International Journal of New Political Economy 4(1): 69-94, 2023

IJEP International Journal of New Political Economy

DOI: 10. 52547/jep.4.1.69

The Optimal Tax Rate, Efficiency and Technological Gap of Government in OECD Countries: Stochastic Meta-frontier Approach

Golnaz Hadian[1], Sara Ghobadi[*2], Majid Sameti[3]

ARTICLE INFO

Article history:

Date of submission: 13-011-2022

Date of acceptance: 30-12-2022

JEL Classification:

C23
C51
E23
E60
H21

Keywords:

Endogenous growth model
Optimal tax rate
Government technical efficiency
Meta-frontier production function
Technology gap ratio

ABSTRACT

In the last decades, many economists have tried to develop models for obtaining the optimal tax rate to maximize economic growth. Aiming to contribute to these studies, this study presents a novel approach to determine the optimal tax rate based on stochastic meta-frontier analysis. To this end, the Meta technical efficiency, group's technical efficiency, technology gap ratio, and optimal tax rate were determined for the period 1996-2018 in a selection of OECD countries. The countries were categorized into three groups, namely the Western European, Eastern European, and other members of OECD countries. The average values of the optimal tax rate were then measured using coefficients of the estimated meta-frontier model and analyzing the optimal rates. The results indicated that the highest average technical efficiency belongs to the Eastern European countries and the highest average Meta technical efficiency and technology gap ratio belong to the Western European countries. The results demonstrated that Luxembourg with the highest average value of Meta technical efficiency as well as technical efficiency and Meta technical efficiency values higher than 0.9 and also the maximum amount of optimal tax rate can be considered as the reference for other countries. It was concluded that with 90% statistical confidence, the average real tax rates in some of the investigated countries are less than the balanced budget optimal tax rate during the studied period, while actual tax rates in some Western European countries countries are more than the optimal tax rate.

1. Introduction

In the last two decades, some economists and policymakers have focused on taxation and its spending plans with the aim of economic growth

1. Department of Economics, Isfahan, Khorasgan Branch, Islamic Azad University, Isfahan, Iran
2. Department of Economics, Isfahan, Khorasgan Branch, Islamic Azad University, Isfahan, Iran, (Corresponding Author), Email: sghobadi@khuisf.ac.ir
3. Department of Economics, University of Isfahan, Isfahan, Iran.

and the welfare of society. To this end, some researchers introduced a new theory of endogenous growth with an emphasis on the government role which is focused on the endogeneity of growth rate in both transaction and stability conditions (Barro, 1989, 1990, 1991; Lucas, 1988; Romer, 1986, 1990). Barro (1991) pointed to the role of governments based on this viewpoint that although governments may suppress economic growth by collecting more taxes, at the same time they can positively contribute to economic growth through the positive effects of R&D, economic infrastructures, education, and health expenditures on the marginal productivity of production inputs. This viewpoint emphasizes the fact that the endogenous growth theory could not ignore the negative and positive effects of the government's economic activities on the growth process. Regarding Barro's view, the tradeoff between government expenditure and economic growth is non-monotonic. Because when the public sector is very wide, the reducing effect of a rise in taxation on growth is more than the increasing effect of expensing it and conversely. Chao and Grubel (1998) stated that some parts of government expenditures will decelerate economic growth by reducing the effective labor supply and investment. These parts of government expenditures may have discouraging effects on the individuals' and agents' economical life and vary their economical behaviors by decreasing their risk components. Also, (Scully, 1996, 2000, 2003, 2006) found that excessive increases in public expenditure have a substantially depressive effect on economic growth. King and Rebelo (1990), Rebelo (1991), Chusseau and Hellier (2008), Forte and Magazzino (2011), and Akhtar et al. (2018) determined the optimal size of government or an optimal tax rate to maximize economic growth using the BARS Curve (the curve relates the size of government to the rate of economic growth). It was found that high Gross Domestic Product (GDP) countries have overcome the level of government size compatible with GDP growth rate maximization.

According to the above literature, the role of government in economic growth has considerably been debated among many researchers. The question that always comes up is whether the role of government through the composition of government expenditure or government consumption and taxes affects long-run economic growth. While the above standard econometric methods for determining the optimal tax rate used are based on the technical efficient behavior assumption (i.e. moving on the frontier of production), the inefficiency in the behavior of economic agents (as government) can violate this assumption. The effect of government economic behavior on the production process may be analyzed by using the stochastic frontier production in which government economic variables can be substituted by private sector input to evaluate the government efficiency and determine the optimal tax rate (OTR) i.e., growth-maximizing. Therefore the stochastic frontier analysis can be significantly better than standard estimation methods to determine the OTR, especially among countries willing to integrate, such as Organisation for Economic Co-operation and Development (OECD) countries.

The paper is organized as follows: A literature review of related works is given in Section 2. The analytical framework is introduced in Section 3 in two subsections. Section 3.1 is allocated to generalize the Scully production function and section 3.2 refers to the estimation method based on stochastic meta-frontier analysis. Data description, model estimation, and statistical analysis are explained in Sections 4 and 5. Finally, Section 6 concludes the paper.

2. Literature review

The effect of taxes on government expenditures and economic growth is an issue that has been researched extensively for many decades but still remains unclear. Although this subject has formed the basis of many theories of growth, it has been interpreted differently in different models and theories in terms of its effects. This section gives a literature review on this subject. To this end, these studies are grouped according to the relationship examined.

2.1. Tax revenues, government expenditures, and economic growth

The relationship between government expenditures and taxes is a subject of increasing interest that has proved enduringly popular. Gebreegziabher

(2018) investigated the influences of government expenditures and taxation on economic growth in Ethiopia using the autoregressive distributed lag modeling approach. It was found that a good performance in the collection of indirect tax revenue and increased productive government consumption positively affects both short and long-run economic growth. Gurdal et al. (2021) investigated the relationship between tax revenues, government expenditures, and economic growth for G7 countries for the period 1980-2016. The results showed that there was a bidirectional causality between economic growth and government expenditures, while unidirectional causality between government expenditures and tax revenues was observed. It was concluded that the taxation policies of G7 countries are powerful financial tools to achieve economic goals. Moyo et al. (2021), using the co-integration analysis, investigated the relationship between taxation, government expenditures, and economic growth using data from 1991-2018 in South Africa. They found that levels of taxation and government expenditures are favorable to economic growth.

