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Abstract

This paper explores the possible link between the presence and stringency of fiscal rules and the overall efficiency levels of the public sector for a sample of 50 economies from different geographical regions around the world. In particular, we are interested in analyzing this possible relationship in the years following the period of fiscal consolidation that most countries experienced after the 2008 financial crisis. To do this, we rely on a nonparametric conditional approach that allows the consideration of two alternative composite indicators representing fiscal rule strength level as a potential conditional factor that might affect the estimation of efficiency scores reflecting public sector performance. Our results suggest that the influence of fiscal rules on public sector efficiency scores is significant and negative, especially when the system of fiscal rules has not reached an advanced stage of development.

Key words: Fiscal rules, Efficiency, Public expenditure; DEA; Two-stage, Nonparametric conditional approach

JEL Codes: H50; H60; C14

1. Introduction

Public spending efficiency measurement is one of the most explored fields in the economic literature[1], since it allows governments to identify possible deficiencies in the management of public resources (Joumard et al., 2004). These studies typically measure public sector efficiency by relating government expenditure to several socio-economic indicators usually targeted by public spending[2]. Moreover, most papers also explore the potential determinants of variations in efficiency levels across countries and over time (e.g., Hauner and Kyobe, 2010; Wang and Alvi, 2011).

Likewise, the literature on fiscal rules imposed by the authorities to promote fiscal discipline and control public spending and indebtedness over the last 30 years has grown in recent years to encompass descriptive and empirical papers on country and cross-country experiences. The analyzed topics are very broad and range from issues related to their design and implementation to the analysis of their effects on fiscal policy design, economic growth or the determination of fiscal performance (Debrun and Kumar 2009; Maliszewski 2009; Vinturis, 2022). Until recently, however, very few studies have explored the possible link between fiscal discipline and public sector efficiency. This is striking, considering the enormous pressure on public spending, especially in developed countries, which complicates compliance with fiscal rules.

In response to the difficulties that increased spending pressure pose to fiscal rule compliance, some studies advocate a review of the fiscal rules themselves, given that they may no longer serve their main purpose, i.e., to set limits on budgetary variables or debt to ensure sustainability (Blanchard, 2021). One piece of evidence suggesting that they may have become obsolete in the face of structural change in the economy and monetary policy exhaustion is the fact that there has been a significant increase in debt in most developed countries in the wake of the COVID-19 pandemic crisis and the war in Ukraine. Furman and Summers (2020) argue that setting limits on debt as a percentage of GDP is meaningless and

[1] See Sant' Ana et al. (2020) for a recent systematic bibliometric review.
[2] Most studies tend to focus on OECD and European countries, although the most recent literature does include some empirical studies focused on developing countries (Afonso et al., 2023).

should be replaced by other measures that more correctly reflect each country's financial position. In addition, the onset of the war has led to supply chain problems and raw material shortages, which have resulted in inflation. Against this backdrop, the large economic blocs have adopted generalized policies of interest rate hikes that have not been offset by the application of restrictive spending policies. In fact, many countries have approved spending packages to stimulate demand and a shift to a production model that is less dependent on fossil fuels. Thus, spending pressures are mounting, making it increasingly important not only to tighten fiscal restraint but also to achieve greater spending efficiency, as spending is set to grow significantly in the coming years.

In this scenario, we believe that it is of great interest to study the potential effects of fiscal rules given that their imposition is becoming increasingly widespread. Moreover, the present moment is particularly relevant, since several institutions, with the EU at the forefront, are in the process of reforming the fiscal rules applicable in their territories. In this paper, we assess the performance of 50 countries from different geographical regions around the world where fiscal rules are in force. We use the information about fiscal rules collected by the International Monetary Fund (IMF) to construct a composite indicator that includes very broad information on both the existence of different types of fiscal rules (expenditure, revenue, deficit and debt) and the different levels of enforcement required as a proxy of their strength level. Public sector efficiency scores are computed from the perspective of how much public spending can be reduced without changing the level of public goods and services provision (input orientation). From a methodological perspective, our main contribution is that we apply a totally nonparametric conditional approach to examine the influence of the above composite strength indicator on public sector performance without having to meet the restrictive separability condition required by the second-stage models commonly used in the literature to analyze the influence of contextual variables on efficiency measures. To the best of our knowledge, this model has not been previously employed in this framework.

The remainder of the paper is structured as follows. Section 2 provides a brief overview of the previous literature and introduces the main research hypotheses.

Section 3 reviews the concept and types of fiscal rules as a preliminary step to explaining how we constructed the composite indicator representing the characteristics of rules existing in the analyzed countries. Section 4 describes the methodology applied to measure efficiency in public expenditure and, subsequently, the approach adopted to examine the link between fiscal rules and public sector efficiency. Section 5 provides a brief description of the data employed and reports the main results. Finally, the paper ends with some concluding remarks in Section 6.

2. Previous literature and theoretical background

The recent economic literature has extensively investigated the effectiveness of fiscal rules in terms of whether the existence of these rules contributes to improving fiscal discipline (Bergman et al., 2016; Heineman et al., 2018). These studies generally conclude that the introduction of fiscal rules has improved the health of public finances by reducing fiscal deficits and debt levels (Combes et al., 2018; Caselli and Wingender, 2021) and supporting more counter-cyclical fiscal policies (Larch et al., 2021). However, some authors have noted that this relationship might, to some extent, be biased by the endogeneity implicit in the fact that more disciplined and prudent governments are more prone to apply fiscal rules (Debrun et al., 2008; Caselli et al., 2018). This has led several studies to apply quasi-experimental designs to deal with this potential endogeneity. Thus, for example, Caselli and Raynaud (2020) adopt an instrumental variable strategy to examine the causal effect of fiscal rules and conclude that the mere existence of fiscal rules has no statistically significant impact on fiscal balance. Nevertheless, they find that when fiscal rules are well designed and reach a certain level of strength, they can have a significant impact on fiscal performance.

Greater fiscal discipline can be achieved by raising taxes or reducing public expenditures (Minea et al., 2021). However, the favorable effect of fiscal rules is most likely to come from public expenditure cuts (Asatryan et al., 2018; Alesina et al., 2019), which, in turn, can apply to both current spending and public investment. Therefore, there is another strand of literature concerned with the effect of fiscal rules in the composition of public finances, which has returned

mixed results (Vinturis, 2023). Regarding this issue, recent research on the topic of social spending refers to the relevance of the so-called social dominance of public spending (Schuknecht and Zemanek, 2018), i.e., the fact that fiscal rules restrain social expenditure much less effectively than government public investments (Dahan and Strawczynski, 2013; Barbier-Gauchard et al., 2021; De Biase and Dougherty, 2022).

There are also studies that have examined the relationship between fiscal rules and economic growth, with the majority reaching the conclusion that they foster growth (Castro, 2011; Afonso and Jalles, 2013; Badinger and Reuter, 2017). This is because fiscal rules reduce fiscal volatility, which has been recognized to be detrimental to growth. Likewise, governments tend to reduce investment expenditures because the political cost of this decision is lower in a context of increased financial constraints (Guerguil et al., 2017). Note, however, that these arguments refer mainly to developed countries, since the number of studies conducted using data for developing countries is limited (Budina et al., 2012; Ray et al., 2015). Besides, according to the results reported by Nabieu et al. (2021) for a sample of Sub-Saharan countries, fiscal rules appear to have the opposite effect in these countries.

The extensive recent literature about fiscal rules and their impact also includes papers focused on analyzing their effect on financial market access (Sawadogo, 2020). The general conclusion is that the effect is positive for developing countries since the adoption of fiscal rules helps to improve the credibility of the respective countries by reducing sovereign bond spreads and increasing sovereign debt ratings. In the same vein, Thornton and Vasilakis (2017, 2018) find that adopting fiscal rules reduces sovereign risk premia and government borrowing costs after analyzing the performance of a large sample of advanced and developing countries. A similar conclusion was reached by Afonso and Talles (2019), who pointed out that this effect is mainly concentrated in the advanced economies.

Nevertheless, there are very few previous empirical studies that have analyzed the relationship between fiscal rules and public sector efficiency even though all

countries are under immense pressure to spend more efficiently in order to maximize the impact and coverage of social demands. This applies especially to the more developed countries, where public spending is very high relative to GDP, and revenue sources are virtually stagnant in GDP terms. Moreover, this pressure is increasingly difficult to contain because of the social dominance of spending, particularly due to the aging of the population and associated social preferences (Delgado-Téllez et al., 2022).

One possible reason for the sparsity of this literature is that fiscal rules were designed to protect the long-term financial sustainability of countries, which, in the belief that reducing or limiting expenditure is the only way to achieve this goal, was not linked to spending efficiency. This is clear from the formal definition of fiscal rule accepted by the European Commission (EC), which uses the term “limit” and at no point takes into account the possible effect of the composition of the expenditure: "*fiscal rules set permanent limits on fiscal policy, usually defined in terms of a fiscal performance indicator, usually expressed as a numerical ceiling as a share of GDP*" (Kopits and Symansky, 1998). In line with this definition, most countries have fiscal rules that regulate the maximum level of indebtedness that a government can reach with respect to GDP. However, in a scenario where public revenue growth is limited or grows at a slower rate than spending needs, fiscal rules, as they are conceived today (with no relation to efficiency), may have a very short run: it may be necessary to stimulate changes in the composition of spending and not only to establish limits on its volume. This factor alone justifies the need to address the analysis of the effect of fiscal rules on efficiency, since this should ensure sustainability. This theory is further supported by the latest research that suggests that recent episodes of fiscal consolidation have not, on average, had any effect on their primary objective, which is none other than to reduce indebtedness (IMF, 2023).

