to t+1. The country at time t could produce output *yp* for input *xt*. With the same input xt it could produce output *yq* at period t+1.

[Figure 1]

4. Efficiency and Productivity Analysis

4.1. Data and Variables

Our dataset includes 36 OECD member countries[6] and it covers three distinct periods: 2003-2007, 2008-2012 and 2013-2017. We gather data from several sources. Tables A1 and A2 in Appendix A provide information on the sources and variable construction.[7]

We start by constructing an output composite for **Public Sector Performance** (PSP), as sugested by Afonso, Schuknecht, and Tanzi (2005) for the three periods. These indicator includes two main components: opportunity indicators and the traditional Musgravian indicators. The **opportunity indicators** focuses on the role of the government in providing various servides for the individuals. These sub-indicators reflect the governments' performance in four areas, administration, education, health and infrastructure. The **administration** sub-indicator includes: corruption, burden of government regulation (red tape), judiciary independence, shadow economy and the property rights. To measure the **education** sub-indicator, we used the secondary school enrolment rate, quality of educational system and PISA scores. For the **health** sub-indicator, we compiled data on the infant survival rate, life expectancy and survival rate from cardiovascular, cancer, diabetes or chronic respiratory diseases. The **infrastructure** sub-indicator is measured by the quality of overall infrastructure. For each sub.indicator, we computed a 5-year average to account for structural changes.[8] The **Musgravian indicators** includes three sub-indicators:

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[6] The 36 OECD member countries are: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

[7] Table A1 lists all sub-indicators to construct the PSP output indicator. Table A2 includes the data on various governments' expenditures area which are used as the input measure.

[8] More specifically, we compute the average for each sub-indicator for the three periods: 2005 and 2011 and for the year 2017, we compute the average for the period between 2012 and 2017.

distribution, stability and economic performance. To measure **distribution**, we used the 5-year average of the gini coefficient. For the **stability** sub-indicator, we used the coefficient of variation for the 5-year average of GDP growth and standard deviation of 5 years inflation. **Economic performance** includes the 5-year average of GDP per capita, GDP growth and unemployment rate. Each sub-indicators is then normalized by dividing the value of a specific country by the average of that measure for all the countries in the sample. This will ensure a convenient benchmark for comparing the results.

[Table 1]

Table 1 summarizes the variables used to construct the PSP indicators. Each sub-indicator of the PSP results from the average of the measures included in each sub-indicator. To compute the PSP, we gave equal weights to each sub-indicator of opportunity and Musgravian indicators.

$$\boldsymbol{PSP_i = \sum_{j=1}^{n} PSP_{ij}} \quad (6)$$

where $\boldsymbol{i}$ denotes the OCDE countries and $\boldsymbol{j}$ is socio-economic indicators. $\boldsymbol{PSP_i}$ is overall performance of the country $\boldsymbol{i}$.

Our input measures include the **Public Expenditure** (PE) as a percentage of GDP. More specifically, we consider the government consumption as the input for administrative performance, government expenditure in education as the input for education performance, health expenditure as the input for health performance and public investment as the input for the infrastructure performance. For the distribution indicator, we consider expenditure on transfers and subsidies as the cost affecting the income distribution. The stability and economic performance indicator as related to the total expenditure. Then, we equally weigh each area of government expenditure to compute public expenditure input.

4.2. DEA efficiency scores

We performed DEA for different models assuming variable returns to scale. We compute baseline model (Model 0) with only one input (PE as percentage of GDP) and one output (PSP), as a starting point. In this case, the efficient countries are Australia, Ireland, South Korea and Mexico (detailed results are in the Table B.0 of Appendix B). Figure 2 illustrates the production possibility frontiers for Model 0 for the periods 2003-2007 and 2013-2017.

[Figure 2]

Moving forward to the main part of the analysis, Table 2 provides a summary of the DEA results for the three periods using input and output-oriented models. The purpose of an input-oriented assessment is to study by how much input quantities can be proportionally reduced without changing the output quantities produced. Alternatively, and by computing output-oriented measures, one can assess how much output quantities can be proportionally increased without changing the input quantities used.

Model 1 uses one input, governments' normalized total spending (PE) and two outputs, the opportunity PSP and the "Musgravian" PSP scores. Model 2 assumes two inputs, governments' normalized spending on opportunity and on "Musgravian" indicators and one output, total PSP scores. The results obtained from the two models are illustrated on Tables B.1 and B.2 of Appendix B.

[Table 2]

In our baseline model, Model 0, the input efficiency scores averaged approximately 0.5 for the three periods suggesting that inputs could be reduced by approximately 50% in each of the periods. The input efficiency scores of Model 1 are larger, averaging 0.679 in 2003-2007, 0.665 in 2008-2012 and 0.667 in 2013-2017. Therefore, inputs could be theoretically lower by around 32% in 2003-2007, 34% in 2008-2012 and 33% in 2013-2017, keeping the same level of output.

Between 2007 and 2017, there were efficiency gains for 47% of the countries (50% in 2007-2012 and 42% in 2012.2017). Model 2 provides similar results as Model 1, but the number of countries experienced efficiency gains increases. The input efficiency scores average ranged between 0.619 in 2003-2007, 0.643 in 2008-2012 and 0.674 in 2013-2017, implying that with the same level of output, inputs could be theoretically lower by around 38%, 36% and 33%, respectively. In this model, 72% of the countries experienced efficiency gains between 2007 and 2017.

Turning to the output efficiency scores, we find that the average scores of our baseline model equaled 1.169, 6.396 and 1.461 for 2003-2007, 2008-2012 and 2013-2017, respectively, For Model 1, the average scores equaled 1.102 in 2003-2007, 1.161 in 2008-2012 and 1.159 in 2013-2017, which means that with the same level of inputs, output could increase by around 9%, 14% and 14%, respectively. Model 2's output efficiency scores averaged 1.163 in 2003-2007, 6.359 in 2008-2012 and 1.442 in 2013-2017. Note that the results for the second period are affected by Greece negative performance on the stability and economic performance sub-indicators. In fact, Greece "Musgravian" PSP score is negative.

Overall, the countries located in the production possibility frontier, hence the more efficient ones in terms of government spending, are: Australia (2008-2012), Ireland (2013-2017), South Korea (three periods), Latvia (2007) and Mexico (three periods). Ireland is efficient by default.

In addition, and in terms of the stability of results over time, we see that the correlation between the efficiency scores increased, reaching around 0.9 in the periods 2012-2017 for both input and output oriented scores (while it was around 0.7 in the periods 2007-2012).

4.3. Malmquist indices

Table 3 reports the set of results for the Malmquist indices of efficiency, technology and TFP changes for the period 2007 to 2017, using Model 1 and 2 and assuming variable returns to scale (the detailed results obtained for the three periods are on the supplementary online material).

[Table 3]

The results show that between 2007 and 2017 there were increases in efficiency, notably in Model 1, with one input and two composite PSP outputs. However, the Malmquist indices show also an overall decrease in technology improvements, and also a reduction in TFP. In the case of Model 2, with two inputs (so-called opportunity and Musgravian related government spending) and the overall single composite PSP output, we find a decrease of both technical efficiency and technology, with again a drop in TFP. Therefore, in this OECD country sample, the mixture of inputs and processes, leading to lower efficiency, would flag the existence of room for overall improvements.

5. Efficiency and Tax Structure Analysis

5.1. Tax Patterns

Data from taxation was retrieved from ICTD government revenue dataset (ICTD/UNU-WIDER, 2018). These dataset combines data from different international sources under a standard classification system. For detailed information on the data construction, see Prichard et al. (2014) and McNabb (2017).

[Figure 3]

To better frame the empirical results, we review some stylized facts about OCDE's taxation patterns and trends. Figure 3 shows the interquartile range over time of government revenue categories for all countries in our sample. We observe that, as a result of the global financial crisis and the need to consolidate after the stimulus package that many countries implemented to boost aggregate demand, total revenues (as a ratio to GDP) started increasing considerable. The rebound of economic activity as the recovery phase unfolded led to direct and indirect taxes to catch-up relative to pre-crisis levels. Also, as the labor market improved, social security contributions saw their share in GDP rising in the early 2010s.