2.2. Tax revenues-economic growth

Empirical studies on the relationship between tax revenues and economic growth report different results. Saibu (2015) and Chokri and Ali (2018) studied the OTR for South Africa for the period 1994-2016 using the ARDL approach. No significant relationship between taxation and economic growth was observed for the studied period. Amgain (2017) investigated the OTR for 32 Asian countries using the Scully and quadratic model for the period 1991-2012. The results showed an 18% share of GDP as the growth maximizing tax burden. These findings supported theoretical propositions that there is an optimal tax level at which economic growth is maximized. Koatsa et al. (2021) estimated the relationship between tax burden and economic growth in Lesotho using Scully's tax optimization model. It was reported that an optimal tax burden cannot be established since the variables were negative and insignificant. Gross and Klein (2022) investigated optimal tax policy in a Romer-style endogenous growth model. Some relations were derived for the OTR on capital, labour, and innovation on a balanced growth path. They stated that taxes on innovative activities that lead to the growth of the economy is dependent on government spending needs. Using Scully's model, Ofori et al. (2021) estimated the OTR value at which economic growth is maximized in Ghana, for the period 2007-2017. It was found that to achieve economic growth at an average rate of 8.9% the OTR should increase from 15.3% to 27.7%. The study of Kavese and Phiri (2020) differs from the previous studies in two respects. Firstly, they distinguished between revenue-maximizing and growth-maximizing optimal tax rates. Secondly, they go beyond the traditional reliance on aggregated tax rates and provided optimal tax estimates for six sub-categories of tax rates employed by South African fiscal authorities. The results indicated that fiscal authorities have generally implemented revenue-maximizing tax policy during economic recession whilst leaning towards growth-maximizing tax rates during expansion periods.

2.3. Government expenditures-economic growth

As with the theoretical models, the empirical studies on this subject demonstrate different results. Shkodra et al. (2022) examined the influence of government expenditures on economic growth in Southeast EU countries. It was found that government expenditures positively affect economic growth. Kirikkaleli and Ozbeser (2022) studied the correlation between government expenditures and economic growth by employing the wavelet coherence method in the United States using data from 1960-2019. It was found that economic growth results in government expenditure. On the other hand, using a panel threshold regression model, Akram and Rath (2020) pointed to the positive and significant impact of government size on economic growth within the estimated thresholds for both aggregate and sub-panels based on income and regions. Similar results were reported for the Middle East and North African countries (Asghari et al., 2014). Divino et al. (2020) employed a theoretical framework to find optimal relations among government size, public spending, and economic growth and confront them with panel data for the Brazilian states. It was concluded that the average state-level government is below the optimal level. Thus, it is possible to raise the growth rate of consumption by increasing government spending under a balanced public budget in some Brazilian states. Using regression and panel techniques, Sáez et al. (2017) provided new evidence of the effect of government expenditures on economic growth in the European Union countries. It was found that a clear relationship between government expenditures and economic growth cannot be established for the period 1994–2012.The above review is by no means exhaustive but it shows that the relationship between government expenditures, tax revenues, and economic growth is subject to several different factors, including the selection of countries, level of countries' development, timelines, variables included in the model, methodology used, etc. Also, it can be concluded that most of these researches employ Scully's OTR model and his framework is extended to other countries. Additionally, two shortcomings are noted in these studies. Firstly, the standard econometric methods used to determine the OTR are based on the technical efficient behavior assumption. Secondly, none of the previous studies has provided a relationship between OTR and government efficiency.

The present study uses the model developed by Scully (2003) to estimate the optimal tax rate (OTR) that maximizes economic growth. In Scully's model, Cobb–Douglas production function has a constant return to scale. Also, the OTR is determined by assuming a balanced budget. While in this study, the Cobb–Douglas production function has a variable return to scale. Additionally, a balanced budget is not employed. Moreover, this study tries to establish a link between the OTR and government efficiency. To this end, the influence of government economic behavior on the production process is assessed using the stochastic frontier production in which government economic variables are substituted by private sector input to analyze the efficiency of the government and determine the OTR. Generally, This paper addresses two important questions in optimal taxation: (1) how to empirically estimate optimal tax rates; and, (2) how do optimal tax rates vary across contexts?. To this end, the relationship between the government technical efficiency and OTR in a selection of OECD countries for the period 1996-2018 is determined using a novel method based on stochastic meta-frontier analysis. The paper benefits from comparisons across a wide range of countries. These comparisons could be expanded to help provide more intuition for why the developed model finds the optimal tax rates that it does.

3. Methodology and data

This section describes the methodology of the study and the data. The first part focuses on calculating the optimal tax rate and the second part is devoted to introducing the econometric model. The third part describes the data used in this study.

3.1. The growth maximizing tax rate

Consider the aggregate production function of an economy as a Cobb-Douglas form:

$$Y_t = A_t L_t^a K_t^b \tag{1}$$

Where Y_t, L_t, K_t denote GDP, labor force, and private capital stocks in period *t*, respectively and *A* is exogenous technical progress in the form $A_t = Ae^{\omega t}$.

Based on the studies of Barro (1990) and Scully (1995), if the ratio of disposal income (*YD*) to private capital stocks (K_t) is assumed as a monotonic function of the ratio of government expenditure (*G*) to private capital stocks (Eq. 2)[1]:

1. In Barro's model, productivity is linked to the ratio of government-provided goods and services to physical capital. Thus output per worker in the Cobb-Douglas framework is $Y = AK(\frac{G}{K})^{\alpha}$.

$$\frac{YD_t}{K_t} = \zeta(\frac{G_t}{K_t})^{\theta} \qquad \text{With} \quad \zeta, \theta > \tag{2}$$

Therefore private capital stocks are:

$$K_t = \lambda YD_t^{\phi} G_t^{(1-\phi)} \qquad \text{With} \quad \lambda = \zeta^{-\frac{1}{1-\phi}} \text{ and } \phi = \frac{1}{1-\theta} \tag{3}$$

Considering $YD_t = (1-\tau_t)Y_t$ and replacing Eq. 3 in Eq. 1, the logarithm of the production function is as follows:

$$\ln Y_t = \Omega + \alpha \ln L_t + \rho \ln(1-\tau_t) + \delta \ln G_t + \omega t \tag{4}$$

Where $\Omega = (\frac{1}{1-\phi b})\ln(A\lambda^{\beta})$, $\alpha = \frac{a}{1-\phi b}$, $\rho = \frac{\phi b}{1-\phi b}$, $\delta = \frac{(1-\phi)b}{1-\phi b}$

and τ is the average tax rate[1].