Although economic theory would suggest that fiscal rules should have a positive effect on efficiency, the real effect is difficult to predict as they keep in check the misuse of public resources (Von Hagen, 2002). On the one hand, as we have just mentioned, they might have a positive effect by imposing balanced budgets, which, in turn, force governments to limit or reduce spending, thus avoiding

superfluous expenditure (Schelker and Eichenberger, 2010). However, a balanced budget rule (such as the one applied in the EU) tends to be procyclical. This may limit decision-making flexibility regarding the allocation of resources to different policies reducing the room for maneuver of the countries when facing external shocks and this can be detrimental in terms of spending efficiency. Similarly, Asatryan et al. (2018) argue that there may be a negative relationship between the existence of fiscal rules and efficiency since fiscal rules may provide an incentive for policymakers to raise taxes and thus lower efficiency. However, there are also other studies that point out that fiscal rules have no impact on spending. Thus, for example, Eliason and Lutz (2018) found that, for the United States, fiscal rules are neutral, affecting neither the tax burden nor spending behavior, as they are avoided by policymakers, and do not, therefore, help to control excessive spending.

As previously mentioned, the available empirical evidence on the possible effect of fiscal rules on public sector efficiency is still scarce and also shows mixed results. For instance, Christl et al. (2020) examine the impact of various factors, including fiscal rules and revenue decentralization, on the general efficiency of the public sector for a sample of European countries using a two-stage semi-parametric approach. Although they did not find a statistically significant correlation between efficiency and fiscal rules, they did report that they could be detrimental if combined with high decentralization. More recently, Apeti et al. (2023) assess the effect of fiscal rules on public expenditure efficiency estimated using a parametric approach for a sample of 159 developed and developing countries over the period 1990-2017. They concluded that adopting a fiscal rule has a positive and significant effect on expenditure efficiency, which tends to increase over time. Finally, Barbier-Gauchard et al. (2023a) explore the potential correlation between the presence and stringency of fiscal rules and overall government efficiency over the period 2003-2015 for 36 advanced OECD economies. The only significant relationship that they found was in the years following the financial crisis of 2008, when governments were constrained by fiscal rules, which may have conditioned their spending policies.

Since there are so few prior studies that have examined the relationship between these two phenomena from a cross-country perspective and viewpoints and methodologies in the recent literature differ considerably, we are interested in investigating the following hypotheses:

H1: The existence of fiscal rules has a significant influence on public spending efficiency levels across countries. This hypothesis is tested using four different efficiency models to ensure the robustness of the results.

H2: The effect of fiscal rules could be positive if they lead to a decrease in the amount of public spending and reduce discretionary budgetary decision-making policies. In other words, we hypothesize that their impact may be negative if the design of fiscal rules focuses on reducing debt levels without considering their possible effects on efficiency, that is, they may constrain decision-making on resource allocation and/or create incentives to raise taxes. This is tested using a conditional nonparametric approach whereby we can directly incorporate a composite index representing the strength of fiscal rules as an external factor (Z) conditioning the estimation of public sector efficiency measures and thus explore how they can be influenced by this factor.

3. Fiscal rules: Conceptual issues

3.1. Definition and typology of fiscal rules

Fiscal rules have their roots in the restrictions established by citizens, as taxpayers, on governments to control the possible misuse of the money collected through taxes and the squandering of resources (Von Hagen, 2002). These rules were mostly developed in the 1990s in response to the deterioration of the fiscal situation in many advanced economies after a very prolonged period of increased public spending that began in the 1970s[3]. Broadly speaking, they can be defined as legislative agreements designed to control fiscal policy for the purpose of achieving sustainability and macroeconomic stability (Buiter, 2003; Grembi et al., 2016). Subsequently, since the global financial crisis, the so-called second-

[3] Until 1990, only five countries (Germany, Indonesia, Japan, Luxembourg and the United States) had fiscal rules.

generation fiscal rules have emerged and spread worldwide: they are more enforceable, flexible and operational than their predecessors (Schick, 2010).

At the macroeconomic level, a fiscal rule can be formally defined as a permanent constraint on fiscal policy, expressed in terms of fixed numerical limits (floors or ceilings) on an indicator of overall fiscal performance set in legislation and binding for at least three years (Lledó et al., 2017). Their main purpose is to mitigate deficit bias and promote fiscal discipline by reducing the scope of policymaker action to constrain decisions about spending and revenue programs. The rules, therefore, make it possible to correct incentives to overspend, especially at times of growth in the economic cycle, while seeking to ensure fiscal responsibility, long-term debt sustainability, and intergenerational equity.

Most of the rules are usually implemented at the national or sub-national level, although supranational rules have also been introduced in the last two decades to avoid fiscal behavior inconsistent with the joint needs of the countries that are part of a monetary union. This is the case of the European Union (EU), the Eastern Caribbean Currency Union (ECCU), the West African Economic and Monetary Union (WAEMU) or the Central African Economic and Monetary Community (CEMAC).

The concept of fiscal rule is instrumentalized using different metrics or controls, which are established for application either individually or in combination by governments to manage fiscal policy. Looking at the classifications devised by Kopits and Symansky (1998) and Doray-Demers and Foucault (2017), they could be grouped as follows:

- Budget balance rules (BBR) or deficit rules. They can be defined in nominal terms (a balance is required between public revenue and non-financial public expenditure in order not to generate a deficit or a limit is set on the public deficit as a percentage of GDP), structural terms (a balance is required between the cyclically adjusted revenue and non-financial expenditure or a limit is set on structural deficit as a percentage of GDP) or by establishing rules with respect to the balance between

current revenue and expenditure, whereby debt-related expenditure is not computed and is exempt from fiscal constraint.

- Debt rules (DR). It usually consists of setting a limit on the volume of gross or net debt as a function of GDP and/or defining a target for reserves in an extra-budgetary contingency fund.
- Revenue rules (RR). They establish ceilings or floors for public revenue for the purpose of boosting revenue collection and/or preventing an excessive tax burden.
- Expenditure rules (ER). They set a ceiling on budget spending in nominal terms or on spending growth based on variables such as actual or potential economic growth.

In most cases these rules are used in combination to mitigate their respective disadvantages and combine their benefits. The advantages and disadvantages of each type of rule were established by Schaechter et al. (2012), who demonstrated that none could achieve all the objectives individually. In any case, the usefulness of different types of fiscal rules may depend on their final formulation and/or degree of compliance, which requires analysis. A clear example would be the expenditure rule, where the level of coverage (i.e., expenditure included in the calculation of the rule) is critical to determine its usefulness.

Regardless of the type or combination of established rules, tax rules must be recognized in a legal document (international treaty, a country's internal legislation, i.e., laws or regulations) in order to both enforce compliance and provide credibility for the authorities formulating compliant public policies.

3.2. Fiscal rules around the world and construction of a representative index

The global financial crisis that began in 2008 and its persistent effects on economies and public financial balances led to a strengthening and/or reformulation of existing fiscal rules within the European Union, as well as in many other countries around the world with the aim of safeguarding fiscal sustainability. In this paper, we use the International Monetary Fund (IMF) Fiscal

Rules Dataset as our source of underlying data to gather information on fiscal rules in all these countries (see Davoodi et al., 2022a, for details). This database includes detailed information on rules implemented at the level of the central or general government in many (more than 70) countries including the type of rule, year of implementation, number of rules, legal basis, coverage, monitoring, enforcement, institutional supporting features and stabilization features, such as budget balance rules accounting for the state of the economy. Data is collected from many different sources such as fiscal framework legislations, information provided by national authorities, published and unpublished country documents or IMF staff reports and other IMF papers. Unfortunately, values for multiple key variables are missing for many countries (especially in Asia and Africa) which we have decided to omit from our study. After an exhaustive information filtering and processing process, our sample is composed of 50 countries, including mostly European countries (32), together with a large number of American countries (13), the two main countries in Oceania, and a small representation from Asia (3)[4].

The database covers a very long period (1985-2015) during which different numbers and types of rules have been applied in each country. However, our empirical analysis focuses on a single year, i.e., the baseline that we use are the regulations in force in the last year of the period (2015). Given the purpose of our research, we consider that the construction of a composite indicator that represents the strength of fiscal rules in force in each country is the best approach to summarize this information as suggested by Caselli and Reynaud (2020).

The idea of constructing a composite indicator was originally proposed by Deroose et al. (2006). They considered six dimensions related to fiscal rules (coverage, statutory/legal base, media visibility, monitoring, enforcement and compliance) to which they assigned different scores that attempted to reflect the extent to which the fiscal rule was strong or effective for the member states of the European Union. Their composite indicator was constructed by calculating the average value of the above six dimensions considered after conducting a

[4] Table A1 in Appendix A includes the list of all the countries included in the sample grouped by geographic area.

normalization process that homogenized the scores to values between 0 (minimum) and 10 (maximum).

Subsequently, other authors and institutions have used a similar procedure to construct an index reflecting the strength of fiscal rules. For instance, Iara and Wolff (2014) construct a composite fiscal rule strength index to assess its influence on the interest required on government bonds in financial markets considering five criteria (statutory/legal base, monitoring, enforcement, media visibility and room for revising objectives) for each type of rule and applying random weights to each criterion[5]. A similar approach is applied by Fernandez and Parro (2019) to construct a fiscal rule strength index that they use to examine the effect of fiscal rules on sovereign ratings, although they consider only four strength dimensions (statutory/legal base, flexibility, monitoring and enforcement) for each type of rule, as well as the level (national or supranational) of application. Similarly, both the EC and the IMF also construct composite proxy indicators of the strength of fiscal rules considering different institutional criteria and different types of fiscal rules (BBR, RR, DR and ER) with declining weights assigned to each additional rule reflecting government coverage. The main difference between these indices is that the IMF index is constructed using a principal component procedure (Kumar et al., 2009), whereas the EC index is calculated by combining several indicators representative of different criteria (European Commission, 2022).