5.2. Second Stage Regression

Exogenous and non-discretionary inputs, such as socio-economic characteristics or a particular relevant determinant - in our case the tax system structure -, can jointly contribute to each country's efficiency score. We empirically assess the set of potential determinants, and most notably countries´ tax structures, of the previously computed set of public efficiency scores. The following reduced-form panel data specification is estimated:

$$\theta_{it} = \beta_t + \beta_r + T'_{it-1}\beta_1 + Z_{it-1}{}'\beta_2 + \varepsilon_{it} \quad (7)$$

where i denotes country, β_r denotes region effects to control for geography-specific time invariant characteristics and β_t denotes time (year) effects to control for global common shocks. ε_{it} is a disturbance term satisfying standard assumptions.

Our dependent variable, θ_{it}, is the DEA input efficient scores, computed in the previous section. The input orientation scores are more suitable for this analysis, because they ensure that a given country's efficiency is determined by its ability to minimize per capita expenditures to provide a fixed level of (public) services. Our set of variables of interest are included in vector T_{it}, which comprises of several tax variables evaluated in percent of GDP. Z_{it} is a vector of other sociodemographic, macroeconomic and institutional controls that may affect public sector performance. Both these vectors are lagged by one year to minimize reverse causality concerns.

As far as variables in vector T_{it} are concerned, we study the role played by: i) total tax revenue (% GDP); ii) direct taxes (% GDP) defined as total direct taxes excluding social contributions but including resource taxes[9]; iii) taxes on income, profit and capital gains, including

[9] In other words, direct taxes nclude taxes on income, profits and capitals gains, taxes on payroll and workforce and taxes on property. The total value of direct taxes may sometimes exceed the sum of these sub-components, owing to revenue that is unclassified among these sub-components.

taxes on natural resource firms (% GDP)[10]; iv) personal income tax (% GDP) (pit)[11]; v) corporate income tax (% GDP) (cit), including taxes on resource firms; vi) payroll and workforce taxes (% GDP)[12]; vii) property taxes (% GDP); viii) indirect taxes (% GDP), which includes taxes on goods and services, taxes on international trade and other taxes (including resource revenues); ix) other taxes (% GDP); x) social security contributions (% GDP); and xi) non-tax revenues (% GDP), which comprises of data categorized as either "non-tax revenue" or "other revenue" or grants received by the government..

In vector Z_{it} we include: i) a proxy of country size, defined as the logarithm of domestic residents to control for the monitoring costs of government's discretional behavior (Grossman et al., 1999); ii) a proxy of economic and technological development given by the number of internet users; iii) a measure capturing a reality exogenous to the government , and give by the share of tourism revenues in exports; iv) a couple of political variables identifying the incumbent government´s political ideology (either left or center, define as binary variables).[13] Definitions and sources of all variables used in the second stage are presented in Table A.3 in the Appendix A.

Equation (7) was estimated for all countries considered using Simar and Wilson´s (2007) estimation approach. This method is described by the authors as a superior approach to alternatives such as OLS or censored (Tobit like) regressions. Such naïve estimators ignore that estimated DEA efficiency scores are calculated from a common sample of data and treating them as if they were

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[10] Taxes may sometimes exceed the sum of individuals and corporations taxes, due to revenues that are unallocated between the two.
[11] This variable is always exclusive of resource revenues in available sources.
[12] This variable is entirely distinct from social contributions, though in underlying sources social contributions are very occasionally reported as payroll taxes.
[13] We also included other variables including institutional controls (checks and balances, measures of democratic quality) and proxies of human capital (number of yearsl of schooling, attainment and completion rates at the secondary level) but none yielded significant results. In addition, data availability constrained the sample further reducing the total number of observations. Consequently, we decided to leave these out.

independent observations is not appropriate since the problems related to invalid inference due to serial correlation arise. Simar and Wilson (2007) procedure takes this (and other pitfalls) into account by constructing an underlying data generating process consistent with two-stage estimation implying a truncated regression model.

Our main results from estimating Equation (7) using input DEA scores from Model 1 are displayed in Table 4. Looking at specification (1), we observe that on average both tax and non-tax revenues reduce the level of efficiency, while the effect of social security contributions is not statistically different from zero. In particular, an increase of 1% of GDP in tax revenues leads to a 1% decrease in the DEA efficiency score and in government spending efficiency. Going more granular lead us to specification (2) where we see that the negative tax revenue effect on government performance stems mainly from indirect taxes (the different between this coefficient estimate and that from direct taxes is statistically significant). By disaggregating further we now get the negative and significant result on social security contributions with a magnitude similar to that of direct taxes or non-tax revenues. In specifications (3) and (4) we try to further decompose revenue components but not much else is revealed simply confirming previous findings. The strongly stable and significant coefficient estimates on indirect taxes and social security contributions are reassuring as far as robustness is concerned.

[Table 4]

A brief comment on other regressors. Size seems to matter with larger countries typically being more efficient. Also, countries technologically more advanced have more efficient governments and also those that are able to attract more tourists (which also proxies for the weather and natural conditions, quality of institutions, public transportation and general services). Finally, centered-placed governing parties are the ones associated with a better public sector performance, in contrast with leftist parties where the coefficient estimate is consistently negative (even though statistically not different from zero).

As a sensitivity exercise, we replaced the dependent variable in equation (7) by the input scores from Models 0 and 2. Results presented in Tables C.0 and C.1 in Appendix C show the strong negative influence of direct taxes, while now indirect taxes come out statistically insignificant in Model 2. In this case, specifications (3) and (4) are more revealing in the sense that both PIT and CIT seem to be the ones (out of direct taxes) driving the result in specification (2). Payroll and property taxes yield statistically insignificant coefficients (also not that the share of these components in tax revenues is considerably smaller).

Our results are no too different when the analysis is performed using different estimation methods – Tobit and OLS regression with fixed effects. These estimation models show similar results to the Simar and Wilson´s (2007) estimation approach.

Finally, instead of looking at input scores, in Table C.2 in Appendix C we rely on Model´s 1 output scores and re-estimate Equation (7). As in Table 5, indirect taxes matter considerably by negatively affecting output efficiency scores. However, in contrast in Table 4, having an ideologically-centered government seems to lower government output performance. The same effect is true for larger and more developed countries. Consequently, there is a clear difference in evaluating the determinants of government performance by focusing on either input versus output scores.

6. Conclusion

We analyzed to what extent a country´s tax system relates to public spending efficiency in a sample of 36 advanced economies between 2003 and 2017. We follow a two-step approach: first, we computed DEA efficiency scores and Malmquist productivity indices. Secondly, we assess how the structure of taxes affects efficiency scores using a reduced-form panel data regression analysis.

Our results can be summarized as follows: i) inputs can be theoretically lower by around 32-34% in those years, keeping the same level of output; ii) between 2007 and 2017, there were efficiency gains for 47% of the countries; iii) between 2007 and 2017 there were some increases in efficiency, but the Malmquist indices show an overall decrease in technology and in TFP. Regarding the second step analysis, using Simar and Wilson's algorithm, we find: iv) a negative direct tax effect on government performance; v) there is also a negative and significant effect from social security contributions with a magnitude similar to that of direct taxes or non-tax revenues; vi) and a negative impact on efficiency from indirect taxes, in this case with a higher magnitude than for the other tax items.

Our findings carry some relevant messages for policy making. On the one hand, there is room for improvement in terms of government spending efficiency, with potential gains for the 36 countries in our sample. On the other hand, the fact that several tax items have a different perceived negative effect on government spending efficiency, also adds relevant information notably for the budgetary authorities when choosing their respective tax structures and designing their tax policies, notably in the context of discretionary fiscal policy making.

This study, however, does not come without its limitations. First, there is the issue of selecting inputs and outputs to compute efficiency scores and the selection of the set of control variables for the second-stage part of the analysis. Although such choice relied on the role of the government and other key variables previously evaluated in the literature, naturally a different set of variables could have also been chosen. The same applies to the set of control variables in the second-stage estimation (there could be an omitted variable bias problem that we tried, to the best of our abilities, minimize). Second, the macro-economic context in the three periods was very different and countries were affected in a different manner. Between 2008 and 2012, countries faced the outbreak of the global economic and financial crisis, nevertheless some countries were less exposed while others (e.g. Portugal and Greece) had to ask for an international financial bailout.