Considering government expenditure is equal to the sum of government tax revenue ($\tau_t Y_t$) and other government revenue[2] (OR_t), the maximizing condition of gross domestic production with respect to tax rate is:

$$\frac{d \ln Y_t}{d \tau_t} = (\frac{d \ln Y_t}{d \ln(1-\tau_t)})(\frac{d \ln(1-\tau_t)}{d \tau_t}) + (\frac{d \ln Y_t}{d \ln G_t})(\frac{d \ln(\tau_t Y_t + OR_t)}{d \tau_t}) = -\frac{\rho}{1-\tau_t} + \frac{\delta Y_t}{G_t} \tag{5}$$

And finally, the optimal tax rate is calculated as follows[3]:

$$\tau_t^* = \frac{\delta - \rho(\frac{OR_t}{Y_t})}{\rho + \delta} \tag{6}$$

3.2. Econometric model

Firms[1] in different situations are faced with various production opportunities.

---

1. This production presents either direct effects of government taxation on GDP or indirect effects of government expenditure (from labor force) on GDP.
2. Including budget deficit items, foreign aids etc.
3. "Optimal tax rate" refers to revenue-maximizing or growth-maximizing tax rate in the optimal tax rate literature. Additionally The optimal tax rate in the balanced budget condition ($OR_t = 0$) is constant (i.e. $\tau_t^* = \frac{\delta}{\rho + \delta}$).

In these conditions, entrepreneurs choose different technology sets to change the available combinations of input-output sets. Changes in these technology sets will be affected by changes in the labor force, human capital, economic infractions, existing natural resources, and social-economic conditions that are usually altered by taxation and government spending. Therefore, measuring the technical efficiencies of firms in various groups must be estimated in separate frontier technology sets. However, the comparison of measured efficiency levels subjected to different frontiers is generally impossible because one frontier cannot be compared to another one.

Meta-frontier production function was first introduced by Hayami (1969), and Hayami and Ruttan (1970) and then developed by Battese and Rao (2002), Battese et al. (2004), and O'Donnell et al. (2008). Meta-frontier production is based on the idea that producers in various production groups have potential access to a set of technologies, but each may choose a particular technology, depending on the specific circumstances mentioned above. This method provides the possibility of comparing the technical efficiencies among firms in a single industry in which there are different technology sets. The technology gap (Meta technology) ratio is considered as a measure for making this comparison. The frontier of an unrestricted technology set is defined as a common frontier, hence restricted technology sets are considered as groups' frontiers. The meta-frontier production function is a frontier function that envelops all frontiers of individual regions/groups. Fig. 1 presents an illustration of a simple case with one input. At a given input bundle, the technology gap ratio (TGR) is defined as the highest possible output within the region divided by the highest possible output at the meta-frontier. The technical efficiency relative to the meta-frontier is defined as the real output of a county divided by the highest possible output at the meta-frontier.

1. In this study, total of an economy is considered as one firm.

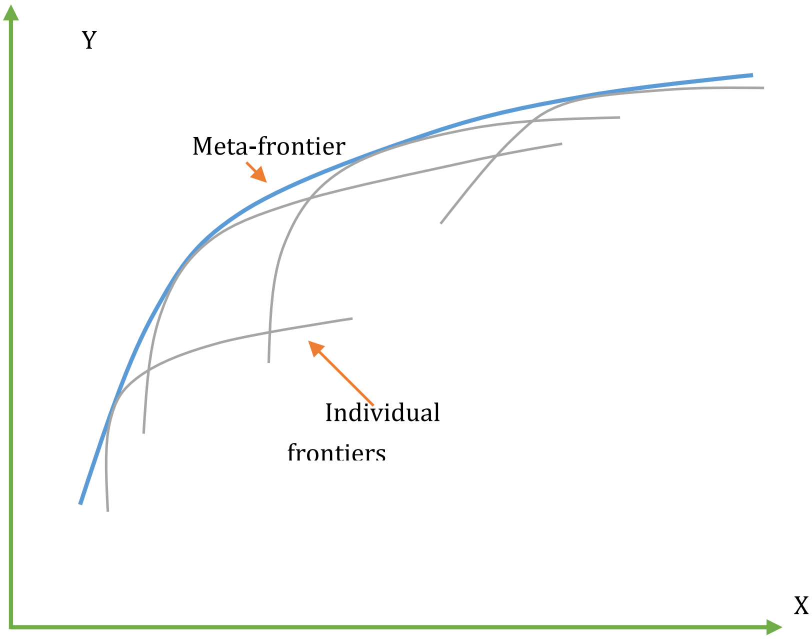

Fig. 1. Illustration of meta-frontier and individual frontiers

Based on the studies of Battese and Rao (2002), Battese et al. (2004), and Karthick et al. (2015) it is assumed that the stochastic frontier of a frontier production model in *K* groups is as follows:

$$Y_{it}^{m} = f(X_{it}, \beta^{m}) \exp(v_{it}^{m} - u_{it}^{m}) = e^{X_{it}\beta^{m} + v_{it}^{m} - u_{it}^{m}} \quad (7)$$

where Y_{it}^{m} is the product of i_{th} firm existing in m_{th} group, X_{it} is inputs vector used by i_{th} firm existing in m_{th} group, β^{m} is unknown parameter vector due to m_{th} group, v_{it}^{m} is traditional disturbance term of i_{th} firm existing in m_{th} group with a normal distribution (i.e., $v_{it}^{m} = IN(0, \sigma_{v^m}^{2})$), u_{it}^{m} is inefficiency term of i_{th} firm existing in m_{th} group with normal distribution truncated in zero which has average μ_{i}^{m} and variance $\sigma_{u^m}^{2}$ and t

is time subscript. As proposed by Battese and Coelli (1995), u_{it}^{m} is defined in the appropriate inefficiency model[1] and technical efficiency of i_{th} firm subjected to the frontier of m th group in period t will be:

$$TE_{it}^{m} = \frac{Y_{it}^{m}}{e^{X_{it}\beta^{m}+v_{it}^{m}}} = e^{-u_{it}^{m}} \tag{8}$$

