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Rough diamonds : how the volatility of commodity prices polishes or tarnishes the effectiveness of public spending in Africa ?

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Abstract

This study examines the impact of commodity price volatility on the efficiency of public spending in 44 African countries between 1998 and 2018. Through a two-step econometric approach, combining stochastic frontier analysis and fractional regression, we evaluate the relationship between commodity price fluctuations and the efficiency of public spending. The results reveal that an increase in volatility is significantly associated with a reduction in public spending efficiency, highlighting the vulnerability of African public finances to exogenous shocks. The study highlights the importance of economic diversification, institutional quality, and governance in mitigating the negative effects of this volatility. Countries with sovereign wealth funds appear to better withstand price shocks, while countries without such mechanisms are particularly affected. Identified transmission channels include inflation, political stability, workforce, and income inequalities, each exerting distinct influences on spending efficiency. These findings call for strengthened public policies to stabilize budgetary revenues and promote more efficient management of public resources, while enhancing democratic institutions and developing human resources. The research contributes to the literature on the 'resource curse' and provides recommendations for policymakers in managing resource-rich economies.

Keywords : • Commodity price volatility • Public expenditure efficiency • Economy diversification • Institutions and governance • Natural resources.

JEL Codes :

Acknowledgments : .

1 Introduction

The volatility of commodity prices is a major phenomenon affecting many countries dependent on the export of natural resources, particularly developing countries. Erratic fluctuations in the prices of these commodities, particularly oil, metals and agricultural products, lead to great instability in budget revenues for these economies [Arezki et al. \(2017\)](#). This fiscal instability caused by the commodities cycle can have harmful effects on the management of public finances and the efficiency of public spending ([Collier et al. \(2010\)](#); [Frankel \(2011\)](#); [Majumder et al. \(2022\)](#); [Ngundu \(2023\)](#)). However, in the literature, several channels have been identified through which commodity price volatility could impact the effectiveness of public spending. Indeed, via a variety of mechanisms, it has different repercussions on different countries.

First and foremost, it affects the terms of trade of importing and exporting countries. According to standard macroeconomic theory, a rise in commodity prices leads to a deterioration in the terms of trade for importing countries, reducing their real incomes. In this context, the effectiveness of expansionary fiscal policies (increased public spending or lower taxes) is reduced because part of this stimulus 'leaks' abroad through more expensive imports ([Mundell \(1968\)](#)). In the case of exporting countries, when prices rise, their export earnings increase in foreign currency. Conversely, a fall in prices reduces their foreign exchange earnings. This instability in export revenues has repercussions on overall domestic demand via wealth effects and effects on public finances ([Mendoza \(1995\)](#); [Blattman et al. \(2007\)](#); [Jebran et al. \(2018\)](#)). For example, a rise in oil prices increases the purchasing power of oil-exporting countries, which stimulates household consumption and business investment. Government tax revenues also rise, allowing public spending to increase. The opposite occurs when oil prices fall. However, not all countries absorb these shocks to their terms of trade in the same way. The extent of the effects depends on the counter-cyclical macroeconomic policies put in place ([Kaminsky \(2010\)](#); [Peres-Cajías et al. \(2022\)](#)). Countries such as Chile and Norway are mitigating the transmission of volatile commodity prices to their domestic economies through stabilisation funds and prudent fiscal policy.

In addition to the terms of trade, a second channel through which the possibility of commodity prices affects the economy is that of uncertainty. The unpredictability of world prices and their high variability over time create a highly uncertain environment for economic decision-makers ([Van der Ploeg and Poelhekke \(2009\)](#)). This uncertainty has a negative impact on investment, in both physical and human capital. Businesses are reluctant to invest and hire if future price trends are highly unpredictable. Similarly, households reduce their spending on education if the future return on this investment is perceived as risky because of the volatility. This slows down the country's long-term economic growth, particularly when the share of raw materials in exports is high. However,

Van der Ploeg and Poelhekke (2009) qualifies this result. Using panel data regressions, they show that the negative effect of commodity price volatility on growth depends on the country's degree of financial development. In other words, they show that uncertainty weighs less on economies with more complete financial markets.