In this study, we construct our own composite fiscal rule indicator (FRI) following some basic criteria inspired by Deroose et al. (2006). Specifically, we select six sub-indices reflecting the number and type of existing fiscal rules and some of their main characteristics like monitoring, enforcement, legal basis, application (national or supranational) level and whether there is an independent body setting budget assumptions (Schaechter et al., 2012). For each sub-index, scores are assigned following the criterion reported in Appendix A. In the absence of a strong theoretical base regarding the weight allocated to each individual sub-index, we applied equal weights for aggregation, i.e., calculating the arithmetic average of

[5] Random weights are applied due to the lack of theoretical guidance regarding the relevance of each criterion included in the composite index (see details in Sutherland et al., 2005).

the six sub-indicators. Table A2 in Appendix A shows the values of the sub-indices separately and the value of the composite indicator calculated for each country. The main advantage of this indicator is that it is easy to interpret and appears to be a fairly reliable representation of the strength of the fiscal rules existing in the different countries, as illustrated by the fact that the value of its correlation index (around 87%) is high with respect to another indicator constructed following a more complex procedure, namely the composite index developed by the IMF (Davoodi et al., 2022b). IMF indicator has been labelled as FRI2, and its values are also shown in the last column of Table A2. Both indices will be used in our empirical analysis to test the robustness of our empirical results.

4. Measuring efficiency in public expenditure: conceptual issues

4.1. Public sector performance and efficiency scores

The literature on the measurement of public sector technical efficiency has grown significantly in the last decades (Wong, 2020). These studies typically measure public sector efficiency by relating government expenditure (inputs) to several socio-economic indicators usually targeted by public spending as outcomes of public sector performance (outputs). They can be divided into two main measurement categories: the macro approach estimates the efficiency of total spending on all the services provided by the government (e.g., Tanzi and Schuknecht, 1997; Afonso et al., 2005, 2010; Afonso and Alves, 2023a, 2023b), whereas the micro approach aims to measure the efficiency of a particular public service, mostly education and health (e.g., Afonso and St Aubyn, 2006; 2011; Khumbakar, 2010; Agasisti, 2014; Varabyova and Müller, 2016; Dutu and Sicari, 2020).

Given the context of our study, we adopt the macro approach to measure the overall technical efficiency of the public sector in the 50 countries for which we have information regarding their fiscal rules. Following Afonso et al. (2005, 2010, 2021a, 2021b), we assess public sector performance (PSP) by constructing composite indicators based on observable socioeconomic variables that are assumed to be the output of pursued public policies. Specifically, we use two

groups of indicators to define PSP: (1) process or opportunity indicators[6] and (2) traditional or Musgravian indicators.

The first group comprises outcomes derived from government activities as a public administrator and provider of public services for citizens, including four main areas: the administration, education, health and infrastructure sectors. In our empirical analysis, we select several sub-indicators representing each of these areas. The administration sub-indicator includes four different measures: corruption, burden of government regulation (red tape), independence of the judiciary and size of the shadow economy. The rationale behind these indicators is the application of the rule of law, enforcement of contracts, defense of property rights and operability of well-functioning markets promoted by the state. Government performance as a supplier of public goods and services is represented by the provision of education, health, and public infrastructure. For education, we use the secondary school enrolment rate, quality of educational system and PISA scores. As a proxy of the health sub-indicator, we compile data on the infant survival rate and life expectancy at birth. Finally, the infrastructure sub-indicator is measured by the quality of overall infrastructure. By using all these indicators, we try to reflect the quality of the interaction between fiscal policies and market processes, i.e., the effect of public policies on individual opportunities (Afonso et al., 2010).

The second group is composed of outcome indicators of basic public sector tasks in terms of allocation, distribution and stabilization as defined by Musgrave. Thus, we select several sub-indicators as representative of each of these areas. To measure income distribution and inequality, we use the Gini coefficient. For the stability sub-indicator, we use the coefficient of variation for the 5-year average of GDP growth and 5-year standard deviation of inflation. As a measure of economic performance, we include the 5-year average of GDP per capita and unemployment rate.

[6] This term is because these indicators are intended to approximate the quality of the interaction between fiscal policies and market processes, i.e., the effect of public policies on individual opportunity/realization.

With the aim of ensuring a convenient benchmark for comparing results, the measure of each sub-indicator representing public sector performance has been normalized by dividing the value for each country by the average measure for all the countries in the sample for each year. Hence, countries with PSP scores greater than one are seen as good performers, as opposed to countries with PSP values below the mean. Table A3 in the Appendix summarizes the variables used to construct the PSP indicators and provides further information on the sources and variable construction.

Each PSP sub-indicator is the average of the measures included in each sub-indicator. To compute the PSP, we weighted each opportunity sub-indicator and Musgravian indicator equally:

$$PSP_i = \sum_{j=1}^{n} PSP_{ij}$$

where *i* denotes the countries and *j* represents socio-economic indicators. PSP_i represents overall performance of the country *i.*

Our input measures include total public expenditure (PE) as a percentage of GDP and also several indicators representing different areas of expenditure that can be linked to selected output sub-indicators. Specifically, we consider government consumption as the input for administrative performance, government expenditure on education as the input for education performance, health expenditure as the input for health performance and public investment as the input for infrastructure performance. For the distribution indicator, we consider expenditure on transfers and subsidies as the cost affecting the income distribution. Stability and economic performance are related to total expenditure. Again, each sub-indicator should be first normalized across countries, with each of the expenditure categories taking the average value of one. Table A4 included in Appendix A provides further information on the sources and variable construction.

Regarding public sector efficiency (PSE), we consider a production technology where the production set is the set of all feasible input-output combinations (x,y). This can be defined as

$$\psi = \{(x, y) \in \mathbb{R}_{+}^{p+q} | \; x \text{ can produce } y\}. \quad (1)$$

If we assume an input orientation, the Farrell (1957) measure of technical efficiency for a unit operating at the level (x, y) is given by

$$\theta(x, y) = inf\{\theta > 0 | (\theta x, y) \epsilon \, \psi\}. \quad (2)$$

By construction, $\theta(x, y) \in (0,1)$ for all $(x, y) \in \psi$. This measure yields the feasible, proportionate reduction in input levels at constant output levels for a unit operating at $(x, y) \in \psi$. The unit is said to be technically efficient (inefficient) in the input direction if $\theta(x, y) = 1$ ($\theta(x, y) < 1$).

Since the production set ψ cannot be observed as well as the efficiency scores, it has to be estimated from a random sample of production units denoted by $\mathcal{S}_{XY,n} = \{(X_i, Y_i) | \; i = 1, \dots, n\}$. Of the multiple approaches that can be used to achieve this goal, we use data envelopment analysis (DEA), as this is the most commonly used approach in the literature (Afonso et al., 2005; Hauner and Kyobe, 2010; Dutu and Sicari, 2020). The preference for this nonparametric approach is mainly justified by its flexibility, since it does not require the assumption of a specific functional form for the production process, where it is sufficient for the evaluated units to satisfy a set of minimum assumptions (convexity, free availability and minimum extrapolation). Using this approach, the analysis can also account for multiple inputs and outputs and is thus well suited to the specific peculiarities of public service provision (Ruggiero, 2007).

Considering an input orientation and assuming variable returns to scale (VRS), the DEA estimator of ψ can be expressed as a linear programming problem (Charnes et al., 1978):

$$\hat{\psi}_{DEA} = \left\{ \begin{array}{c} (x,y) \in \mathbb{R}_{+}^{p+q} \mid y \leq \sum_{i=1}^{n} \gamma_i Y_i \,;\; x \geq \sum_{i=1}^{n} \gamma_i X_i \; for \;\; (\gamma_i, \ldots . \gamma_n \\ st. \sum_{i=1}^{n} \gamma_i = 1;\; \gamma_i > 0; i = 1, \ldots . , n \end{array} \right\} \qquad (3)$$

4.2. Exploring the link between fiscal rules and public sector efficiency

Cross-country studies that attempt to measure overall PSE usually also explore the possible determinants of efficiency differences among countries. For example, Adam et al. (2014) assess the impact of fiscal decentralization using data about 21 OECD countries, Antonelli and de Bonis (2019) examine the effects of some socio-economic and institutional variables such as population size, corruption or education in 22 European countries, while Afonso et al. (2021a) analyze the role of structural tax reforms in 18 OECD economies. Related to our topic, Christi et al. (2020) explore the influence of fiscal rules and decentralization on the overall efficiency of a sample of 23 European countries using a composite index representative of the existence of fiscal rules similar to the ones described in Section 3 as a potential explanatory variable of efficiency scores.

Most of these studies explore the possible influence of variables representing the environment on the distribution of efficiency scores using two-stage models. This approach consists of regressing efficiency scores estimated in a first stage with DEA or an alternative approach[7] ($\hat{\theta}$) on external or environmental variables (Z) using either Tobit regression or ordinary least squares in the second stage (see Hoff, 2007 for details):

$$\hat{\theta} = f(Z, \beta) + e \qquad (4)$$

However, two influential papers by Simar and Wilson (2007, 2011) demonstrate that previous applications of the two-stage approach were invalid due to its failure to account for the bias and serial correlation present among efficiency estimates. To address this problem, they developed an alternative approach that constructs

[7] Although DEA is the most common option, other estimators, such as FDH (Deprins et al., 1984) or partial frontiers (Cazals et al., 2002; Daouia and Gijbels, 2011), can also be used.

an underlying data generating process that is consistent with the regression of nonparametric estimates in the second stage and proposed two different algorithms based on bootstrapping methods in a truncated regression model. These algorithms enable valid inference while simultaneously generating standard errors and confidence intervals (Simar and Wilson, 2007).

In more recent studies, this method has mostly been used to identify the influential determinants of efficiencies and explore the direction of the effect (positive or negative) according to the value of the estimated coefficient, which guarantees more consistent results. However, the validity of the results using this approach depends on whether the separability condition between the input-output space and external variables holds, i.e., whether it can be assumed that the explanatory factors only affect the distribution of the inefficiencies and not the shape of the estimated frontier (Badin et al., 2014).