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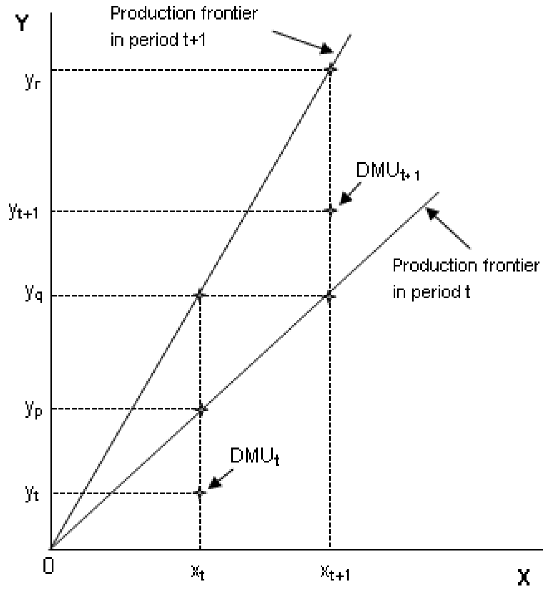
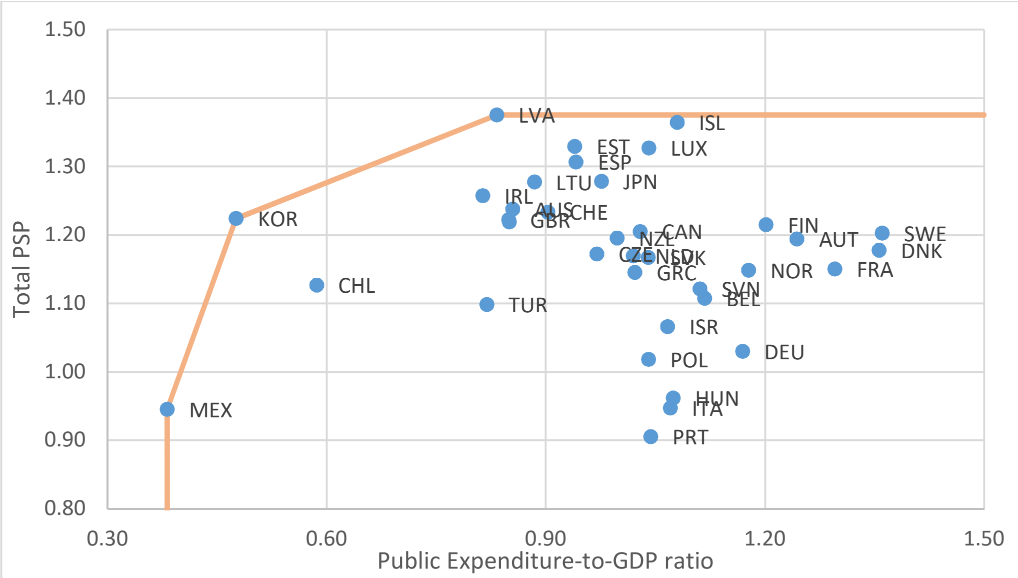
Figure 1 – Malmquist TFP



The DMU (country) produces less than feasible under each period's production frontier. The MPI indicates the potential rise in productivity as the frontier shifts from period *t* to *t+1*. The country at time *t* could produce output y_p for input x_t;. With the same input x_t it could produce output y_q at period *t+1.* EC, efficiency change; TC, technology change; TFP, total factor productivity change (TFP = EC*TC).

Figure 2 – Production Possibility Frontiers (2003-2007 and 2013-2017), Model 0

2a – 2003-2007



2b – 2013-2017

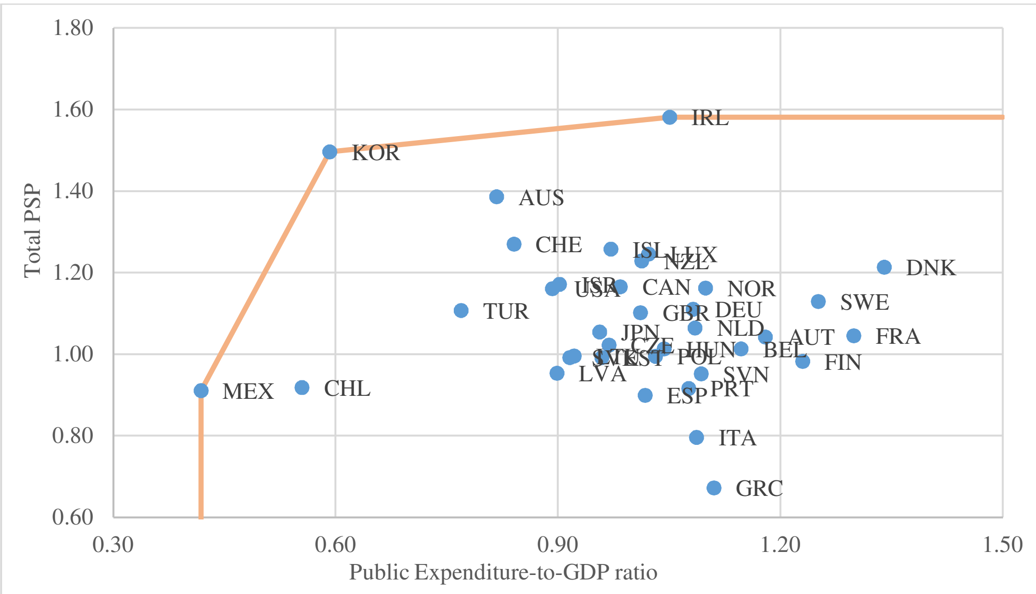
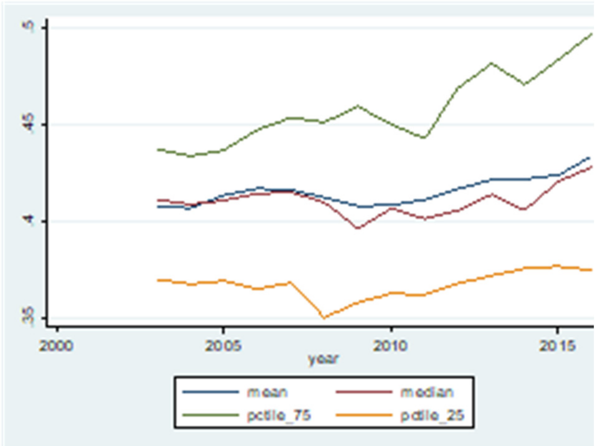


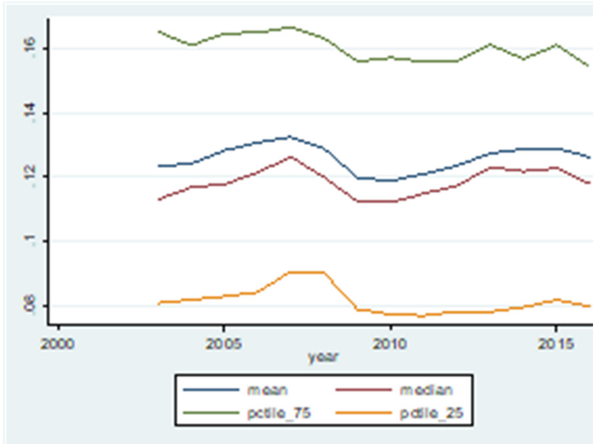
Figure 2 plots the production possibility frontiers for Model 0 and periods 2003-2007 and 2013-2017. AUS – Australia; AUT-Austria; BEL – Belgium; CAN – Canada; CHE – Switzerland; CHL – Chile; CZE – Czech Republic; DEU – Germany; DNK – Denmark; ESP – Spain; EST – Estonia; FIN – Finland; FRA – France; GBR – United kingdom; GRC – Greece; HUN – Hungary; IRL – Ireland; ISL – Iceland; ISR – Israel; ITA – Italy; JPN – Japan; KOR – South Korea; LTU – Lithuania; LUX – Luxembourg; LVA – Latvia; MEX – Mexico; NLD – Netherlands; NOR – Norway; NZL – New Zealand; POL – Poland; PRT – Portugal; SVK – Slovak Republic; SVN – Slovenia; SWE – Sweden; TUR – Turkey; USA – United States of America.