The volatility of commodity prices also has an impact on the composition of public spending in those countries that are fiscally dependent on them. When prices are high and tax revenues temporarily increase, governments are encouraged to save these exceptional revenues rather than consume them by increasing current expenditure (civil servants' salaries, subsidies, etc.) (Shabsigh and Ilahi (2007); Moore and Prichard (2020)). This precautionary saving generally takes the form of deposits in sovereign wealth funds, which enable income from boom periods to be set aside for use when commodity prices are at their lowest. For example, during the boom of the 2000s, many exporting countries such as Russia, Venezuela and Algeria invested massively in their sovereign wealth funds. However, not all countries are adopting the same cautious approach. Céspedes and Velasco (2014) uses econometric estimates on a panel of countries show that the propensity to save depends on the quality of institutions. Countries with strong democratic and budgetary constraints tend to save more temporary income. Conversely, those with weaker institutions and deficient governance tend to increase their current expenditure in boom times.

Several solutions have been proposed to mitigate these effects, such as the adoption of countercyclical fiscal rules, economic diversification, stabilisation funds or better governance of resources (Manasseh et al. (2019); Frankel (2011); Arezki et al. (2017); Medina (2010); Adegboye (2021); Peres-Cajías et al. (2022)). However, although several studies have analysed the impact of commodity prices on the macroeconomic performance of developing countries (Guillaumont et al. (1999); Combes and Guillaumont (2002); Collier and Goderis (2007); Van der Ploeg and Poelhekke (2009)), few have focused on the specific case of African countries. In addition, the implications of this use for the effectiveness of public spending remain little explored in the literature. Our study contributes to this emerging literature by analysing the case of African countries in depth and by using a rich econometric model to assess the causal impact of commodity price volatility on various dimensions of public spending efficiency.

Our study aims to fill in some of the gaps in the existing literature on the impact of commodity price volatility in developing countries. It is distinctive in two respects. First, it focuses specifically on the case of African countries, which are structurally more vulnerable to erratic fluctuations in world prices. Indeed, many of the continent's economies are heavily dependent on exports of raw materials. To our knowledge, no research has specifically studied the implications of this volatility for the effectiveness of public spending in the African context. Our study therefore fills this gap by proposing an in-depth analysis of the causal impact on a large sample of 44 countries over the period 1998-2018.

Second, in terms of methodology, we use an innovative two-stage approach. First, policy effectiveness scores are estimated using a stochastic frontier model. This technique makes it possible to take rigorous account of the specific features of public sector performance measurement. Secondly, the effect of price volatility is assessed using a fractional regression model adapted when the dependent variable is between 0 and 1. This strategy thus coherently combines two complementary econometric tools. To our knowledge, such a two-phase approach has not yet been used on this issue. It therefore provides real added value for rigorously estimating the impact of price volatility. With its focus on Africa and its innovative methodology, our research aims to make progress on a blind spot in the literature and to provide a robust assessment of the stakes for public finances in the region.

The paper is organised as follows. Section 2 reviews the existing literature on the impact of commodity price volatility in developing countries. Section 3 presents the conceptual framework of public expenditure efficiency and the methodology used to estimate it. Section 4 details the two-stage econometric strategy. Section 5 provides descriptive statistics. Section 6 presents the estimation results. Robustness tests are carried out in section 7. Section 8 examines the heterogeneity of the impact according to country characteristics. Section 9 identifies the transmission channels. Section 10 concludes by drawing out the implications for economic policy.

2 Literature review

The volatility of world commodity prices is a structural feature of economies dependent on these exports. This instability affects public revenues and hence the conduct of fiscal and monetary policies, with potential repercussions on countries' economic performance. This literature review analyses the results of recent studies on the effects of commodity price volatility on public finances.

2.1 Impact on public finances

The volatility of commodity prices has a significant impact on government finances. Indeed, the budget revenues of these countries are heavily dependent on the income generated by exports of natural resources, which fluctuate according to the international economic situation. Numerous empirical studies have demonstrated the procyclical nature of public finances in relation to variations in world prices. For example, [Urbina and Rodríguez \(2023\)](#), in the case of Peru, find that a 1% rise in mining prices leads to a 1.5 to 2.5% increase in mining tax revenues. This rapid transmission effect reflects high fiscal vulnerability to exogenous shocks. On a macroeconomic level, this positive correlation between commodity prices and budget revenues limits governments' counter-cyclical

room for manoeuvre. Excess liquidity during a boom reduces the incentive to save excess profits, while a sudden collapse in prices during a recession forces pro-cyclical budget cuts. This phenomenon accentuates the instability of public spending and its mismatch with economic cycles. For example, [Medina \(2010\)](#) highlights the high sensitivity of fiscal balances to commodity prices in 8 Latin American countries over the period 1975-2008.