This assumption can be tested using either the nonparametric tests suggested by Daraio et al. (2018) or the bootstrap method described in Simar and Wilson (2020). If this condition is met, i.e., the null hypothesis of the separability condition cannot be rejected, the semi-parametric bootstrap-based approach proposed by Simar and Wilson (2007) is meaningful and can be applied to test the influence of an external factor (the composite index representing fiscal rules in our framework). However, if this condition is not met (the null hypothesis of separability is rejected), this method should not be applied.

Fortunately, there is a more general and appealing approach in the literature that can be used to deal with environmental variables without having to assume the above separability condition. This is the nonparametric conditional approach developed by Daraio and Simar (2005, 2007a, 2007b). This method can incorporate the effect of Z variables directly into the estimation of efficiency scores such that we can examine the influence of a Z variable on efficiency levels by analyzing the differences between the conditional model (with the Z variable) and the unconditional model (without the Z variable). In the following, we provide a non-technical description of this methodology to facilitate the interpretation of

our results. Additionally, a more detailed explanation of this approach and its main computational issues is provided in Appendix B.

The conditional approach is based on a probabilistic formulation of the production process, which can account for the variables in the efficiency estimation by conditioning the production process to a given value of Z = z. For example, this variable is represented in our study by the composite FRI, where higher values represent stronger fiscal rule regulations. This approach estimates efficiency measures by comparing the performance of each country with other countries with a similar environment regarding fiscal rules, i.e., whose Z values are within a specified range defined by an interval (this interval is determined by the so-called bandwidth in our framework), which we estimate using the procedure suggested by Badin et al. (2010).

Since we have access to longitudinal data, we have adapted this approach to a dynamic framework by considering the time factor *(t)* as an additional contextual variable following the model proposed by Mastromarco and Simar (2015). In this framework, we analyze the pooled dataset, i.e., we construct a single frontier and compare countries simultaneously with each other and across time. Thus, we implicitly assume that there are no changes in the production technology between periods. However, PSE in a period could possibly depend on the efficiency in other periods.

As mentioned earlier, we examine the potential influence of conditional factors (contextual variables and time) on the attainable frontier by analyzing the observed values of the ratio of the conditional to the unconditional efficiency scores (estimated without considering the effect of Z variables) against Z:

$$Q(x,y|z,t) = \frac{\theta_t(x,y|z)}{\theta(x,y)} \tag{5}$$

In an input-oriented conditional model, a decreasing trend in the ratio denotes that the FRI has a favorable effect on the efficient frontier since it operates as an extra input that is freely available. In contrast, an upward trend means that the

effect of FRI on the efficient frontier is unfavorable because it operates as an extra output that is to be produced, which is undesirable as it requires the use of more inputs.

Finally, note that we can use this methodological approach to investigate the statistical significance of Z in explaining the variations of efficiency levels. To do this, we use the bootstrap test proposed by Racine (1997). This procedure roughly consists of a nonparametric regression of the ratios on the exogenous variables, which can be interpreted as the nonparametric equivalent of the standard t-tests used in ordinary least squares regression models (De Witte and Kortelainen, 2013). Accordingly, each of the *p*-values will determine whether or not the external variable (FRI) has a significant influence.

5. Data and results

In our empirical analysis, we assess the public sector efficiency of the countries included in our sample and, subsequently, examine the possible relationship between this magnitude and the strength of the fiscal rules in force. Our dataset comprised a panel of 50 countries spanning the period 2016–2019. Therefore, we have a pooled dataset including 200 observations which we can use to examine the influence of the fiscal rules in a dynamic framework. We first report our main results using a composite index representative of the strength of fiscal rules (FRI) constructed following the criteria proposed by Deroose et al. (2006). We then perform a robustness analysis using the alternative composite fiscal rule index developed by the IMF (FRI2)[8].

5.1. Public sector efficiency estimates

In order to estimate PSE scores, we rely on DEA assuming the more flexible option of variable returns to scale (VRS) and adopting an input orientation because the output levels are more or less externally imposed, where nations only have control over their expenditure. Following Afonso et al. (2021a), we estimate four alternative models:

[8] See Davoodi et al. (2022b, p. 34-35) for details.

- A baseline model (BM), with only one input (total expenditure as a percentage of the GDP) and one output (PSP);
- Model 1 with one input (total expenditure) and two outputs: the opportunity PSP and the so-called Musgravian PSP scores;
- Model 2 with two inputs (expenditure on opportunity and Musgravian indicators) and one output (total PSP score);
- Model 3 with the above two inputs and outputs.

Table 1 provides the main descriptive statistics (mean, median, standard deviation, maximum and minimum) of efficiency scores estimated for the four alternative models using the pooled dataset of 200 observations. The average efficiency score throughout the period is around 0.75 for the 1-input and 1-output model (baseline model) and around 0.8 for the alternative models (Models 1, 2 and 3). This implies that some possible efficiency gains could be achieved with on average around 20% less government spending without any change to the output.

Table 1. Descriptive statistics of efficiency scores estimated with DEA for alternative models using the pooled dataset

	BM	Model 1	Model 2	Model 3
Mean	0.7467	0.8056	0.7726	0.8285
Median	0.7451	0.8089	0.8027	0.8590
SD	0.1424	0.1220	0.1432	0.1199
Min	0.4049	0.5657	0.4049	0.5657
Max	1.0000	1.0000	1.0000	1.0000

It is clear from the standard deviation values and the minima and maxima that there are notable differences between countries, as illustrated by the values reported in Table 2, reporting the average values for each country over the four years. The countries with the highest values include Switzerland, Ireland, Sweden, Israel and Australia, whereas several Latin American countries (Brazil, Argentina, Colombia and Ecuador) along with Russia and Greece are at the other end of the scale.

Table 2. Average efficiency scores by country (2016-2019)

	UMB	UM1	UM2	UM3
Argentina	0.4480	0.6293	0.4480	0.6294
Australia	0.9435	0.9560	0.9435	0.9560
Austria	0.8592	0.9187	0.8592	0.9187
Belgium	0.8797	0.8876	0.8797	0.8876
Brazil	0.4087	0.5756	0.4087	0.5756
Bulgaria	0.7278	0.7838	0.7736	0.8507
Canada	0.8341	0.8750	0.8341	0.8750
Chile	0.6996	0.8703	0.7410	0.9092
Colombia	0.5003	0.6103	0.5151	0.6283
Costa Rica	0.9194	0.9634	0.9285	0.9686
Croatia	0.6897	0.6996	0.6970	0.7207
Cyprus	0.6688	0.7402	0.6801	0.7526
Czech Republic	0.7754	0.7913	0.7779	0.7996
Denmark	0.8860	0.8934	0.8860	0.8934
Ecuador	0.5357	0.6077	0.5574	0.6304
Estonia	0.7159	0.8071	0.7159	0.8071
Finland	0.8534	0.9386	0.8534	0.9386
France	0.7372	0.8377	0.7372	0.8377
Germany	0.8210	0.8745	0.8210	0.8745
Greece	0.5975	0.6707	0.6062	0.6800
Hungary	0.6501	0.6664	0.6501	0.6666
Iceland	0.8509	0.8658	0.8509	0.8658
India	0.5872	0.7005	0.9788	0.9801
Ireland	0.9452	0.9818	0.9732	0.9928
Israel	0.9512	0.9899	0.9512	0.9922
Italy	0.6322	0.6878	0.6516	0.7078
Japan	0.8752	0.9178	0.8752	0.9178
Latvia	0.6141	0.6990	0.6143	0.6997
Lithuania	0.6658	0.7209	0.6971	0.7516
Luxembourg	0.9099	0.9432	0.9512	0.9815
Malta	0.7954	0.8198	0.8017	0.8488
Mexico	0.6232	0.6845	0.8010	0.8525
Netherlands	0.8963	0.9576	0.8963	0.9576
New Zealand	0.8004	0.9173	0.8004	0.9173
Norway	0.8155	0.8619	0.8155	0.8619
Panama	0.7915	0.8770	0.8774	0.9323
Paraguay	0.7543	0.8209	0.8811	0.8889
Peru	0.7451	0.7620	0.8311	0.8667
Poland	0.6945	0.7117	0.6959	0.7151
Portugal	0.7441	0.7898	0.7659	0.8118
Romania	0.5985	0.6306	0.6531	0.6790
Russia	0.5550	0.6231	0.5849	0.6534
Slovakia	0.6390	0.6748	0.6464	0.6832
Slovenia	0.7263	0.7375	0.7263	0.7375
Spain	0.7010	0.7761	0.7212	0.7974
Sweden	0.9480	0.9596	0.9480	0.9596
Switzerland	0.9696	0.9983	0.9697	0.9986
United Kingdom	0.8715	0.9115	0.8715	0.9115
United States	0.9143	0.9394	0.9143	0.9394
Uruguay	0.5689	0.7213	0.5710	0.7239
Mean	**0.7467**	**0.8056**	**0.7726**	**0.8285**

5.2. *Exploring the relationship between fiscal rule strength (FRI) and public sector efficiency (PSE)*

In this section, we provide evidence to empirically test the two main hypotheses stated in Section 2. To do this, the first step is to check whether the separability assumption is met, as this will determine the methodological approach to be applied. To do this, we apply the bootstrap method described in Simar and Wilson (2020) for our pooled dataset (Table 3). The results rule out the application of the two-stage approach developed by Simar and Wilson (2007), since the values of the statistics lead us to reject the separability hypothesis in three out of the four models[9]. Therefore, we must use the conditional approach to explore the influence of fiscal rules on PSE.