Figure 3 - Interquartile Range of Government Revenues (ratio to GDP)

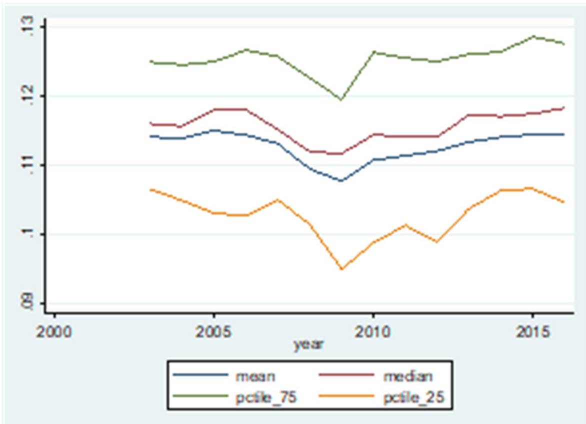
a) Total Revenues



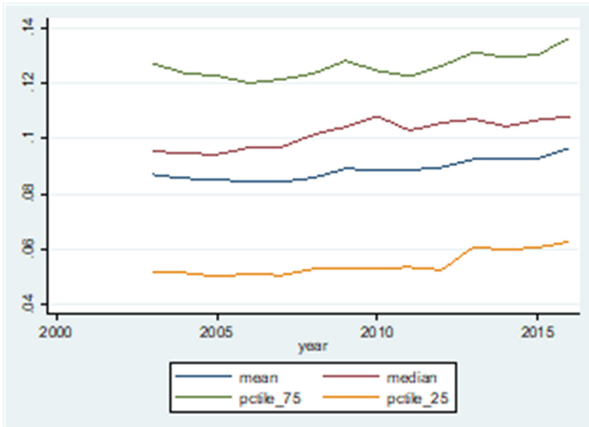
b) Direct Taxes



c) Indirect Taxes



d) Social Security Contributions



Note: Figure 3 plots the mean, median, top and bottom quartile of revenues´ distributions over time for the entire sample of countries studied.

Table 1 – Total Public Sector Performance (PSP) Indicator (2003-2017)

Sub Index	Variable
Opportunity Indicators	
Administration	Corruption
	Red Tape
	Judicial Independence
	Property Rights
	Shadow Economy
Education	Secondary School Enrolment
	Quality of Educational System
	PISA scores
Health	Infant Survival Rate
	Life Expectancy
	CVD, cancer, diabetes or CRD Survival Rate
Public Infrastructure	Infrastructure Quality
Standard Musgravian Indicators	
Distribution	Gini Index
Stabilization	Coefficient of Variation of Growth
	Standard Deviation of Inflation
Economic Performance	GDP per Capita
	GDP Growth
	Unemployment

Table 2 – Summary of DEA

		Model 0			Model 1			Model 2		
		2007	2012	2017	2007	2012	2017	2007	2012	2017
Efficient	Number	3	3	3	5	4	5	3	4	4
	Name	South Korea, Latvia, Mexico	Australia, South Korea, Mexico	Ireland, South Korea, Mexico	Iceland, South Korea, Switzerland, Latvia, Mexico	Australia, South Korea, Mexico, Switzerland	Chile, Ireland, South Korea, Mexico, Switzerland	South Korea, Latvia, Mexico	Australia, Chile, South Korea, Mexico	Chile, Ireland, South Korea, Mexico
Input	Average	0.538	0.500	0.515	0.679	0.665	0.667	0.619	0.643	0.674
	Median	0.462	0.449	0.468	0.674	0.643	0.634	0.539	0.597	0.643
	Min	0.339	0.318	0.353	0.385	0.411	0.423	0.413	0.484	0.511
	Max	1	1	1	1	1	1	1	1	1
	Stdev	0.195	0.186	0.174	0.200	0.168	0.17	0.179	0.15	0.132
Output	Average	1.169	6.396	1.461	1.102	1.161	1.159	1.163	6.359	1.442
	Median	1.147	2.078	1.485	1.07	1.12	1.114	1.143	2.047	1.452
	Min	1	1	1	1	1	1	1	1	1
	Max	1.519	152.000	2.354	1.393	1.427	1.408	1.519	151.626	2.345
	Stdev	0.127	24.974	0.264	0.105	0.13	0.129	0.13	24.917	0.274

Note: summary of the DEA results for the periods 2003-2007, 2008-2012 and 2013-2017 using input and output-oriented models. Model 0 uses one input, governments' normalized total spending and one output, the total PSP. Model 1 uses one input, governments' normalized total spending and two outputs, the opportunity PSP and the "Musgravian" PSP scores. Model 2 assumes two inputs, governments' normalized spending on opportunity and on "Musgravian" indicators and one output, total PSP. The results obtained from the three models are illustrated on Tables B.0, B.1 and B.2 of Appendix B.

Table 3 – Summary of Malmquist Indices

		2007-2012			2012-2017			2007-2017		
		EC	TC	TFP	EC	TC	TFP	EC	TC	TFP
Model 1	Average	1.112	0.925	1.031	0.960	1.018	0.978	1.060	0.929	0.983
	Median	1.095	0.894	0.990	0.973	1.030	0.983	1.091	0.920	0.997
	Min	0.775	0.893	0.793	0.657	0.938	0.649	0.705	0.904	0.715
	Max	1.734	1.045	1.811	1.083	1.030	1.104	1.281	1.014	1.158
	Stdev	0.163	0.051	0.188	0.081	0.023	0.088	0.111	0.025	0.089
Model 2	Average	0.793	1.057	0.837	2.809	0.942	2.643	0.930	0.996	0.926
	Median	0.780	1.066	0.819	1.162	0.940	1.092	0.932	1.002	0.933
	Min	0.011	0.953	0.011	0.576	0.938	0.542	0.562	0.960	0.563
	Max	1.616	1.066	1.690	56.883	1.010	53.491	1.249	1.002	1.251
	Stdev	0.321	0.022	0.338	9.277	0.012	8.724	0.160	0.013	0.158

Note: summary of the Malmquist Indices for the periods 2007-2012, 2012-2017 and 2007-2017. Model 1 uses one input, governments' normalized total spending and two outputs, the opportunity PSP and the "Musgravian" PSP scores. Model 2 assumes two inputs, governments' normalized spending on opportunity and on "Musgravian" indicators and one output, total PSP scores. The results obtained from the two models are illustrated on Tables C.1 and C.2 of Appendix C.

Table 4 – Second Stage Regression DEA Efficiency Model 1

Regressors \ specification	(1)	(2)	(3)	(4)
Tax revenue (% GDP), t-1	-0.922***			
	(0.181)			
Direct taxes (% GDP), t-1		-0.443**		
		(0.214)		
Taxes income, profit capital (% GDP), t-1			-0.492*	
			(0.275)	
pit (% GDP), t-1				-0.417
				(0.316)
cit (% GDP), t-1				-0.622
				(1.050)
Payroll taxes (% GDP), t-1			-0.625	-0.652
			(0.930)	(0.938)
Property taxes (% GDP), t-1			-1.102	-1.142
			(1.049)	(1.059)
Indirect taxes (% GDP), t-1		-2.141***	-2.124***	-2.209***
		(0.509)	(0.505)	(0.513)
Other taxes (% GDP), t-1		-0.290	-0.325	-0.134
		(0.663)	(0.685)	(1.272)
SSC (% GDP), t-1	-0.167	-0.518**	-0.969***	-0.907***
	(0.234)	(0.248)	(0.276)	(0.289)
Non-tax revenue (% GDP), t-1	-0.647**	-0.565*	-0.581*	-0.603*
	(0.311)	(0.330)	(0.323)	(0.340)
Population (log), t-1	0.017***	0.010	0.012*	0.011*
	(0.006)	(0.007)	(0.007)	(0.007)
Internet users, t-1	0.007***	0.005***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
Tourism revenues (% exports), t-1	0.004**	0.004**	0.004**	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)
Left political orientation, t-1	-0.016	-0.024	-0.021	-0.021
	(0.022)	(0.022)	(0.022)	(0.022)
Center political orientation., t-1	0.107***	0.093***	0.097***	0.099***
	(0.025)	(0.025)	(0.026)	(0.026)
Observations	94	94	94	94
Sigma	0.071***	0.070***	0.069***	0.069***
	(0.005)	(0.005)	(0.005)	(0.005)
Region Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes

Note: The table reports the estimated coefficients from Equation (7) using Simar and Wilson two-stage efficiency regression model. The dependent variable is the DEA input scores between 2007 and 2017 using Model 1. The definition and sources of the independent variables are presented in Table A.3 of Appendix A. Five regions and year fixed effects are included but not reported for reasons of parsimony. Constant term also omitted. ***, **, * denote statistical significance at 1%, 5% and10% levels, respectively.