Also, as proposed by O'Donnell et al. (2008), the stochastic meta-frontier production function for all firms can be presented as:

$$Y_{it}^{*} = f(X_{it}, \beta^{*}) = e^{X_{it}\beta^{*}} \tag{9}$$

Where Y_{it}^{*} is meta-frontier production in period t and β^{*} is the vector of meta-frontier parameters that must satisfy the following restriction[2]:

$$X_{it}\beta^{*} \geq X_{it}\beta^{m} \quad \text{for all } m = 1,2,\ldots,M \tag{10}$$

This restriction satisfies that the meta-frontier function cannot stay below any group's function. Therefore, an estimated meta-frontier function (as the envelop curve of estimated groups functions curves) can be obtained by solving the above restricted optimizing problem. Now, Eq. 8 can be presented in a different form by using Eq. 10:

$$Y_{it}^{m} = e^{-u_{it}^{m}} \times \frac{e^{X_{it}\beta^{m}}}{e^{X_{it}\beta^{*}}} \times e^{X_{it}\beta^{*}+v_{it}^{m}} \tag{11}$$

Where $e^{-u_{it}^{m}}$ is technical efficiency subject to the frontier of m_{th} group (group's technical efficiency) for i_{th} firm in a period of t and the second term shows the technology gap ratio (TGR):

$$TGR_{it}^{m} = \frac{e^{X_{it}\beta^{m}}}{e^{X_{it}\beta^{*}}} \quad \text{Where } 0 \leq TGR \leq 1 \tag{12}$$

1. In this study, the inefficiency is considered as time varying model in the form of $u_{it}^{m} = -\eta^{m}(T-t)u_{i}^{m}$, where η^{m} is unknown parameter of m_{th} group, T is period of end, t is consideration period and u_{i}^{m} is average inefficiency of i th firm existing in m_{th} group.
2. Meta-frontier is an envelope function of the stochastic frontiers of the different groups.

TGR_{it}^{m} is defined as the ratio of ith firm product in the frontier production function of m_{th} group to the potential product measured by the meta-frontier function in a period of t and the gap between group frontier and meta-frontier is reduced when its value tends to one.

Finally, Meta technical efficiency (MTE) of ith firm in tth period is given by:

$$MTE_{it} = \frac{Y_{it}}{e^{X_{it}\beta^{*}+v_{it}^{m}}} \quad (13)$$

Or by considering Eq. 12, the estimated meta-frontier technical efficiency is:

$$\hat{MTE}_{it} = \hat{TE}_{it}^{m} \times \hat{TGR}_{it}^{m} \quad (14)$$

In this study, government efficiency means product efficiency since the government variables such as government expenditure (G) and tax rate (1-τ) in Eq. 4 are used in the model. Therefore, the effect of these variables on production is evaluated.

3.3. Data description

This study uses the OECD database to provide gross domestic product[1] data and government expenditure[2] (both in billion dollars, PPP exchange rate, and constant price of 2011), the number of employment[3] (in million persons), and the average rate of tax for 28 selected OECD countries during 1996-2018. Due to the heterogeneity in these countries, they have been used in the following three country groups:

i) **The Western EU countries** as group WEU, including Austria, Belgium, Denmark, Finland, France, Germany, Greek, Ireland, Italy, Luxemburg, Nederland, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom.

ii) **The Eastern EU countries** as group EEU, including the Czech Republic,

1. This variable is obtained by dividing GDP (in current price) by the consumer price index.
2. This variable is calculated by multiplying the ratio of government expenditure in GDP by GDP.
3. This variable is drived by multiplying the employment rate by the number of workers.

Hungary, Poland, and Estonia.

iii) **Other members of OECD countries** as group OM, including Australia, Canada, Island, Japan, South Kore, New Zealand, and the United State of America.

4. Estimation model and statistical analysis

A summary of the aggregate statistical criteria of the variables studied in three groups of countries is given in Table 1. The differences in these statistics indicate differences in the characteristics of these three groups of countries.

Table 1. Summary statistics of variables for the investigated OECD countries

Group	Statistic	GDP	Real Tax Rate	Government Expenditure	Employment	Number of Countries	Number of Observations
WEU	Mean	876.211	0.3762	411.3599	13314.97	17	391
	Standard Deviation	947.3232	0.0607	453.4052	13299		
EEU	Mean	311.79	0.3571	139.73	7621.09	4	92
	Standard Deviation	265.02	0.025	113.4509	6804.083		
OM	Mean	3201.802	0.2922	1205.075	45645.244	7	161
	Standard Deviation	4846.401	0.049	1866.191	59996.59		

Source: Research findings and OECD database

Log-likelihood ratio test based on the logarithm of maximum likelihood results of the estimation models under the null and opposite hypothesis was used to determine the structure of inefficiencies distribution and select the appropriate estimation method between the pooled model of three groups of countries and the meta-frontier model. The results of testing these assumptions are presented in Table 2.