Table 3. Results of the separability test (H_0: separability is present)

	Tau statistic	p-value
BM	0.788	0.232
Model 1	0.739	0.000
Model 2	0.918	0.006
Model 3	0.899	0.044

Table 4 reports the main descriptive statistics (mean, median, standard deviation, maximum and minimum) of efficiency scores estimated for the four alternative models using the conditional approach. We find that the average efficiency scores for the four alternative estimated models (CBM, CM1, CM2 and CM3) are higher than for the unconditional DEA model, which did not include information about fiscal rules in force. This is because the reference set for comparison in the case of the alternative models only includes units with similar environmental characteristics, and the number of units with which each unit is compared is smaller, leading to a higher estimated score.

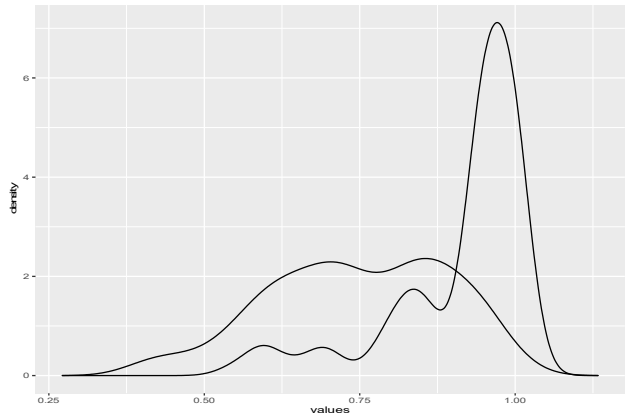
Table 4. Descriptive statistics of efficiency scores estimated with the conditional approach for alternative models using FRI as conditional factor

	CBM	CM1	CM2	CM3
Mean	0.9121	0.9103	0.8876	0.8896
Median	0.9546	0.9375	0.9413	0.9177
SD	0.1109	0.1029	0.1183	0.1102
Min	0.5467	0.6518	0.5367	0.6191
Max	1.0000	1.0000	1.0000	1.0000

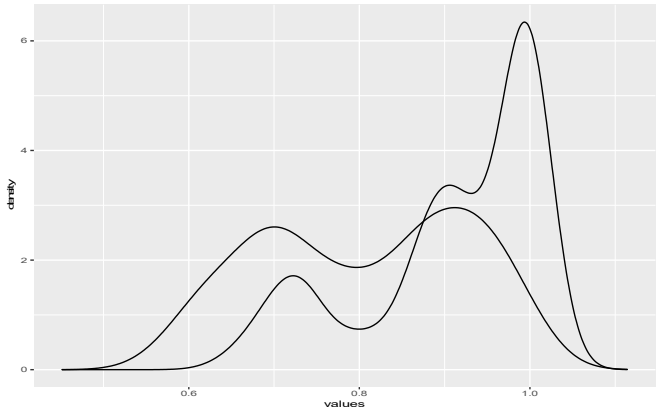
[9] To test the separability assumption, we used the FEAR package (version 3.1) in R.

The relationship between the two efficiency scores (conditional and unconditional) can be visualized by comparing the density plots for each model shown in Figure 1. They all clearly show a higher concentration of scores near unity for the estimates using the conditional approach. As a result, the correlation between the two scores is relatively low for all models, as illustrated by the values shown in Table 5, which lists three different correlation coefficients (Pearson's r, Spearman's ρ and Kendall's τ). Likewise, Table 6 reports the results of applying the nonparametric test proposed by Li et al. (2009) to explore whether the distribution of divergences between distributions is significant. According to the value of this test, we can reject the null hypothesis that the efficiency score distributions can be considered as equal in all scenarios. This suggests that the consideration of the environmental variable representing the strength of the tax rules existing in each country appears to affect the efficiency of their total public expenditure.

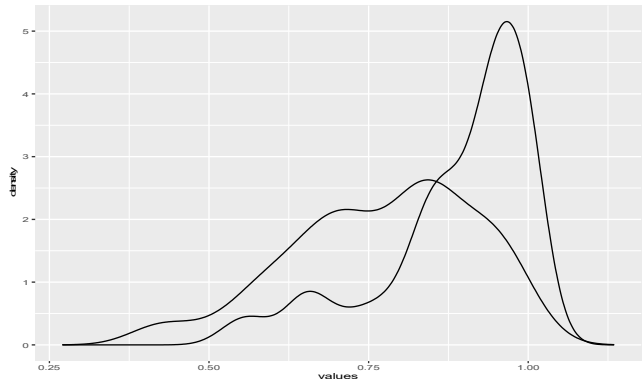
Figure 1. Density plots of conditional and unconditional efficiency scores for each model



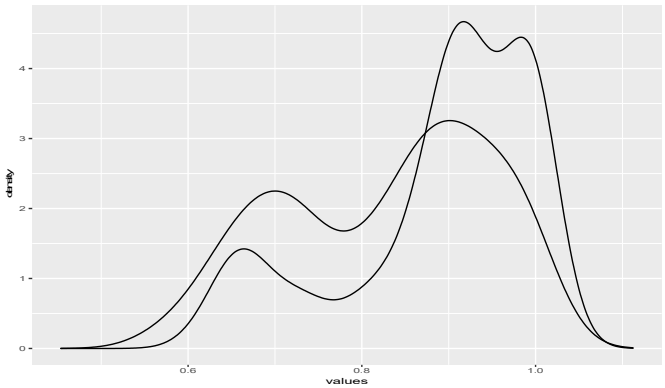
Baseline model



Model 1



Model 2



Model 3

Table 5. Correlation coefficients between the two alternative approaches (conditional with FRI vs. unconditional)

	Pearson	Spearman	Kendall
MB	0.3825	0.3503	0.2576
M1	0.1284	0.0685	0.0689
M2	0.6001	0.5547	0.4158
M3	0.4595	0.3962	0.2899

Table 6. Results of the equality of density test for M and CM (H_0: equality)

	tau-statistic	p-value
MB	46.14	0.000***
M1	40.64	0.000***
M2	23.58	0.000***
M3	13.85	0.000***

To check the extent to which this initial intuition is true, we test the significance of the influence of FRI with respect to the efficiency scores using the bootstrap test proposed by Racine (1997) (see Table 7). These results corroborate that this external factor has a significant influence on public sector efficiency.

Table 7. Significance of FRI in conditional models

	p-value
Baseline model	0.000 ***
Model 1	0.000 ***
Model 2	0.000 ***
Model 3	0.000 ***

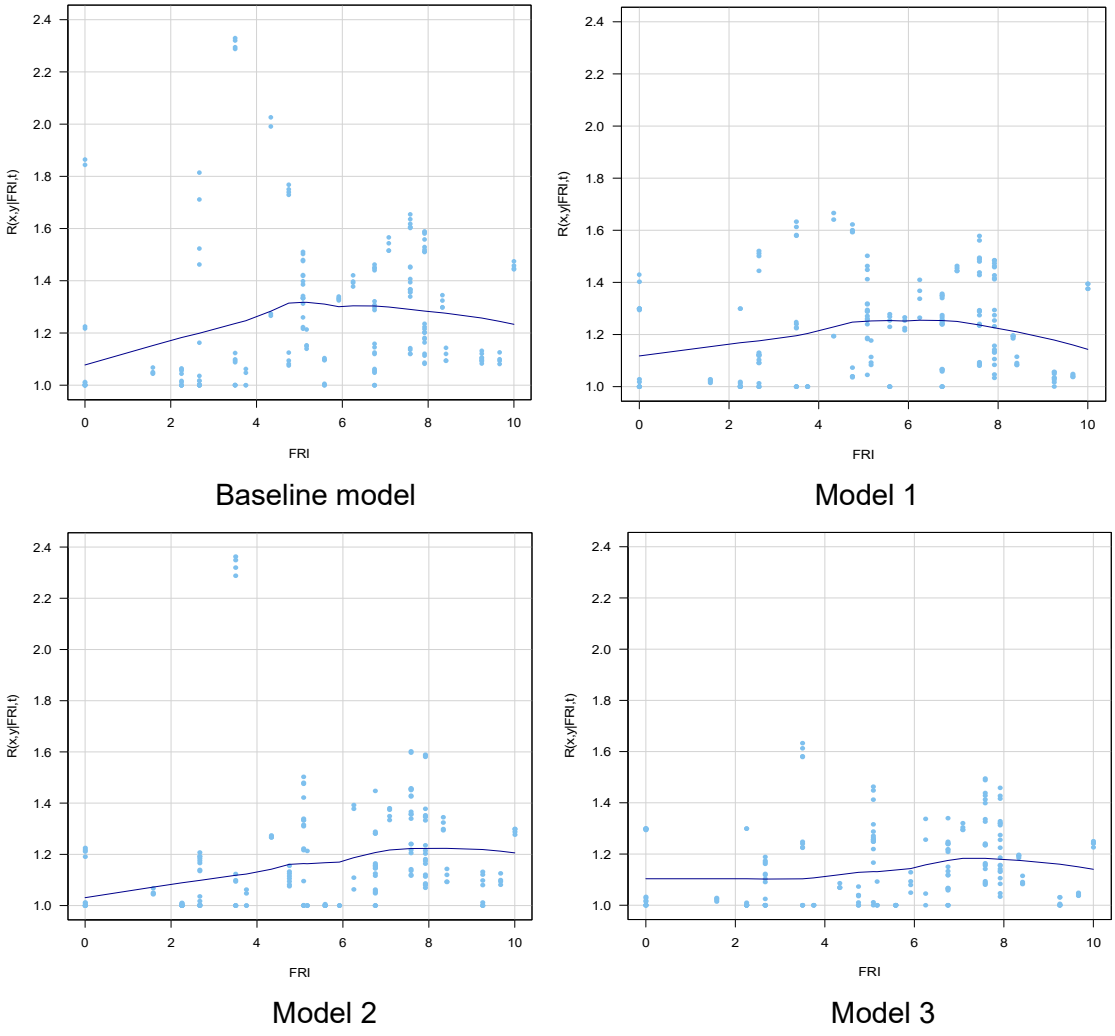
(***) 99% significance level.