APPENDIX

Appendix A – Variable Definitions and Sources

Table A.1: Output Components

Sub Index	Variable	Source	Series
Opportunity Indicators			
Administration	Corruption	Transparency International's Corruption Perceptions Index (CPI) (2003- 2017)	Average (5y) corruption on a scale from 10 (Perceived to have low levels of corruption) to 0 (highly corrupt), for the period 2003-2011; Average (5y) corruption on a scale from 100 (Perceived to have low levels of corruption) to 0 (highly corrupt), for the period 2012-2017.
	Red Tape	World Economic Forum: The Global competitiveness Report (2006-2017)	Average (5y) burden of government regulation on a scale from 7 (not burdensome at all) to 1 (extremely burdensome).
	Judicial Independence	World Economic Forum: The Global competitiveness Report (2006-2017)	Average (5y) judicial independence on a scale from 7 (entirely independent) to 1 (heavily influenced).
	Property Rights	World Economic Forum: The Global competitiveness Report (2006-2017)	Average (5y) property rights on a scale from 7 (very strong) to 1 (very weak).
	Shadow Economy	Schneider (2016) (2003-2016) (a)	Average (5y) shadow economy measured as percentage of official GDP. Reciprocal value 1/x.
Education	Secondary School Enrolment	World Bank, World Development Indicators (2006-2017)	Average (5y) ratio of total enrolment in secondary education.
	Quality of Educational System	World Economic Forum: The Global competitiveness Report (2006-2017)	Average (5y) quality of educational system on a scale from 7 (very well) to 1 (not well at all).
	PISA scores	PISA Report (2003, 2006, 2009, 2012, 2015)	Simple average of mathematics, reading and science scores for the years 2015, 2012, 2009; Simple average of mathematics and reading for the year 2003.
Health	Infant Survival Rate	World Bank, World Development Indicators (2006-2017)	Average (5y) infant survival rate Infant survival rate = (1000-IMR)/1000. IMR is the infant mortality rate measured per 1000 lives birth in a given year.
	Life Expectancy	World Bank, World Development Indicators (2006-2017)	Average (5y) life expectancy at birth, measured in years.
	CVD, cancer, diabetes or CRD Survival Rate	World Health Organization, Global Health Observatory Data Repository (2000, 2005, 2010, 2015, 2016)	Average (5y) of CVD, cancer and diabetes survival rate. Survival Rate CVD, cancer and diabetes=100-M. M is the mortality rate between the ages 30 and 70.
Public Infrastructure	Infrastructure Quality	World Economic Forum: The Global competitiveness Report (2006-2017)	Average (5y) infrastructure quality on a scale from 7 (extensive and efficient) to 1 (extremely underdeveloped)

Standard Musgravian Indicators

Distribution	Gini Index	Eurostat, OECD (2003-2016) (b)	Average (5y) gini index on a scale from 1(perfect inequality) to 0 (perfect equality). Transformed to 1-Gini.
Stabilization	Coefficient of Variation of Growth	IMF World Economic Outlook (WEO database) (2003-2017)	Average (5y) coefficient of variation. Coefficient of variation=standard deviation/mean of GDP at constant prices (percent change). Reciprocal value 1/x
	Standard Deviation of Inflation	IMF World Economic Outlook (WEO database) (2003-2017)	Standard deviation (5y) of inflation, consumer prices (percent change). Reciprocal value 1/x
Economic Performance	GDP per Capita	IMF World Economic Outlook (WEO database) (2003-2017)	Average (5y) GDP per capita based on PPP, current international dollar
	GDP Growth	IMF World Economic Outlook (WEO database) (2003-2017)	Average (5y) GDP, constant prices (percent change)
	Unemployment	IMF World Economic Outlook (WEO database) (2003-2017)	Average (5y) unemployment rate as a percentage of total labor force. Reciprocal value 1/x

(a) For Chile, Iceland, Israel, South Korea and Mexico, we use the data available in Medina and Schneider (2017).
(b) For Switzerland, we were only able to collect data for the period between 2009 and 2016.

Table A.2: Input Components

Sub Index	Variable	Source	Series
Opportunity Indicators			
Administration	Government Consumption	IMF World Economic Outlook (WEO database) (1998-2012)	Average (5y) general government final consumption expenditure (% of GDP) at current prices
Education	Education Expenditure	UNESCO Institute for Statistics (1998-2012) (a)	Average (5y) expenditure on education (% of GDP)
Health	Health Expenditure	OECD database (1998-2012)	Average (5y) expenditure on health (% of GDP)
Public Infrastructure	Public Investment	European Commission, AMECO (1998-2012) (b)	Average (5y) general government gross fixed capital formation (% of GDP) at current prices
Standard Musgravian Indicators			
Distribution	Social Protection Expenditure	OECD database (1998-2013) (c)	Average (5y) aggregation of the social transfers (% of GDP)
Stabilization/ Economic Performance	Government Total Expenditure	OECD database (1998-2013) (d)	Average (5y) expenditure total expenditure (% of GDP)

(a) From the IMF World Economic Outlook (WEO database), we retrieved data for Greece for the period between 2006 and 2012, for Luxembourg for the period 1999 and 2003 and for the USA for the period 1998 and 2007.

(b) We were not able to collect data on the following countries: Australia, Canada, Mexico, New Zealand, Chile, Israel and South Korea.

(c) From IMF World Economic Outlook (WEO database), we retrieved data for Mexico for the period between 1998 and 2000 and for New Zealand for the period 2004 and 2012. For Turkey, we retrieve data from European Commission, AMECO database. For Chile and Iceland, we were only able to collect data for the period between 2013 and 2016. For Mexico, we were only able to collect data for the period between 1995 and 2000. For Turkey, we were only able to get data for the period between 2009 and 2015. We were not able to collect data for Canada. For Japan, we were only able to collect data for the period between 2005 and 2016. For New Zealand, we were only able to collect data for the period between 2004 and 2016.

(d) From the IMF World Economic Outlook (WEO database), we retrieved data for Canada for the period between 1998 and 2012 and for New Zealand for the period 2009 and 2012. For Turkey, we retrieve data from European Commission, AMECO database. We were not able to collect data for Mexico. For Chile and Iceland, we were only able to collect data for the period between 2013 and 2016. For New Zealand, we were only able to collect data for the period between 2009 and 2016. For Japan, we were only able to collect data for the period between 2005 and 2016.

Table A.3 – Second-stage regression

Variable	Definition	Source
Tax revenue (% GDP), t-1	Previous year total tax revenue as a percentage of GDP	ICTD government revenue dataset
Direct taxes (% GDP), t-1	Previous year total direct taxes, excluding social contributions but including resource taxes, as a percentage of GDP. Includes taxes on income, profits and capital gains, taxes on payroll and workforce and taxes on property. The total value of direct taxes may sometimes exceed the sum of these sub-components, owing to revenue that is unclassified among these sub-components.	
Taxes income, profit capital (% GDP), t-1	Previous year total taxes on income, profits and capital gains, including taxes on natural resource firms, as percentage of GDP. The taxes may sometimes exceed the sum of individuals and corporations taxes, due to revenues that are unallocated between the two.	
pit (% GDP), t-1	Previous year total income, capital gains and profit taxes on individuals, as a percentage of GDP. This figure is always exclusive of resource revenues in available sources.	
cit (% GDP), t-1	Previous year total income and profit taxes on corporations, including taxes on resource firms, as a percentage of GDP.	
Payroll taxes (% GDP), t-1	Previous year total taxes on payroll and workforce, as a percentage of GDP. This variable is entirely distinct from social contributions, though in underlying sources social contributions are very occasionally reported as payroll taxes.	
Property taxes (% GDP), t-1	Previous year total taxes on property as percentage of GDP.	
Indirect taxes (% GDP), t-1	Previous year total indirect taxes, including resource revenues. Includes taxes on goods and services, taxes on international trade and other taxes.	
Other taxes (% GDP), t-1	Previous year total other taxes, as percentage of GDP.	
SSC (% GDP), t-1	Previous year total social contributions, as a percentage of GDP.	
Non-tax revenue (% GDP), t-1	Previous year total non-tax revenue as percentage of GDP. Comprises data categorized as either "non-tax revenue" or "other revenue" or grants received by the government.	
Population (log), t-1	Logarithm of previous year domestic residents.	World Bank World Development Indicators
Internet users, t-1	Number of internet users in the previous year.	World Bank World Development Indicators
Tourism revenues (% exports), t-1	Share of tourism revenues in exports in the previous year.	World Bank World Development Indicators
Left political orientation, t-1	Dummy variable equal one if the government is from the left political ideology, and zero otherwise.	Database of Political Institutions
Center political orientation., t-1	Dummy variable equal one if the government is from the center political ideology, and zero otherwise.	Database of Political Institutions