Furthermore, the preference for budget revenues reduces the predictability of the resources available to finance public policies. This budgetary uncertainty complicates the multi-annual programming of investments and undermines their effectiveness [Chuku et al. \(2018\)](#). Thus, fiscal dependence on fluctuating revenues leads to macroeconomic and fiscal vulnerability, which constrains the optimal conduct of public policies in commodity-exporting countries. This affects the sustainability and effectiveness of their development model.

2.2 Impact on the composition and efficiency of public spending

The instability of world commodity prices has a considerable impact on public revenues in exporting countries, which affects the allocation of spending and therefore limits its effectiveness. For example, [Manasseh et al. \(2019\)](#) use a heteroscedastic generalised exponential conditional autoregression (EGARCH) model to find that, in Nigeria over the period 1970-2013, fluctuations in oil revenues skew the structure of spending towards allocations that are sub-optimal from a development perspective. Similarly, [Chuku et al. \(2018\)](#) observe from African data that fiscal policy is often pro-cyclical, whereas Keynesian theory recommends a counter-cyclical stance to stabilise the economy. Moreover, fiscal policy seems to particularly affect certain expenditure items. [Akinleye \(2017\)](#) show that infrastructure spending is very sensitive to changes in oil revenues, which undermines the predictability of public investment.

However, the effect on allocative efficiency varies according to the category of expenditure. For example, [Ogundipe \(2020\)](#) indicates that trade openness mitigates the negative impact of volatile prices on growth in 53 African countries in the short term. This effect is explained by a more efficient allocation of resources on international markets. Similarly, [Abaidoo and Agyapong \(2023\)](#) find on a panel of 30 emerging economies that the effect of commodity availability on banking stability depends on the product under consideration and the measure of financial stability used.

2.3 Mitigating role of fiscal and monetary policies

Existing empirical studies highlight the crucial role that fiscal and monetary policies can play in mitigating the adverse effects of commodity price volatility on countries' economic and financial performance. From a budgetary perspective, [Majumder et al. \(2022\)](#) show that the negative impact of commodity price volatility on government budget ba-

lances can be mitigated by a decrease in the real interest rate. Their empirical results obtained using a dynamic panel model on a large sample of 108 countries reveal that accommodative monetary policy aiming to reduce real interest rates can help preserve budgetary balances in the face of commodity price shocks. Beyond monetary policy, [Roch \(2019\)](#) emphasizes the stabilizing role that other institutional mechanisms can play, such as exchange rate regime flexibility, adoption of inflation targeting, and implementation of budgetary rules. His SVAR study on 22 commodity exporters shows that these macroeconomic arrangements contribute to further protect economic activity from fluctuations in terms of trade in commodity markets. From a financial perspective, [Kinda et al. \(2016\)](#) specifically study the consequences of commodity price shocks on banking sector fragility. Their empirical results on 71 developing exporting countries reveal that negative shocks to these prices weaken bank soundness, resulting in an increase in non-performing loans, a reduction in profits, and liquidity. However, these effects appear to be less pronounced in countries with macroprudential mechanisms, sovereign wealth funds, and a more diversified export base.

Thus, existing studies converge to underline the important role that certain budgetary, monetary, and prudential policies can play in strengthening the resilience of commodity-exporting economies to pricing in these markets. The establishment of stabilization funds, countercyclical budgetary rules, greater exchange rate flexibility, and inflation targeting seem to be useful mechanisms for mitigating the adverse transmission of option shocks to economic and financial balances.

3 Conceptual framework

3.1 Effectiveness of public spending

The effectiveness of public spending can be defined as "the ability to achieve the desired objectives at the lowest cost" ([Publishing \(2017\)](#)). In other words, according to [Mandl et al. \(2008\)](#), the effectiveness of public spending refers to the State's ability to use budgetary resources in such a way as to optimise their socio-economic impact. This means maximising the outputs and outcomes of public policy for a given level of spending.