The next step, which is even more relevant, is to explore the direction of this effect through the analysis of the ratios between conditional and unconditional efficiency measures. To do this, we first examine the scatter plots reported in Figure 2, which are useful for visualizing and interpreting the potential marginal effect of our external variable (FRI) on efficiency scores estimated with the four alternative models. Since we adopt an input orientation, a decreasing nonparametric regression line indicates a positive effect, whereas an upward trend is associated with an unfavorable effect, as explained above.

A similar trend can be observed in all scenarios, where the lowest values of the FRI index have a clearly negative effect up to certain point where the effect reverses and becomes slightly positive for the highest values of the index. This result can be interpreted as a refinement of the findings by Christl et al. (2020),

who detected that fiscal rules might have a negative impact on public sector efficiency for a sample of European countries. Nevertheless, our finding somewhat contradicts the evidence recently reported by Apeti et al. (2023) or Barbier-Gauchard et al. (2023a) for a larger sample of countries from other areas of the world with heterogeneous characteristics.

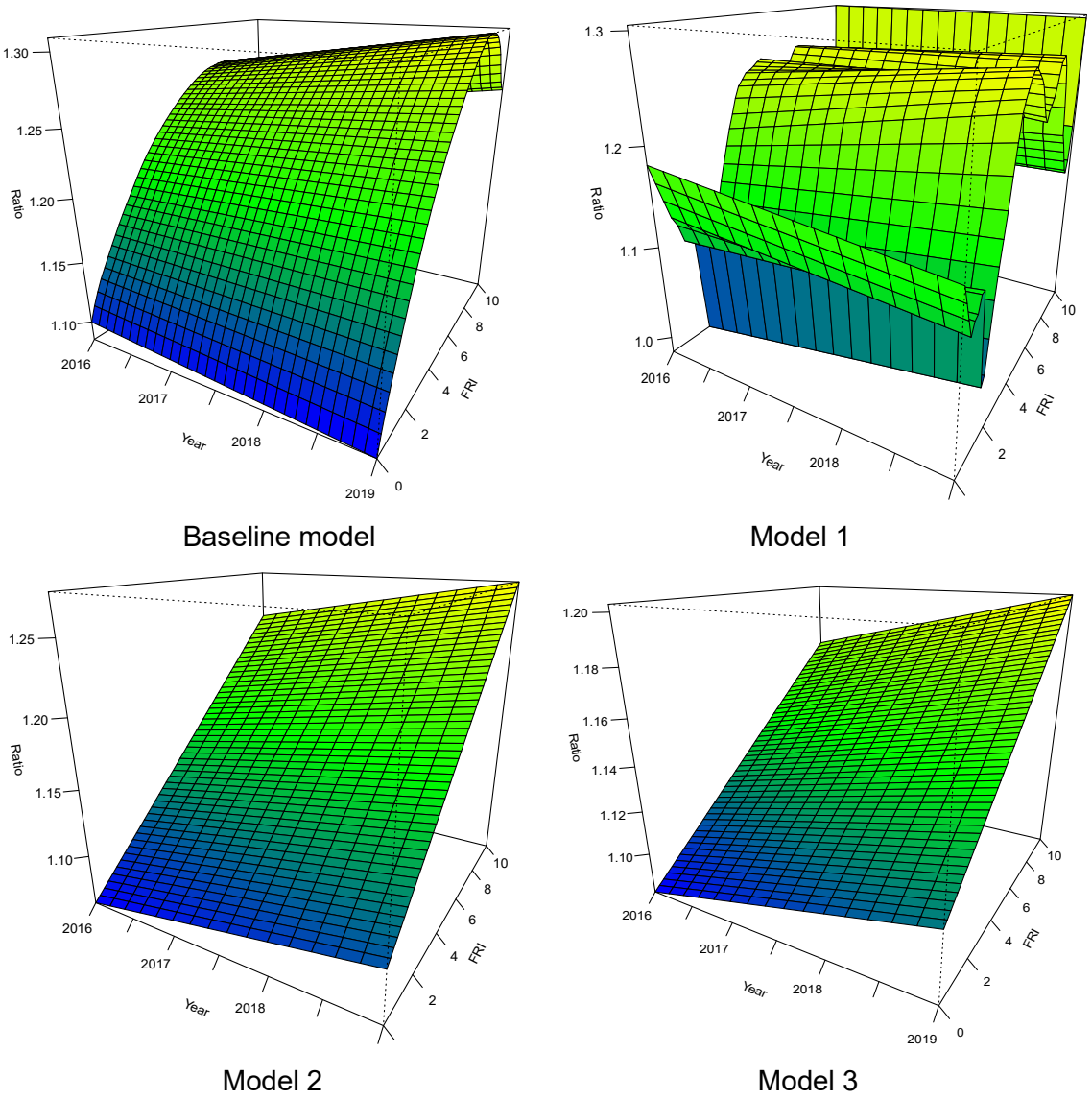
Figure 2. Marginal effect of FRI on efficiency scores for each model



Likewise, we can also explore how the effect of FRI on the frontier has evolved over time (frontier shift) through the three-dimensional graphs shown in Figure 3. These graphs can be interpreted like the scatter plots in Figure 2, in the sense that increasing trends indicate a negative effect, whereas decreasing trends denote a positive effect. In this case, there are some differences between the different models considered. Thus, the two abovementioned effects (negative for low and positive for higher index values) in the first two graphs, which show the

evolution for the baseline model and Model 1, are unchanged over the period, with hardly any differences in the effects over time. However, differences were observed over the period for Models 2 and 3, where the predominantly negative effect is observed for practically all the values of the FRI index diminishes over the years. This may imply that fiscal rules need to be in effect for some time before they have observable effects on PSP.

Figure 3. The effect of FRI on PSE over time (3D plots)



5.3. Robustness analysis

In this section, we conduct robustness analyses of our main results using the fiscal rule index constructed by the IMF (FRI2) as an alternative measure of the strength of fiscal rules existing in the countries comprising our sample. As we did for the proposed index (FRI), we first check whether the separability assumption holds, and we reach the same conclusion as in the previous case after applying the nonparametric tests suggested by Daraio et al. (2018) and Simar and Wilson (2020): the best methodological option to examine the potential effect of FRI2 on PSE is the conditional approach[10].

Again, the consideration of the conditional variable Z (FRI2) in the estimation raises the values of the conditional efficiency scores, as shown in Table 4B. Note also that the consideration of the conditional factor FRI2 implies an important modification of the distribution of the efficiency scores with respect to those estimated using the unconditional model[11]. This implies that the correlation between the estimated efficiency scores is relatively low, as shown by the values reported in Table 5B[12]. Consequently, the results of the nonparametric significance test shown in Table 7B for the different alternative models clearly indicate that FRI2 has a significant influence on overall public sector efficiency.

Table 4B. Descriptive statistics of efficiency scores estimated with the conditional approach for alternative models using FRI2 as a conditional factor

	CBM	CM1	CM2	CM3
Mean	0.9163	0.9397	0.8811	0.9106
Median	0.9546	0.9690	0.9397	0.9362
SD	0.1053	0.0817	0.1257	0.1030
Min	0.5659	0.6471	0.5440	0.6191
Max	1.0000	1.0000	1.0000	1.0000

[10] The results of the separability test are not reported for reasons of space, but they are available upon request.

[11] The density plots of conditional and unconditional efficiency scores (with and without considering FRI2 in the estimation) are not shown for reasons of space, but they are also available upon request.

[12] Likewise, the results of applying the nonparametric test proposed by Li et al. (2009) to the values estimated with FRI2 lead to the same conclusion as in the previous case: the overall public sector efficiency appears to be influenced by the degree of rigidity of the applicable fiscal rules. These results are also available upon request.

Table 5B. Correlation coefficients between the two alternative approaches (conditional with FRI2 vs. unconditional)

	Pearson	Spearman	Kendall
BM	0.2994	0.3053	0.2279
M1	0.1931	0.0799	0.0814
M2	0.5765	0.5469	0.4188
M3	0.5657	0.5089	0.3987

Table 7B. Significance of FRI2 in conditional models

	p-value
Baseline model	0.000 ***
Model 1	0.000 ***
Model 2	0.000 ***
Model 3	0.000 ***

(***) 99% significance level

Finally, as explained previously, it is important to examine the direction of the detected marginal effect of the conditional variable (FRI2) on efficiency scores. As in the case of the FRI, four alternative models were estimated, exploring the ratios between conditional and unconditional efficiency measures. To do this, we rely on the scatter plots reported in Figure 2B, which show a similar trend across all scenarios, which does, however, differ somewhat from the pattern previously observed for FRI. In this case, the result is even more revealing with respect to the effect of fiscal rules on efficiency since a negative influence is observed for the whole distribution of composite index values[13]. This implies that the effect is negative even for countries with more stringent fiscal rules.