Appendix B – DEA Efficiency Scores

Table B.0 – Input and Output-oriented DEA VRS Efficiency Scores for Model 0

	Input			Output		
	2007	2012	2017	2007	2012	2017
AUS	0.594	**1.000**	0.684	1.111	**1.000**	1.110
AUT	0.374	0.373	0.388	1.152	1.930	1.517
BEL	0.391	0.388	0.391	1.242	2.044	1.562
CAN	0.456	0.478	0.502	1.141	1.808	1.347
CHE	0.551	0.555	0.624	1.115	1.620	1.215
CHL	0.755	0.903	0.758	1.128	1.179	1.494
CZE	0.473	0.417	0.466	1.173	2.494	1.532
DEU	0.351	0.394	0.441	1.336	1.992	1.424
DNK	0.339	0.318	0.379	1.168	2.156	1.304
ESP	0.712	0.448	0.411	1.053	3.783	1.752
EST	0.771	0.493	0.461	1.035	3.140	1.578
FIN	0.393	0.353	0.357	1.132	2.298	1.610
FRA	0.348	0.326	0.353	1.196	2.112	1.513
GBR	0.560	0.450	0.470	1.125	2.242	1.429
GRC	0.440	0.395	0.377	1.201	152.000	2.354
HUN	0.360	0.371	0.430	1.431	3.128	1.560
IRL	0.681	0.481	**1.000**	1.088	2.793	**1.000**
ISL	0.747	0.399	0.536	1.008	2.652	1.246
ISR	0.396	0.571	0.549	1.291	1.358	1.327
ITA	0.357	0.390	0.385	1.452	3.651	1.987
JPN	0.618	0.465	0.482	1.076	2.224	1.483
KOR	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
LTU	0.680	0.509	0.481	1.077	3.009	1.565
LUX	0.690	0.406	0.506	1.037	1.983	1.266
LVA	**1.000**	0.526	0.480	**1.000**	4.362	1.629
MEX	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
NLD	0.449	0.416	0.428	1.176	2.018	1.486
NOR	0.382	0.414	0.448	1.198	1.789	1.361
NZL	0.467	0.495	0.506	1.151	1.658	1.282
POL	0.390	0.620	0.430	1.351	1.213	1.587
PRT	0.366	0.394	0.390	1.519	3.659	1.727
SVK	0.439	0.466	0.483	1.178	2.156	1.569
SVN	0.397	0.391	0.394	1.227	2.967	1.662
SWE	0.344	0.336	0.386	1.144	2.007	1.400
TUR	0.529	0.574	0.619	1.247	1.809	1.381
USA	0.558	0.495	0.552	1.128	2.035	1.338
Count	3	3	3	3	3	3
Average	0.538	0.500	0.515	1.169	6.396	1.461
Median	0.462	0.449	0.468	1.147	2.078	1.485
Min	0.339	0.318	0.353	1.000	1.000	1.000
Max	1.000	1.000	1.000	1.519	152.000	2.354
Stdev	0.195	0.186	0.174	0.127	24.974	0.264

Table B.1 – Input and Output-oriented DEA VRS Efficiency Scores for Model 1

	Input			Output		
	2007	2012	2017	2007	2012	2017
AUS	0.908	**1.000**	0.856	1.017	**1.000**	1.025
AUT	0.624	0.649	0.602	1.049	1.062	1.107
BEL	0.564	0.583	0.582	1.122	1.140	1.147
CAN	0.698	0.777	0.723	1.068	1.075	1.102
CHE	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
CHL	0.786	0.991	**1.000**	1.090	1.008	**1.000**
CZE	0.483	0.500	0.549	1.160	1.299	1.288
DEU	0.623	0.650	0.659	1.076	1.094	1.104
DNK	0.612	0.587	0.540	1.030	1.062	1.082
ESP	0.781	0.574	0.585	1.041	1.226	1.221
EST	0.828	0.637	0.634	1.031	1.195	1.208
FIN	0.710	0.697	0.648	1.020	1.031	1.034
FRA	0.542	0.542	0.520	1.085	1.104	1.139
GBR	0.778	0.690	0.688	1.045	1.143	1.121
GRC	0.451	0.434	0.423	1.195	1.401	1.408
HUN	0.397	0.411	0.458	1.346	1.393	1.352
IRL	0.750	0.691	**1.000**	1.041	1.161	**1.000**
ISL	**1.000**	0.738	0.740	**1.000**	1.060	1.073
ISR	0.456	0.584	0.634	1.193	1.198	1.193
ITA	0.385	0.420	0.446	1.393	1.427	1.380
JPN	0.849	0.797	0.770	1.032	1.094	1.084
KOR	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
LTU	0.743	0.580	0.564	1.071	1.314	1.311
LUX	0.864	0.679	0.717	1.027	1.086	1.068
LVA	**1.000**	0.582	0.565	**1.000**	1.329	1.341
MEX	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
NLD	0.743	0.735	0.726	1.061	1.066	1.040
NOR	0.557	0.575	0.631	1.103	1.137	1.115
NZL	0.649	0.717	0.727	1.094	1.095	1.069
POL	0.398	0.676	0.468	1.343	1.172	1.353
PRT	0.449	0.506	0.571	1.229	1.225	1.200
SVK	0.467	0.502	0.496	1.174	1.413	1.387
SVN	0.404	0.485	0.483	1.218	1.263	1.312
SWE	0.500	0.573	0.563	1.082	1.080	1.113
TUR	0.561	0.579	0.640	1.218	1.334	1.258
USA	0.874	0.796	0.814	1.028	1.100	1.094
Count	5	4	5	5	4	5
Average	0.679	0.665	0.667	1.102	1.161	1.159
Median	0.674	0.643	0.634	1.070	1.120	1.114
Min	0.385	0.411	0.423	1.000	1.000	1.000
Max	1.000	1.000	1.000	1.393	1.427	1.408
Stdev	0.200	0.168	0.170	0.105	0.130	0.129