Table 2. Composite hypothesis test related to the parameters of γ, μ, η

H_2	H_1	$\sum_{i=1}^{3}\log L(H_0)$	$\sum_{i=1}^{3}\log L(H_1)$	LR statistics	Test result
$\gamma = \mu = \eta = 0$	$\gamma \neq 0, \mu = \eta = 0$	713.219	934.167	441.908	H_0 reject
$\gamma \neq 0, \mu = \eta = 0$	$\gamma, \mu, \eta \neq 0$	934.167	950.585	32.836	H_0 reject
$\gamma \neq 0, \mu = \eta = 0$	$\gamma, \mu \neq 0, \eta = 0$	934.167	944.873	21.412	H_0 reject
$\gamma \neq 0, \mu = \eta = 0$	$\gamma, \eta \neq 0, \mu = 0$	934.167	966.586	64.838	H_0 reject
$\gamma, \mu \neq 0, \eta = 0$	$\gamma, \mu, \eta \neq 0$	944.873	950.585	11.424	H_0 reject

Source: Research findings

From the results of the first test, it is evident that the traditional average production in the three group countries is not an adequate representation of the data (i.e. the null hypothesis lack of stochastic frontier production function is rejected). Furthermore, the results of other hypothesis tests point to the normal distribution and its variation over time for inefficiencies components in accordance with the model of Battese and Coelli (1992) as follows[1]:

$$u_{it} = \{\exp[-\eta(t-T)]\}u_i \tag{15}$$

Since the LR statistical calculated value (=332.88) of the likelihood ratio test reported in Table 3 is larger than the critical value of x^2 statistical with 16 degrees of freedom in one percent level of error, the hypothesis of identical technology between the group's stochastic frontier models is rejected. Therefore, due to the impossibility of applying the pooled model, one needs to employ the meta-frontier model to determine the efficiency of the governments in the three groups of countries.

Table 3. The likelihood ratio test for the selection of the model estimation technique

1. Because, for three groups countries in 5 percent level of error, the null hypothesis $\eta = 0$ is rejected in every condition and the null hypothesis $\mu = 0$ (restricted to $\gamma, \eta \neq 0$) is not rejected.

Null Hypothesis	$\log L(pooled)$	$\sum_{i=1}^{3}\log L(H_1)$	LR statistics	Test result
Polled model is true	784.14	950.585	332.88	H_0 reject

Source: Research findings

The maximum likelihood estimation results of a stochastic frontier production function for the individuals and pooled model of the three groups, together with their meta-frontier function by using the linear programming method are shown in Table 4.

Table 4. Estimations of group frontiers, pooled frontier, and meta-frontier production

variable	**coefficient**	**WEU**	**EEU**	**OM**	**Pooled**	**Meta-frontier**
constant	Ω	-2.5055 (-5.36)	-3.4156 (-3.84)	0.7994 (2.42)	-0.8171 (-2.01)	-3.0794 (-4.26)
ln(emp)	α	0.3202 (12.69)	0.3913 (7.37)	0.4063 (35.01)	0.3608 (23.61)	0.3285 (8.44)
ln(G)	δ	0.6022 (21.62)	0.5388 (9.23)	0.3705 (20.88)	0.5092 (24.54)	0.6365 (21.62)
$\ln(1-\tau)$	ρ	0.6532 (5.95)	0.6799 (2.93)	0.7004 (8.43)	0.3813 (4.35)	0.7588 (3.6454)
Time trend	$\boldsymbol{\omega}$	0.0052 (6.44)	0.0185 (5.63)	0.0156 (12.18)	0.0032 (3.97)	0.01316 (8.8)
-	σ^2	0.1944 (2.86)	0.0068 (5.39)	0.0141 (5.32)	0.0612 (12.23)	-
-	γ	0.9825 (150.9)	0.7645 (9.96)	0.8893 (33.08)	0.937 (87.78)	-
-	η	-0.0098 (-4.28)	-0.0926 (-5.11)	-0.0406 (-4.91)	0.0066 (5.63)	-
-	μ	-0.5935 (-1.88)	0.1446 (2.38)	0.2243 (3.59)	0.4789 (8.99)	-
Log Likelihood		515.819	158.954	275.812	784.144	-

Source: Research findings

These results emphasize that all of the production function coefficients in each of the three groups' frontiers are statistically significant in one percent level of errors.

On the other hand, the estimated results show that both the coefficients of the marginal tax rate and the government expenditure variables in the meta-frontier production function have positive signs and are statistically significant in less than the level of one percent errors[1]. The estimated coefficients for all groups show their elasticity. Government expenditures elasticity in WEU, EEU, and OM are 0.6022, 0.5388, and 0.3705, respectively. This means that government expenditures in WEU and EEU Groups have a more pronounced effect on production function as compared with the OM Group. Additionally, marginal tax rate elasticity values for WEU, EEU, and OM Groups are 0.6532, 0.6799, and 0.7004, respectively which are higher than the government expenditures elasticity. Moreover, government expenditures and marginal tax rate elasticities in the meta-frontier production function are respectively 0.6365 and 0.7588. This is the ideal position in which all groups are homogeneous and have only one government expenditure and marginal tax rate elasticity. As is observed in Table 4, government fiscal instruments (i.e., government expenditures and tax revenues) have a more significant effect on the production function as compared with labour force.

The calculated average values of the technology gap ratio (TGR), group's technical efficiency (TE), and meta-technical efficiency (MTE) are reported in Tables 5 and 6. Based on these results, the highest average value of TGR, TE, and MTE is allocated to WEU Group with 0.8798, EEU Group with 0.9780, and OM Group with 0.7613, respectively. Also, the lowest ones are devoted to EEU Group with 0.5775, OM Group with 0.7941, and EEU Group with 0.5288, respectively. Similarly, in terms of the group's average values, the highest values of TGR and MTE dedicate to OM Group and the

1. The bootstrapping method was used to calculate the standard deviation of the coefficients of this function. This technique was built by creating a random sample with 1000 members (of 1000 cycles), with mean and covariance matrix of the group's stochastic frontier production function estimated coefficients for each of the three groups of countries.

highest value of the group's TE belongs to EEU Group. In other words, in the EEU Group, group frontier production functions have the greatest distance compared to the Meta frontier production function. While this group has the smallest distance with its group frontiers. Also, in both the WEU and OM groups, the group frontier production function and Meta frontier production function have the smallest distance from each other.

Also, USA, Italy, and Luxembourg have the highest average TGR, group's TE, and MTE, respectively. The results demonstrate that Luxembourg enjoys the highest average value of MTE among the countries and also has TE and TGR values higher than 0.9. Additionally, Denmark has the minimum average group's TE, and MTE and the minimum TGR belongs to Poland.