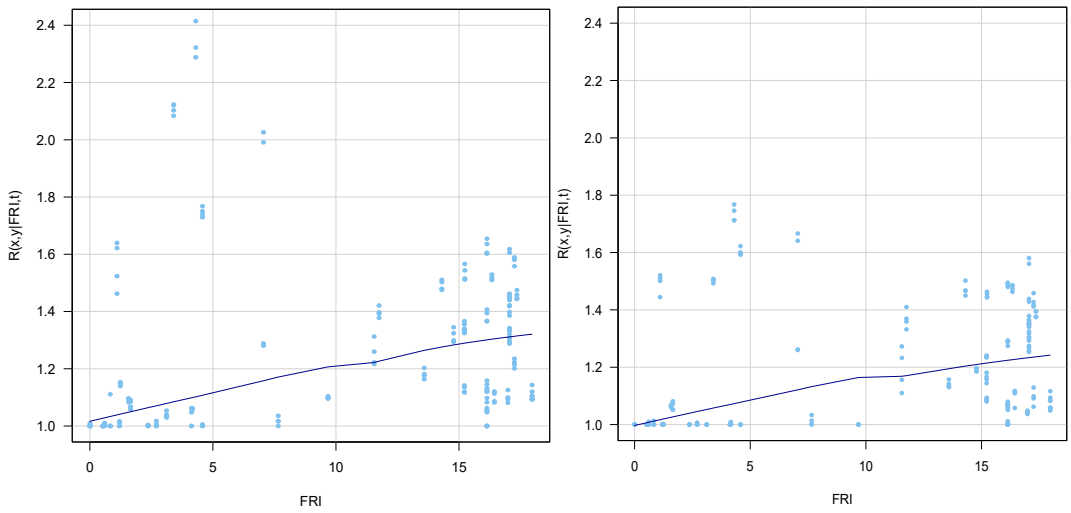
This result corroborates the negative effect already detected for relatively low values of the index. However, it also raises some doubts about the true effect that having a really strict set of rules can have on efficiency, since, depending on the criterion used to define the index, the effect is mixed (positive for a relatively simple index such as FRI or negative for a more complex one such as FRI2). In any case, our findings suggest that the imposition of fiscal rules leads to lower rather than greater efficiency in public sector behavior for most of the values of the two alternative strength fiscal rule indices considered in our empirical analysis. This is partly because the introduction of such fiscal rules is designed

[13] A similar effect can also be observed in 3-D graphs representing the evolution of the effect of FRI2 on the frontier over time (frontier shift). These graphs are also available upon request.

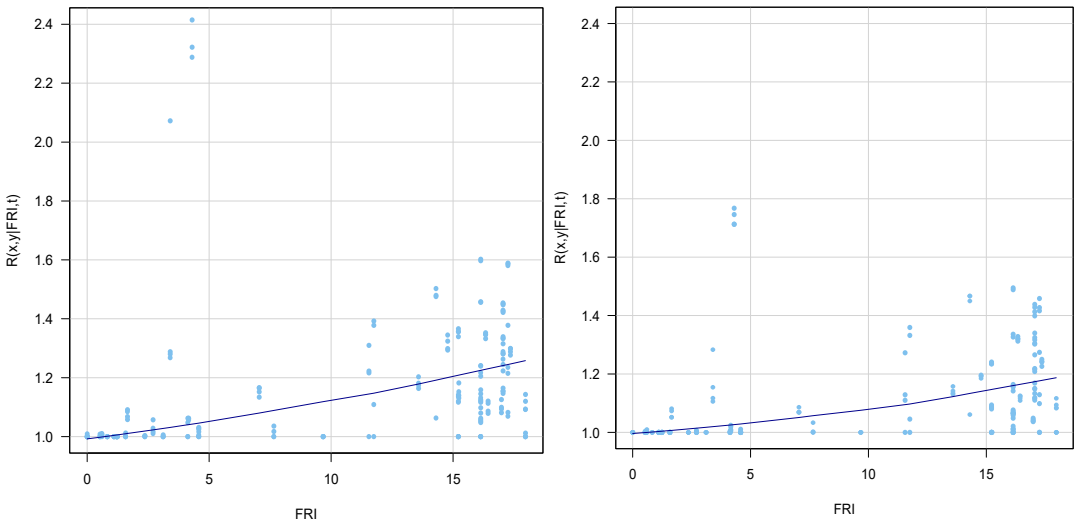
not to increase efficiency but to achieve other high-priority economic policy goals that do not appear to align with better resource management in the evaluated period. This can distort spending policy decisions and may result in reductions in specific non-superfluous expenditure that contributes to providing better public services.

As mentioned above, our results are not consistent with the findings of some previous studies that analyzed this issue using simpler methodological approaches (e.g., Apati et al., 2023; Barbier-Gauchard et al., 2023a), in which the fiscal rules were found to have a positive influence on public sector efficiency. However, it is worth mentioning that the above studies analyze a longer period in which there was greater financial instability. In contrast, our results may be conditioned to some extent by the characteristics of the analyzed period (2016-2019), when the financial situation of the countries had improved significantly following the fiscal consolidation policies implemented after the financial crisis.

Figure 2B. Marginal effect of FRI2 on efficiency scores for each model



Baseline model Model 1



Model 2 Model 3

6. Conclusions

This paper has explored the relationship between the existence of fiscal rules and their level of strength and public sector efficiency considering a wide range of countries from different geographical regions of the world. To do this, we developed our own composite indicator applying a relatively simple procedure to measure the strength of fiscal rules summarizing the ample information available in the IMF's fiscal rules database. We also used the fiscal rule strength indicator provided by the same database to test the robustness of our empirical results. Moreover, from a methodological viewpoint, the main contribution of this study relies on the use of a completely nonparametric approach, the so-called conditional approach, which had not been previously applied in this context. Its main advantage is that it allows us to explore the possible relationship between fiscal rules and public sector performance without having to adopt the restrictive assumption of separability between our variable of interest and the variables (inputs and outputs) used to construct our proxy measure of the overall efficiency level of countries.

Our findings suggest that fiscal rules have a negative influence on efficiency when they are still few and far between or in their early stages of implementation, i.e., when strength levels tend to be low. Nevertheless, when stricter, stronger or more enforceable fiscal rule mechanisms are established, they can contribute to achieving efficiency gains in public sector performance. It is worth mentioning

that this inverted-U relationship is only observed for one of the fiscal rule strength indices used, since, for the other index available in the IMF fiscal rule dataset, the effect is negative across the entire distribution of index values. This result corroborates the conclusions drawn in our initial analysis conducted with our own composite indicator and supports our hypothesis that the impact of fiscal rules on expenditure efficiency was not taken into consideration when they were designed and that this might have distorting effects on spending decisions.

In any case, our analysis covers a short time period, which means that we should interpret this interesting result with caution. In this regard, we decided against expanding the analysis to incorporate more recent data, because the application of fiscal rules has been suspended in most of the analyzed countries in recent years because of the COVID-19 crisis. COVID-19 forced countries to significantly increase their spending and debt levels to meet social demands. Moreover, the methodology applied in our empirical analysis prevents us from identifying causal relationships. This would mean neglecting potential data endogeneity due mainly to a problem of omitted information since many other factors not considered in our empirical analysis might be also affecting public sector efficiency.

Finally, we would like to mention some possible extensions that we propose for further development. First, we would like to test an alternative definition of the PSP indicator based on the use of a more flexible benefit-of-the-doubt approach (Cherchye et al., 2007). Likewise, we are interested in analyzing how overall public sector efficiency may be affected by the level of fiscal rule compliance, since rule existence is not the same thing as rule compliance.

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APPENDIX A

Scores assigned to construct the fiscal rule index (FRI)

1) Number of fiscal rules applied. We consider the main four main types of fiscal rules that can be applied (BBR, ER, RR and DR) and check how many of them are applied in each country. Accordingly, if all four are applied, the score would be 4, if three are applied, the score would be 3, and so on. If none were applied, the score would be 0.
2) Monitoring. The score of this index will be 1 if there is an independent body monitoring the implementation of the fiscal rules and 0 otherwise.
3) Level of application. The value of this indicator is 2 if most of the fiscal rules are applied at both supranational and national level (considering all four types), 1 if most of the rules apply only at the national level and 0 if there are no rules in force.
4) Enforcement. The score will be 2 if there is an automatic mechanism to enforce compliance for most of the applicable rules (considering all four types), 1 if there is such a mechanism for any rule(s) and 0 if there is no enforcement mechanism.
5) Legal basis. This index presents a value of 5 if the highest applicable rule is included in the constitution, 4 if it is included in an international treaty, 3 if it is included in a national law, 2 if it is based on a coalition agreement and 1 for no statutory underpinning.
6) Independent body setting budget assumptions. This index is defined as a binary variable that takes the value 1 if there is an independent body performing this task or 0 otherwise.

Each sub-index is re-scaled to build variables with values between 0 and 10 so that they are all placed on the same scale.

Table A1. List of countries included in the sample divided by geographic region

	Europe		America	Asia	Oceania
Countries	Austria Belgium Bulgaria Croatia Cyprus Czech Republic Denmark Estonia Finland France Germany Greece Hungary Iceland Ireland Italy	Latvia Lithuania Luxembourg Malta Netherlands Norway Poland Portugal Romania Russia Slovakia Slovenia Spain Sweden Switzerland United Kingdom	Argentina Brazil Canada Chile Colombia Costa Rica Ecuador Mexico Panama Paraguay Peru United States Uruguay	India Israel Japan	Australia New Zealand
TOTAL	**32**		**13**	**3**	**2**

Table A2. Indices representing the strength of fiscal rules

		(1)	(2)	(3)	(4)	(5)	(6)	Composite indicator	IMF Overall Index
1	Argentina	0	0	0	0	0	0	0.000	3.400
2	Australia	10	0	5	0	6	0	3.500	4.156
3	Austria	7.5	10	10	10	8	0	7.583	15.217
4	Belgium	7.5	10	10	10	8	10	9.250	16.133
5	Brazil	5	0	5	5	6	0	3.500	4.300
6	Bulgaria	7.5	0	10	10	8	0	5.917	15.217
7	Canada	0	0	0	0	0	0	0.000	0.000
8	Chile	2.5	10	5	0	6	10	5.583	4.575
9	Colombia	5	10	5	0	6	0	4.333	7.050
10	Costa Rica	2.5	0	5	0	6	0	2.250	1.200
11	Croatia	7.5	0	10	5	8	0	5.083	17.050
12	Cyprus	7.5	10	10	5	8	0	6.750	17.050
13	Czech Republic	7.5	0	10	5	8	0	5.083	11.550
14	Denmark	7.5	10	10	10	10	0	7.917	16.433
15	Ecuador	5	0	5	0	6	0	2.667	1.100
16	Estonia	7.5	10	10	10	8	0	7.583	15.217
17	Finland	7.5	10	10	5	8	0	6.750	16.133
18	France	10	10	10	10	10	0	8.333	14.777
19	Germany	7.5	10	10	10	10	0	7.917	13.583
20	Greece	7.5	10	10	10	8	0	7.583	16.133
21	Hungary	7.5	0	10	5	8	0	5.083	14.300
22	Iceland	0	0	0	0	0	0	0.000	0.000
23	India	0	0	0	0	0	0	0.000	1.575