Table B.2 – Input and Output-oriented DEA VRS Efficiency Scores for Model 2

	Input			Output		
	2007	2012	2017	2007	2012	2017
AUS	0.612	**1.000**	0.702	1.075	**1.000**	1.099
AUT	0.469	0.559	0.591	1.152	1.930	1.517
BEL	0.507	0.579	0.602	1.242	2.044	1.562
CAN	0.491	0.590	0.627	1.141	1.808	1.338
CHE	0.573	0.644	0.716	1.103	1.620	1.208
CHL	0.787	**1.000**	**1.000**	1.106	**1.000**	**1.000**
CZE	0.533	0.553	0.629	1.173	2.494	1.521
DEU	0.507	0.619	0.636	1.336	1.992	1.424
DNK	0.421	0.484	0.511	1.168	2.156	1.304
ESP	0.739	0.616	0.650	1.053	3.783	1.751
EST	0.920	0.626	0.629	1.016	3.140	1.565
FIN	0.486	0.545	0.575	1.132	2.298	1.610
FRA	0.430	0.492	0.539	1.196	2.112	1.513
GBR	0.678	0.680	0.673	1.125	2.158	1.424
GRC	0.515	0.565	0.652	1.201	151.626	2.345
HUN	0.509	0.546	0.670	1.431	3.128	1.550
IRL	0.709	0.633	**1.000**	1.054	2.793	**1.000**
ISL	0.990	0.491	0.579	1.002	2.652	1.226
ISR	0.475	0.604	0.660	1.291	1.358	1.316
ITA	0.544	0.608	0.668	1.452	3.651	1.973
JPN	0.671	0.644	0.684	1.072	2.224	1.482
KOR	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
LTU	0.688	0.670	0.685	1.071	2.935	1.560
LUX	0.715	0.563	0.674	1.037	1.983	1.260
LVA	**1.000**	0.692	0.692	**1.000**	4.262	1.623
MEX	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
NLD	0.534	0.564	0.574	1.176	2.018	1.480
NOR	0.433	0.515	0.559	1.198	1.789	1.355
NZL	0.473	0.547	0.571	1.142	1.658	1.263
POL	0.589	0.758	0.625	1.351	1.213	1.581
PRT	0.468	0.557	0.622	1.519	3.659	1.727
SVK	0.526	0.691	0.723	1.178	2.050	1.566
SVN	0.492	0.569	0.606	1.227	2.967	1.662
SWE	0.413	0.494	0.517	1.144	2.007	1.400
TUR	0.741	0.871	0.817	1.226	1.508	1.381
USA	0.645	0.572	0.622	1.063	1.912	1.317
Count	3	4	4	3	4	4
Average	0.619	0.643	0.674	1.163	6.359	1.442
Median	0.539	0.597	0.643	1.143	2.047	1.452
Min	0.413	0.484	0.511	1.000	1.000	1.000
Max	1.000	1.000	1.000	1.519	151.626	2.345
Stdev	0.179	0.150	0.132	0.130	24.917	0.274

Appendix C – Second Stage Regression

Table C.1 – DEA Input Efficiency Scores for Model 0

Regressors \ specification	(1)	(2)	(3)	(4)
Tax revenue (% GDP), t-1	-1.109***			
	(0.155)			
Direct taxes (% GDP), t-1		-0.885***		
		(0.208)		
Taxes income, profit capital (% GDP), t-1			-1.139***	
			(0.261)	
pit (% GDP), t-1				-1.243***
				(0.302)
cit (% GDP), t-1				-0.967
				(0.922)
Payroll taxes (% GDP), t-1			-0.653	-0.567
			(0.879)	(0.909)
Property taxes (% GDP), t-1			-0.690	-0.736
			(1.032)	(0.996)
Indirect taxes (% GDP), t-1		-1.305***	-1.183***	-1.128***
		(0.381)	(0.386)	(0.406)
Other taxes (% GDP), t-1		0.807	0.961	0.827
		(0.629)	(0.638)	(1.113)
SSC (% GDP), t-1	-0.305	-0.428*	-1.411***	-1.403***
	(0.217)	(0.227)	(0.262)	(0.273)
Non-tax revenue (% GDP), t-1	-0.522*	-0.713**	-0.678**	-0.677**
	(0.280)	(0.301)	(0.298)	(0.310)
Population (log), t-1	-0.003	-0.006	-0.004	-0.002
	(0.006)	(0.006)	(0.006)	(0.007)
Internet users, t-1	0.001*	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Tourism revenues (% exports), t-1	0.001	0.002	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Left political orientation, t-1	0.001	-0.012	-0.010	-0.011
	(0.020)	(0.021)	(0.021)	(0.021)
Center political orientation., t-1	0.079***	0.078***	0.081***	0.083***
	(0.023)	(0.024)	(0.023)	(0.024)
Observations	99	99	99	99
Sigma	0.067***	0.068***	0.067***	0.066***
	(0.005)	(0.005)	(0.005)	(0.005)
Region Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes

Note: The table reports the estimated coefficients from Equation (7) using Simar and Wilson two-stage efficiency regression model. The dependent variable is the DEA input scores for 2007, 2012 and 2017 using Model 0. The definition and sources of the independent variables are presented in Table A.3 of Appendix A. Five regions and year fixed effects are included but not reported for reasons of parsimony. Constant term also omitted. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table C.2 – DEA Input Efficiency Scores for Model 2

Regressors \ specification	(1)	(2)	(3)	(4)
Tax revenue (% GDP), t-1	-0.946***			
	(0.170)			
Direct taxes (% GDP), t-1		-1.193***		
		(0.220)		
Taxes income, profit capital (% GDP), t-1			-1.425***	
			(0.279)	
pit (% GDP), t-1				-1.499***
				(0.322)
cit (% GDP), t-1				-1.793*
				(1.081)
Payroll taxes (% GDP), t-1			-1.484	-1.371
			(0.938)	(0.965)
Property taxes (% GDP), t-1			-0.324	-0.223
			(1.115)	(1.086)
Indirect taxes (% GDP), t-1		-0.115	0.033	0.030
		(0.402)	(0.410)	(0.434)
Other taxes (% GDP), t-1		0.751	0.860	1.286
		(0.668)	(0.680)	(1.276)
SSC (% GDP), t-1	-0.095	-0.013	-1.244***	-1.205***
	(0.238)	(0.240)	(0.279)	(0.290)
Non-tax revenue (% GDP), t-1	-0.922***	-1.046***	-0.999***	-0.996***
	(0.315)	(0.325)	(0.325)	(0.336)
Population (log), t-1	0.006	0.009	0.010	0.011
	(0.007)	(0.007)	(0.007)	(0.007)
Internet users, t-1	0.001	0.001	0.002*	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)
Tourism revenues (% exports), t-1	0.003	0.003	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Left political orientation, t-1	-0.017	-0.020	-0.016	-0.015
	(0.022)	(0.022)	(0.022)	(0.023)
Center political orientation., t-1	0.074***	0.077***	0.077***	0.083***
	(0.027)	(0.026)	(0.026)	(0.027)
Observations	97	97	97	97
Sigma	0.074***	0.072***	0.071***	0.070***
	(0.005)	(0.005)	(0.005)	(0.005)
Region Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes

Note: see table C1.

Table C.3 – DEA Output Efficiency Scores for Model 1

Regressors \ specification	(2)	(2)	(3)	(4)
Tax revenue (% GDP), t-1	-0.155			
	(0.234)			
Direct taxes (% GDP), t-1		-0.599**		
		(0.258)		
Taxes income, profit capital (% GDP), t-1			-0.807**	
			(0.338)	
pit (% GDP), t-1				-1.016***
				(0.372)
cit (% GDP), t-1				-0.146
				(1.301)
Payroll taxes (% GDP), t-1			-1.996	-1.844
			(1.308)	(1.284)
Property taxes (% GDP), t-1			1.773	1.783
			(1.320)	(1.319)
Indirect taxes (% GDP), t-1		1.519**	1.636***	1.756***
		(0.634)	(0.628)	(0.619)
Other taxes (% GDP), t-1		1.137	1.221	0.560
		(0.986)	(1.001)	(1.567)
SSC (% GDP), t-1	0.432	0.771**	0.128	0.049
	(0.341)	(0.329)	(0.341)	(0.359)
Non-tax revenue (% GDP), t-1	0.650	0.339	0.331	0.342
	(0.438)	(0.444)	(0.415)	(0.425)
Population (log), t-1	-0.021**	-0.013	-0.017*	-0.015*
	(0.009)	(0.009)	(0.009)	(0.008)
Internet users, t-1	-0.009***	-0.007***	-0.007***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
Tourism revenues (% exports), t-1	-0.005**	-0.005**	-0.006***	-0.006***
	(0.003)	(0.002)	(0.002)	(0.002)
Left political orientation, t-1	0.002	0.002	0.015	0.015
	(0.029)	(0.028)	(0.028)	(0.027)
Center political orientation., t-1	-0.124***	-0.107***	-0.108***	-0.109***
	(0.038)	(0.036)	(0.034)	(0.035)
Observations	94	94	94	94
Sigma	0.081***	0.076***	0.073***	0.073***
	(0.007)	(0.007)	(0.006)	(0.006)
Region Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes

Note: see Table C1.