As is observed in Table 5, the countries with a technology gap of 1, are fully placed on the meta-frontier production function and other countries must be compared with them. For example, Luxembourg in 1996 and OM countries including Korea, USA, and Japan in 1996, 2001, and 2018, respectively have a technology gap of 1. The average values of actual tax rates ($real\ \tau$) together with the estimated meta-frontier optimal tax rates values ($meta\ \tau$) and the lower bounder of 90% confidence level of $meta\ \tau$ ($L\ meta\ \tau$)[1] for all countries are calculated by replacing the estimated coefficients of the meta-frontier production function and considering both the average of government revenue ratio ($\frac{OR}{y}$) and also balance budget condition in Eq. 6 and are reported in Table 6. These results indicate that the maximum amount of $meta\ \tau$ and $real\ \tau$ tax rates belong to Luxembourg and Denmark and the minimum of them belong to Greece and Korea, respectively.

Although in all countries, the average annual values of the actual tax rate

1. By using the lower bound and the upper bound 90% confidence range, the coefficients δ and ρ are calculated, respectively.

were lower than the mean values of their optimal tax rates, with 90% confidence, it can be stated that the actual tax rate in Ireland, Switzerland, and Korea is less than the optimal rate of it. However, the actual tax rate (real τ) in comparison with the optimal tax rate of the Balanced Budget (equal to 34.81 percent) suggests that with 90% confidence, the actual tax rate in countries in WEU Group (Greece, Ireland, Portugal, Spain, Switzerland, and the UK), EEU Group (the Czech Republic and Poland) and the most countries in OM Group was lower than this optimal tax rate.

Table 5. Annual average of estimated TGR, TE, and MTE

year	WEU			EEU			OM		
	TGR	TE	MTE	TGR	TE	MTE	TGR	TE	MTE
1996	0.8798	0.8653	0.7613	0.5775	0.9780	0.5648	0.8354	0.9087	0.7592
1997	0.8730	0.8641	0.7544	0.5845	0.9759	0.5704	0.8346	0.9051	0.7554
1998	0.8659	0.8630	0.7472	0.5870	0.9736	0.5715	0.8384	0.9014	0.7558
1999	0.8583	0.8618	0.7397	0.5882	0.9711	0.5712	0.8251	0.8976	0.7406
2000	0.8507	0.8607	0.7322	0.5899	0.9683	0.5712	0.8319	0.8937	0.7435
2001	0.8436	0.8595	0.7251	0.5905	0.9653	0.5700	0.8381	0.8895	0.7455
2002	0.8354	0.8583	0.7170	0.5900	0.9620	0.5676	0.8237	0.8853	0.7292
2003	0.8272	0.8571	0.7090	0.5899	0.9584	0.5654	0.8165	0.8809	0.7193
2004	0.8197	0.8559	0.7016	0.5897	0.9545	0.5629	0.8079	0.8763	0.7079
2005	0.8122	0.8547	0.6942	0.5935	0.9502	0.5640	0.8163	0.8716	0.7115
2006	0.8056	0.8535	0.6876	0.5940	0.9456	0.5617	0.8260	0.8667	0.7159
2007	0.7988	0.8523	0.6808	0.5943	0.9405	0.5589	0.8325	0.8617	0.7173
2008	0.7916	0.8510	0.6737	0.5976	0.9350	0.5588	0.8311	0.8565	0.7119
2009	0.7838	0.8498	0.6661	0.5986	0.9289	0.5561	0.7994	0.8511	0.6804
2010	0.7759	0.8485	0.6584	0.6002	0.9224	0.5536	0.7640	0.8455	0.6460
2011	0.7689	0.8473	0.6515	0.6023	0.9152	0.5512	0.7629	0.8398	0.6407
2012	0.7639	0.8460	0.6463	0.6044	0.9075	0.5485	0.7723	0.8338	0.6440
2013	0.7583	0.8447	0.6406	0.6088	0.8991	0.5474	0.7867	0.8277	0.6512
2014	0.7525	0.8435	0.6347	0.6091	0.8899	0.5420	0.7913	0.8214	0.6500
2015	0.7466	0.8422	0.6288	0.6142	0.8801	0.5406	0.8079	0.8149	0.6584
2016	0.7402	0.8409	0.6225	0.6171	0.8694	0.5365	0.8294	0.8081	0.6703
2017	0.7345	0.8396	0.6167	0.6228	0.8579	0.5343	0.8801	0.8012	0.7051

year	WEU			EEU			OM		
	TGR	TE	MTE	TGR	TE	MTE	TGR	TE	MTE
2018	0.7285	0.8382	0.6106	0.6255	0.8454	0.5288	0.8464	0.7941	0.6721
average	0.8007	0.8521	0.6826	0.5987	0.9302	0.5564	0.8173	0.8579	0.7013
Standard Deviation	0.0474	0.0083	0.0471	0.0126	0.0403	0.0130	0.0279	0.0353	0.0402
min	0.6683	0.4280	0.6106	0.5668	0.7470	0.5288	0.4986	0.6759	0.6407
max	1.0000	0.9923	0.7613	0.6550	0.9874	0.5715	1.0000	0.9869	0.7592
Growth rate	-0.0081	-0.0013	-0.0095	0.0034	-0.0063	-0.0028	0.0005	-0.0058	-0.0052

Source: Research findings

Table 6. Average of estimated TGR, TE, and MTE together with real and meta optimal tax rate with 90% confidence