24	Ireland	7.5	10	10	5	8	0	6.750	16.133
25	Israel	5	0	5	0	6	0	2.667	2.363
26	Italy	7.5	10	10	5	10	0	7.083	15.233
27	Japan	2.5	0	5	0	6	0	2.250	0.525
28	Latvia	7.5	10	10	10	10	0	7.917	17.250
29	Lithuania	10	10	10	10	10	10	10.000	17.350
30	Luxembourg	7.5	10	10	10	8	10	9.250	17.967
31	Malta	7.5	10	10	10	10	0	7.917	17.250
32	Mexico	5	0	5	5	6	0	3.500	3.113
33	Netherlands	10	10	10	10	8	10	9.667	16.983
34	New Zealand	5	0	5	0	6	0	2.667	0.825
35	Norway	2.5	0	5	0	2	0	1.583	1.650
36	Panama	5	0	5	0	6	0	2.667	7.650
37	Paraguay	5	10	5	5	6	0	5.167	1.238
38	Peru	7.5	10	5	5	6	0	5.583	9.675
39	Poland	7.5	0	10	10	10	0	6.250	11.750
40	Portugal	7.5	10	10	5	8	0	6.750	17.050
41	Romania	7.5	10	10	10	8	0	7.583	17.050
42	Russia	2.5	10	5	5	6	0	4.750	4.575
43	Slovak Republic	7.5	10	10	10	10	0	7.917	16.333
44	Slovenia	7.5	0	10	5	8	0	5.083	17.050
45	Spain	7.5	10	10	10	8	0	7.583	16.133
46	Sweden	7.5	10	10	5	8	0	6.750	16.133
47	Switzerland	2.5	0	5	5	10	0	3.750	4.125
48	United Kingdom	7.5	10	10	5	8	10	8.417	17.967
49	United States	2.5	10	5	5	6	0	4.750	2.700
50	Uruguay	2.5	0	5	0	6	0	2.250	0.600
	Mean	**5.9**	**5.6**	**7.4**	**5.2**	**7**	**1.2**	**5.383**	**10.256**

(1) Number of fiscal rules applied; (2) Monitoring; (3) Level of application; (4) Enforcement.
(5) Legal basis; (6) Independent body setting budget assumptions.

Table A3. Definition of output components and data source

Opportunity indicators	Variable	Source	Definition
Administration	Corruption	Transparency International's Corruption Perceptions Index (2016-2021)	Corruption on a scale from 10 (perceived to have low levels of corruption) to 0 (highly corrupt)
	Red tape	World Economic Forum: The Global Competitiveness Report (2016-2019)	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 (2016-2019)	Judicial independence on a scale from 7 (entirely independent) to 1 (heavily influenced)
	Shadow economy	Kelmanson et al. (2021)[14] (2016-2019)	Shadow economy measured as percentage of official GDP. Reciprocal value 1/x
Education	Secondary school enrolment	World Bank, World Development Indicators (2016-2019)	Ratio of total enrolment in secondary education
	Quality of educational system	World Economic Forum: The Global Competitiveness Report (2016-2019)	Quality of educational system on a scale from 7 (very good) to 1 (very bad)
	PISA scores	PISA 2018 report	Simple mean of 10 plausible values for each competence (reading, math and science)[15]
Health	Infant survival rate	World Bank, World Development Indicators (2016-2019)	Infant survival rate = (1000-IMR)/1000. IMR is the infant mortality rate measured per 1000 lives birth in a given year
	Life expectancy at birth	World Bank, World Development Indicators (2016-2019)	Life expectancy at birth, measured in years
Infrastructures	Infrastructure quality	World Economic Forum: The Global competitiveness Report (2016-2019)	Infrastructure quality on a scale from 7 (extensive and efficient) to 1 (extremely underdeveloped)

[14] This report only provides data for European countries. For the remaining countries, we use data available in Medina and Schneider (2018).
[15] Scores for Ecuador and Paraguay are drawn from the PISA for development (PISA-D) program since they did not participate in PISA 2018.

Musgravian indicators	Variable	Source	Definition
Distribution	Gini Index	World Bank, World Development Indicators (2016-2019)	Gini index on a scale from 1 (perfect inequality) to 0 (perfect equality). Transformed to 1-Gini
Stabilization	Coefficient of variation of GDP growth (5 years)	IMF World Economic Outlook (WEO database) (2015-2019)	Coefficient of variation=standard deviation/mean of GDP growth based on 5-year data. GDP constant prices (percent change) Reciprocal value 1/x
	Standard deviation of inflation (5 years)	IMF World Economic Outlook (WEO database) (2015-2019)	Standard deviation of inflation based on 5-year consumer prices (percentage change) data Reciprocal value 1/x
Economic Performance	GDP pc (5 years)	IMF World Economic Outlook (WEO database) (2015-2019)	GDP per capita based on PPP, current international dollar.
	Unemployment rate (5 years)	IMF World Economic Outlook (WEO database) (2015-2019)	Unemployment rate, as a percentage of total labor force Reciprocal value 1/x

Table A4. Definition of input components and source of data

Opportunity indicators	Variable	Source	Definition
Administration	Government consumption	IMF World Economic Outlook (WEO database)	General government final consumption expenditure (% of GDP)
Education	Education expenditure	World Bank	Expenditure on education (% of GDP)
Health	Health expenditure	World Bank	Expenditure on health (% of GDP)
Public Infrastructures	Public investment	European Commission, AMECO (2005–2016)	General government gross fixed capital formation (% of GDP) at current prices
Musgravian indicators	**Variable**	**Source**	**Definition**
Distribution	Social protection expenditure	OECD database (2005–2016)	Aggregation of the social transfers (% of GDP)
Stabilization/ Economic Performance	Government total expenditure	IMF World Economic Outlook (WEO database)	Total expenditure (% of GDP)

APPENDIX B

1. Description of the conditional approach (Daraio and Simar, 2005, 2007a)

This approach is based on a definition of the production process using an alternative probabilistic formulation developed by Cazals (2002). It can be described by the joint probability function, denoted by $H_{X,Y}(x, y)$, which represents the probability of dominating a unit operating at level (x, y):

$$H_{X,Y}(x, y) = \text{Prob}(X \leq x, Y \geq y)$$

This probability function can be further decomposed as follows:

$$H_{X,Y}(x, y) = \text{Prob}(X \leq x | Y \geq y) \cdot \text{Prob}(Y \geq y) = F_{X|Y}(x|y) S_y(y)$$

where $F_{X|Y}(x|y)$ represents the conditional distribution of X, and $S_Y(y)$ represents the cumulative distribution function of Y. Under free disposability and adopting an input orientation, the traditional measure of technical efficiency is defined by

$$\theta(x, y) = \inf\{\theta | F_{X|Y}(\theta x, y) > 0\} = \inf\{\theta | H_{XY}(\theta x | y) > 0\}.$$

In this framework, it is possible to introduce contextual or environmental factors Z that might have an influence on the production process. Thus, the attainable conditional production set can be defined by

$$\Psi^Z = \{(x, y) | Z = z), x \text{ can produce } y\}.$$

In the presence of these additional external factors, the conditional distribution can be defined using a probabilistic model that conditions the production process to certain values of these variables $(Z = z)$: $H_{XY|Z}(x, y|z) = Pr(X \leq x, Y \geq y | Z = z)$.

This function represents the probability of a unit at the given level (x, y) of being dominated by other units facing the same environmental conditions $Z = z$. This can also be decomposed into two terms: conditional distribution function of inputs $(F_{X|Y,Z}(x|y, z))$ and the survival conditional function of outputs $(S_{Y|Z}(y|z))$.

As our analysis aims to assess efficiency over a period of time, we need to extend this model to a dynamic framework including the time dimension. Following Mastromarco and Simar (2015), we consider the time factor (t) as an additional conditional variable. Thus, we have the following set of production possibilities:

$$H_{X,Y|Z}^{t}(x,y|z) = Prob(X \leq x, Y \geq y|Z = z, T = t).$$

The conditional input-oriented efficiency measures can be defined as:

$$\theta^{t}(x,y|z) = inf\{\theta | F_{X|Y,Z}^{t}(\theta x|y,z) > 0\}.$$

By a plug-in rule, different nonparametric estimators can be used to estimate the total frontier $\widehat{\lambda^{t}}(x,y|z)$. In this paper, we adopt the well-known DEA alternative following the formulation proposed by Daraio and Simar (2007a, 2007b), which implies a frontier built from real and fictitious units since we are assuming a convex technology.

The computation of conditional efficiency estimators requires adopting smoothing techniques. To do this, we apply the approach proposed by Badin et al. (2010) for bandwidth selection (*h*):

$$\hat{S}_{Y|X,Z}^{t}(y|x,z) = \frac{\sum_{j=(i,v)} I(x_j \leq x, y_j \geq y) K_{h_z}(z_j - z) K_{h_t}(v-t)}{\sum_{j=(i,v)} I(x_j \leq x) K_{h_z}(z_j - z) K_{h_t}(v-t)}$$

Here h_z and h_t are the bandwidth of optimal size and $K(\cdot)$ is a kernel function with compact support. For this study, optimal bandwidths are selected using the least squares cross-validation (LSCV) procedure suggested by Li and Racine (2007). This approach has the appealing feature of detecting the irrelevant factors and smoothing them out by providing large bandwidth parameters.