Online Appendix – Malmquist Efficiency, Technology and Total Factor Productivity Change Indices

Table OA.1 – VRS Malmquist Indices for Model 1

	2007-2012			2012-2017			2007-2017		
	EC	TC	TFP	EC	TC	TFP	EC	TC	TFP
AUS	1.562	1.024	1.598	0.736	0.964	0.709	1.149	0.926	1.064
AUT	1.147	0.894	1.025	0.959	1.030	0.988	1.100	0.920	1.013
BEL	1.101	0.894	0.984	0.951	1.030	0.979	1.047	0.920	0.963
CAN	1.187	0.894	1.061	0.942	1.030	0.970	1.118	0.920	1.029
CHE	1.127	0.894	1.007	1.045	1.030	1.076	1.177	0.920	1.083
CHL	1.235	0.916	1.131	0.927	1.004	0.931	1.145	0.912	1.044
CZE	1.014	0.917	0.930	1.019	1.030	1.049	1.033	0.920	0.951
DEU	1.151	0.894	1.028	1.003	1.030	1.033	1.154	0.920	1.062
DNK	1.106	0.894	0.988	0.941	1.030	0.969	1.040	0.920	0.957
ESP	0.987	0.938	0.926	0.913	1.030	0.940	0.902	0.936	0.844
EST	1.042	0.972	1.013	0.885	1.030	0.911	0.922	0.961	0.886
FIN	1.109	0.894	0.991	0.953	1.030	0.981	1.057	0.920	0.973
FRA	1.091	0.894	0.975	0.956	1.030	0.985	1.044	0.920	0.961
GBR	0.980	0.894	0.876	0.929	1.030	0.957	0.910	0.920	0.838
GRC	0.955	0.923	0.881	0.942	1.030	0.970	0.899	0.925	0.832
HUN	1.033	0.894	0.923	1.081	1.021	1.104	1.117	0.913	1.020
IRL	1.036	0.893	0.924	0.975	0.977	0.953	1.010	0.971	0.980
ISL	1.106	0.894	0.989	1.034	1.027	1.062	1.144	0.910	1.041
ISR	1.301	1.024	1.332	0.985	0.974	0.959	1.281	0.904	1.158
ITA	1.099	0.894	0.982	1.012	1.030	1.042	1.112	0.920	1.023
JPN	1.174	0.894	1.050	0.943	1.030	0.971	1.107	0.919	1.017
KOR	1.000	1.022	1.022	1.000	0.938	0.938	1.000	0.993	0.993
LTU	0.920	1.006	0.926	0.905	1.030	0.932	0.833	0.985	0.820
LUX	1.077	0.894	0.963	1.038	1.030	1.069	1.119	0.906	1.013
LVA	0.775	1.024	0.793	0.909	1.030	0.937	0.705	1.014	0.715
MEX	1.027	0.893	0.917	1.000	1.014	1.014	1.027	0.904	0.928
NLD	1.079	0.894	0.965	0.975	1.030	1.004	1.052	0.920	0.968
NOR	1.132	0.894	1.012	1.024	1.030	1.054	1.160	0.920	1.067
NZL	1.139	0.894	1.018	0.972	1.030	1.001	1.107	0.920	1.019
POL	1.734	1.045	1.811	0.657	0.989	0.649	1.139	0.915	1.042
PRT	1.091	0.894	0.975	0.997	1.030	1.027	1.088	0.920	1.001
SVK	1.078	0.953	1.027	0.980	1.019	0.999	1.056	0.938	0.990
SVN	1.173	0.894	1.048	0.934	1.030	0.962	1.095	0.907	0.993
SWE	1.185	0.894	1.059	0.993	1.030	1.023	1.176	0.920	1.083
TUR	1.037	0.992	1.029	1.083	0.980	1.061	1.123	0.951	1.068
USA	1.041	0.894	0.930	0.980	1.030	1.010	1.021	0.920	0.939
Average	1.112	0.925	1.031	0.960	1.018	0.978	1.060	0.929	0.983
Median	1.095	0.894	0.990	0.973	1.030	0.983	1.091	0.920	0.997
Min	0.775	0.893	0.793	0.657	0.938	0.649	0.705	0.904	0.715
Max	1.734	1.045	1.811	1.083	1.030	1.104	1.281	1.014	1.158
Stdev	0.163	0.051	0.188	0.081	0.023	0.088	0.111	0.025	0.089

Table OA.2 – VRS Malmquist Indices for Model 2

	2007-2012			2012-2017			2007-2017		
	EC	TC	TFP	EC	TC	TFP	EC	TC	TFP
AUS	1.616	1.046	1.690	0.743	0.938	0.697	1.202	0.977	1.174
AUT	0.875	1.066	0.933	1.029	0.940	0.968	0.900	1.002	0.902
BEL	0.853	1.066	0.909	1.041	0.940	0.979	0.888	1.002	0.890
CAN	0.933	1.066	0.994	1.081	0.940	1.017	1.008	1.002	1.011
CHE	0.977	1.066	1.041	1.106	0.940	1.040	1.081	1.002	1.083
CHL	1.128	1.046	1.180	0.791	0.939	0.743	0.892	0.967	0.863
CZE	0.601	1.066	0.641	1.402	0.940	1.318	0.843	1.002	0.845
DEU	1.006	1.066	1.073	1.099	0.940	1.033	1.106	1.002	1.108
DNK	0.766	1.066	0.816	1.334	0.940	1.254	1.021	1.002	1.024
ESP	0.381	1.066	0.406	1.734	0.940	1.631	0.660	1.002	0.661
EST	0.515	1.039	0.536	1.468	0.939	1.379	0.757	0.988	0.748
FIN	0.679	1.066	0.724	1.153	0.940	1.085	0.783	1.002	0.785
FRA	0.797	1.066	0.849	1.170	0.940	1.100	0.932	1.002	0.934
GBR	0.619	1.066	0.660	1.182	0.940	1.112	0.732	1.002	0.734
GRC	0.011	1.066	0.011	56.883	0.940	53.491	0.607	1.002	0.609
HUN	0.604	1.066	0.644	1.879	0.940	1.767	1.136	1.002	1.138
IRL	0.508	1.066	0.541	2.149	0.940	2.021	1.091	1.002	1.094
ISL	0.559	1.023	0.571	1.885	0.941	1.774	1.053	0.966	1.017
ISR	1.450	1.066	1.546	0.861	0.940	0.810	1.249	1.002	1.251
ITA	0.546	1.066	0.582	1.545	0.940	1.453	0.844	1.002	0.846
JPN	0.772	1.066	0.823	1.205	0.940	1.133	0.930	1.002	0.931
KOR	1.000	1.054	1.054	1.000	0.938	0.938	1.000	0.989	0.989
LTU	0.493	1.066	0.526	1.482	0.940	1.393	0.731	1.002	0.732
LUX	0.705	1.066	0.751	1.430	0.940	1.345	1.008	1.002	1.010
LVA	0.272	1.066	0.290	2.068	0.940	1.945	0.562	1.002	0.563
MEX	1.000	0.953	0.953	1.000	1.010	1.010	1.000	0.960	0.960
NLD	0.757	1.066	0.806	1.058	0.940	0.995	0.800	1.002	0.802
NOR	0.978	1.066	1.043	1.092	0.940	1.026	1.068	1.002	1.070
NZL	0.997	1.040	1.037	1.040	0.938	0.975	1.036	0.975	1.010
POL	1.474	1.066	1.571	0.576	0.940	0.542	0.849	1.002	0.851
PRT	0.608	1.066	0.648	1.811	0.940	1.703	1.101	1.002	1.104
SVK	0.883	1.066	0.941	1.083	0.940	1.018	0.956	1.002	0.958
SVN	0.588	1.066	0.627	1.454	0.940	1.367	0.855	1.002	0.857
SWE	0.838	1.066	0.893	1.147	0.940	1.079	0.961	1.002	0.963
TUR	0.959	1.066	1.023	0.948	0.940	0.891	0.910	1.002	0.912
USA	0.788	1.007	0.793	1.183	0.945	1.118	0.932	0.960	0.895
Average	0.793	1.057	0.837	2.809	0.942	2.643	0.930	0.996	0.926
Median	0.780	1.066	0.819	1.162	0.940	1.092	0.932	1.002	0.933
Min	0.011	0.953	0.011	0.576	0.938	0.542	0.562	0.960	0.563
Max	1.616	1.066	1.690	56.883	1.010	53.491	1.249	1.002	1.251
Stdev	0.321	0.022	0.338	9.277	0.012	8.724	0.160	0.013	0.158