Group	Country	TGR	TE	MTE	$L\ meta-\tau$ (%)	$meta-\tau$ (%)	$real-\tau$ (%)
WEU	Austria	0.8121	0.8201	0.6660	28.47	42.73	42.05
	Belgium	0.8060	0.8715	0.7024	29.3	43.40	43.67
	Denmark	0.8220	0.4667	0.3836	29.64	43.67	46.2
	Finland	0.8329	0.7711	0.6422	28.54	42.79	43.02
	France	0.7440	0.9259	0.6889	27.58	42.02	43.52
	Germany	0.7323	0.9670	0.7081	27.74	42.15	35.93
	Greece	0.8138	0.7013	0.5707	24.09	39.23	32.74
	Ireland	0.8392	0.8632	0.7244	29.36	43.45	28.87
	Italy	0.7488	0.9914	0.7424	29.79	43.79	41.13
	Luxembourg	0.9017	0.9689	0.8737	31.79	46.39	36.94
	Netherlands	0.7861	0.8848	0.6955	29.15	43.27	36.24
	Norway	0.8226	0.9363	0.7702	31.54	45.16	40.89
	Portugal	0.8166	0.6739	0.5503	25.38	40.26	31.56
	Spain	0.7635	0.9154	0.6989	28.95	43.11	33
	Sweden	0.8105	0.8282	0.6713	29.73	43.74	45.12
	Switzerland	0.8120	0.9699	0.7876	30.8	44.6	26.81
	United Kingdom	0.7474	0.9298	0.6949	29.05	43.19	31.81
EEU	Czech Republic	0.5961	0.9626	0.5738	28.59	42.83	33.36

Group	Country	TGR	TE	MTE	$L\ meta-\tau$ (%)	$meta-\tau$ (%)	$real-\tau$ (%)
	Hungary	0.5932	0.9224	0.5472	27.39	41.86	38.22
	Poland	0.5805	0.9520	0.5526	27.66	42.08	33.4
	Slovenia	0.6250	0.8837	0.5523	28.2	42.51	37.87
OM	Australia	0.7660	0.9092	0.6964	28.95	43.12	28.35
	Canada	0.8611	0.8206	0.7066	29.5	43.56	33.03
	Iceland	0.5874	0.9789	0.5750	29.27	43.37	35.58
	Japan	0.9198	0.7732	0.7112	27.7	42.12	27.1
	Korea	0.9021	0.8083	0.7292	31.1	44.84	21.97
	New Zealand	0.7634	0.8487	0.6479	32.56	45.01	32.59
	United States	0.9213	0.8667	0.7985	26.09	41.54	26.93
$balance\ buget-\tau$		----	----	----	34.81	62.19	----

Source: Research findings

5- Conclusion and policy implications

According to the average values for the whole period, it can be stated that generally, WEU and OM countries enjoy high values of TGR and TE, and MTE, while EEU countries have the maximum amount of TE. The economic growth in the Western EU is largely due to growth in countries with access to the Atlantic Ocean and with substantial trade with Africa, and Asia via the Atlantic Ocean. In OM Group, the countries are industrial countries with modern technologies that follow open market strategies. These countries have the maximum average TGR. For example, the technology gap in the United States, Japan, and Luxembourg in some years has reached the value of unity. Luxembourg has the highest average value of MTE among the countries during the studied period and also has TE and TGR values higher than 0.9, therefore, governments in the surveyed countries (especially European Union members) can choose this country as the reference to improve their technological behaviors and group’s efficiencies. Moreover, these countries can increase their meta-frontier efficiency by reducing their budget deficits and moving toward a balanced budget tax rate. Luxembourg is the wealthiest country in the European Union. It’s very high level of GDP per capita may be explained by the fact that it employs tens of thousands of foreign workers, mainly from three neighboring countries: Germany, Belgium, and France. Also, its citizens enjoy a high standard of living. This country is a major center for large private banking, and its finance sector is the biggest contributor to its economy.

EEU countries have the same economic structure since they emerge from a socialist/communist system. While these countries have the maximum average group TE, their average TGR values are minimal. For example, TGR for the Czech Republic, Hungary, Poland, and Slovenia is between 0.58 and 0.62. This is attributed to the large government size, lack of competition in markets, and fixed technology. Since the countries of Eastern and Western Europe are members of the European Union, it is suggested that EEU countries choose the WEU countries as the reference and follow their government fiscal policies in production to improve their TGR and maximize economic growth. The observed decreasing trend in the annual average of the governments' TE may be ascribed to the negative effects of the economic integration process in the EU, while the increasing trend in the annual average of TGR in the EEU Group could be due to the positive effects of the integration process. Generally, it can be stated the growth rate of the three investigated indicators (i.e., TGR, TE, and MTE) in the WEU, EEU, and OM Groups is very low or in some cases close to zero. In other words, a harmonious relationship between these countries should be made. Also, policies must be established to encourage the countries to work together.

Additionally, actual tax rates in some WEU countries such as Belgium, Denmark, Finland, France, and Sweden are more than optimal tax rates, indicating that tax structure in these countries should be restructured to bring about a reduction in the optimal tax rate. It is worth mentioning that among the Western EU countries, Denmark has the lowest average group TE. This may be ascribed to the fact that in this country the actual tax rate is more than the OTR. Therefore, by following the tax rate reduction policy, Denmark can improve its economic efficiency. Since the actual tax rate is less than the optimal tax rate of the balanced budget, the emphasis on increasing tax rates to maximize economic growth and the improvement in the efficiency of the governments in Greece, Ireland, Portugal, Spain, Switzerland, the UK, Czech Republic, Poland, and most countries in OM Group seems necessary. The results of the present study have some implications for the surveyed countries. First, a tax rate below the optimal rate will imply the government efficiency is sub-optimal and this may lead to sub-optimal growth. Second, any tax rate beyond the optimal rate may lead to deadweight loss, which will be counterproductive to overall economic growth. Therefore, to achieve the desired growth and government efficiency, the tax rates for all countries except a few WEU countries should be increased. Any attempt to improve the overall tax burden by raising tax rates without improving the efficiency of the tax system will be counterproductive. Increases in taxes are likely to encourage tax evasion and push economic activity underground. Additional efforts should be done by decentralizing the fiscal administration and eliminating fraud, evasion, and corruption. Furthermore, the government should try to return taxes back to the public in an efficient manner. Using taxes in an efficient manner by adequately investing in public goods and services could encourage tax compliance.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statements

The data used in this study are available at “data.oecd.org”.

Statements and Declarations

The authors confirm that there is no financial interest whatsoever to report.

References

Akhtar, N., Tahir, M. S., Tariq, B., & Rashid, M. K. (2018). An essay on optimal size of government: a case study of Pakistan. *Amazonia Investiga*, *7*(17): 453-461.

Akram, V., & Rath, B. N. (2020). Optimum government size and economic growth in case of Indian states: Evidence from panel threshold model. *Economic Modelling*, *88*: 151-162.

Amgain, J. (2017). Estimating optimal level of taxation for growth maximization in Asia. *Applied Economics and Finance*, *4*(3): 47-55.

Asghari, R., Heidari, H., & Mohseni Zonouzi, S. J. (2014). An investigation of the impact of government size on economic growth: New evidence from selected MENA countries. *Iranian Journal of Economic Studies*, 3(2): 63-80.

Barro, R. J. (1989). A cross-country study of growth, saving, and government. *National saving and economic performance*, *1*: 1-67.

Barro, R. J. (1990). Government spending in a simple model of endogeneous growth. *Journal of political economy*, *98*(5): 103-125.

Barro, R. J. (1991). Economic growth in a cross section of countries. *The quarterly journal of economics*, *106*(2): 407-443.

Battese, G. E., & Coelli, T. (1992). Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of productivity analysis*, *3*(1): 153-169.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics*, *20* (2): 325-332.

Battese, G. E., & Rao, D. P. (2002). Technology gap, efficiency, and a stochastic metafrontier function. *International Journal of Business Economics*, *1*(2): 87-93.

Battese, G. E., Rao, D. S., & O'donnell, C. (2004). A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. *Journal of productivity analysis*, *21*(1): 91-103.

Chao, J. C., & Grubel, H. (1998). Optimal levels of spending and taxation in Canada. In *How to use the fiscal surplus: what is the optimal size of government* (pp. 53-68). The Fraser Institute, Vancouver.

Chokri, T., & Ali, B. (2018). Optimal Taxation and Economic Growth in Tunisia: Short and Long Run Analysis. *Journal of Reviews on Global Economics*, *7*: 157-164.

Chusseau, N., & Hellier, J. (2008). Social policies and R&D subsidies: impact on inequality, unemployment, growth and the tax burden. *International Journal of Manpower*, *29*(3): 239-262.

Divino, J. A., Maciel, D. T., & Sosa, W. (2020). Government size, composition of public spending and economic growth in Brazil. *Economic Modelling*, *91*: 155-166.

Forte, F., & Magazzino, C. (2011). Optimal size government and economic growth in EU countries. *Economia politica*, *28*(3): 295-322.

Gebreegziabher, S. (2018). Effects of tax and government expenditure on economic growth in Ethiopia. In *Economic Growth and Development in Ethiopia* (pp. 87-104). Springer.

Gross, T., & Klein, P. (2022). Optimal tax policy and endogenous growth through innovation. *Journal of Public Economics*, *209*: 104645.

Gurdal, T., Aydin, M., & Inal, V. (2021). The relationship between tax revenue, government expenditure, and economic growth in G7 countries: new evidence from time and frequency domain approaches. *Economic Change and Restructuring*, *54* (2): 305-337.

Hayami, Y. (1969). Sources of agricultural productivity gap among selected countries. *American Journal of Agricultural Economics*, *51*(3): 564-575.

Hayami, Y., & Ruttan, V. W. (1970). Agricultural productivity differences among countries. *The American economic review*, *60* (5): 895-911.

Karthick, V., Thilagavathi, M., Surendran, A., Paramasivam, R., & Balaji, S. (2015). Estimation of Resource Use Efficiency and Technical Efficiency of Small Onion Farmers in Tamil Nadu: A Cobb-Douglas and Stochastic Frontier Approach. *Economic Affairs*, *60* (3): 401-407.

Kavese, K., & Phiri, A. (2020). Optimal tax rates in South Africa: new empirical insights to the existing debate. *International Journal of Sustainable Economy*, *12* (1): 44-60.

King, R. G., & Rebelo, S. (1990). Public policy and economic growth: developing neoclassical implications. *Journal of political economy*, *98* (5): 126-150.

Kirikkaleli, D., & Ozbeser, B. (2022). New insights into an old issue: exploring the nexus between government expenditures and economic growth in the United States. *Applied Economics Letters*, *29* (2): 129-134.

Koatsa, N., Paramaiah, C., & Scona, M. (2021). Tax burden and economic growth in Lesotho: An estimate of the optimal tax burden. *Accounting*, *7*(3): 525-534.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of monetary economics*, *22*(1): 3-42.

Moyo, D., Samour, A., & Tursoy, T. (2021). The nexus between taxation, government expenditure and economic growth in South Africa. A fresh evidence from combined cointegration test. *Studies of Applied Economics*, *39*(3).

O'Donnell, C. J., Rao, D. S., & Battese, G. E. (2008). Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical economics*, *34*(2): 231-255.

Ofori, A. G., Baidoo, S. T., & Olesu, S. T. (2021). Optimal tax rate for growth in Ghana: An empirical investigation. *Journal of Public Affairs*, *21*(2): e2223.

Rebelo, S. (1991). Long-Run Policy Analysis and Long-Run Growth. *Journal of Political Economy*, *99*: 500-521.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of political economy*, *94*(5): 1002-1037.

Romer, P. M. (1990). Endogenous technological change. *Journal of political Economy*, *98*(5): 71-102.

Sáez, M. P., Álvarez-García, S., & Rodríguez, D. C. (2017). Government expenditure and economic growth in the European Union countries: New evidence. *Bulletin of Geography. Socio-Economic Series*(36): 127–133-127–133.

Saibu, O. M. (2015). Optimal tax rate and economic growth. Evidence from Nigeria and South Africa. *Euro Economica*, *34*(1): 41-50.

Scully, G. W. (1995). The "growth tax" in the United States. *Public Choice*, *85*(1):, 71-80.

Scully, G. W. (1996). Taxation and economic growth in New Zealand. *Pacific Economic Review*, *1*(2): 169-177.

Scully, G. W. (2000). The growth-maximizing tax rate. *Pacific Economic Review*, *5*(1): 93-96.

Scully, G. W. (2003). Optimal taxation, economic growth and income inequality. *Public choice*, *115*(3): 299-312.

Scully, G. W. (2006). *Taxes and economic growth, National Center for Policy Analysis*.

Shkodra, J., Krasniqi, A., & Ahmeti, N. (2022). The impact of government expenditure on economic growth in southeast European countries. *Journal of Management Information & Decision Sciences*, *25*.