Two interdependent dimensions can be distinguished ([Afonso and Aubyn \(2005\)](#)). Firstly, technical efficiency, which refers to the ability to maximise the quantities of outputs and outcomes for a given level of expenditure. And secondly, allocative efficiency, which refers to the optimal distribution of credits between alternative uses in order to maximise collective well-being. These two aspects reflect a search for optimisation in the allocation and use of public funds. However, this second dimension requires information on the price structure of the factors of production used, data that would be difficult to obtain in the context of our study. We will therefore give priority to technical efficiency,

which has the advantage of requiring only quantitative indicators (Afonso and Fernandes (2008)) that are easy to mobilise.

3.2 Estimating technical efficiency

Estimating the efficiency of public spending has attracted growing interest in recent literature. Numerous studies have examined the evaluation of budgetary efficiency frontiers using parametric and non-parametric methods. Some studies (Herrera and Pang (2005); Wagstaff and Wang (2011); Agasisti (2014); Grigoli (2014); Afonso and Kazemi (2017); Kumbhakar et al. (2015); Herrera and Ouedraogo (2018); Krejnus et al. (2023); Mohanty et al. (2023); Andonova and Trenovski (2023) Afonso et al. (2023)) use the non-parametric DEA (Data Envelopment Analysis) and FDH (Free Disposal Hull) methods. The non-parametric approach owes its popularity to its advantage of requiring no assumption about the functional form of the production function, and to its ability to handle both multiple inputs and multiple outputs (Moradi-Motlagh and Emrouznejad (2022)). However, it is described as deterministic due to the fact that it takes no noise into account and that all deviations from the frontier are considered inefficient, and therefore susceptible to outliers (Wilson (1995); Simar (2003); Porembski et al. (2005)). In contrast, parametric models require a functional form to be specified for the production frontier. The advantage of this approach is that production technology and inefficiency can be estimated simultaneously. Parametric models have the particularity of being able to explain why observations deviate from the deterministic frontier due to the existence of measurement errors and stochastic variations in the data. The idea is to say that no economic agent can exceed this ideal frontier. The most frequently used parametric model is the SFA (Stochastic Frontier Analysis) model. Parametric approaches, using stochastic frontiers (Aigner et al. (1977)), allow the error to be broken down into an inefficiency component and an idiosyncratic component that captures random events. However, they are based on strong assumptions about the distribution of the data, which is often assumed to be semi-normal, exponential or truncated normal (Stevenson (1980)). While the first works using the parametric approach (Battese and Coelli (1992); Kumbhakar (1990); Cornwell et al. (1990)) were initially content to divide the error term into two components, extensions of the SFA model were developed to take into account technological heterogeneity and temporal variations in inefficiency. Some models such as Kumbhakar et al. (2014), Tsionas and Kumbhakar (2014) and Colombi et al. (2014) dissociate short- and long-term efficiency by dividing the error term into four components. Some of them (e.g. Tsionas and Kumbhakar (2014)) use a Bayesian approach while others (e.g. Colombi et al. (2014)) use a maximum likelihood estimator. Others such as Filippini and Greene (2016) favour a simulated maximum likelihood method. In this study, we will use a fairly recent parametric approach, namely Kumbhakar et al. (2014) to estimate efficiency scores. Indeed,

compared to previous parametric approach techniques, [Kumbhakar et al. \(2014\)](#) allows to distinguish unobserved heterogeneity between units from inefficiency. This makes it possible to capture heterogeneous characteristics between countries, such as their level of development, structural or institutional characteristics. Also, although other works such as [Greene \(2005a,0\)](#) are content to separate individual heterogeneity from stochastic noise, [Kumbhakar et al. \(2014\)](#) provides a further decomposition of efficiency by distinguishing persistent or long-term efficiency from transient or variable (short-term) efficiency. This allows us to consider the efficiency resulting from structural characteristics that persist over time and that resulting from the short term.

4 Econometric modelling

In order to assess the efficiency of public spending and estimate the impact of terms of trade volatility, we use a two-stage methodological framework. First, the efficiency scores of public spending are determined using an econometric model based on the conceptual framework presented above. Then, in a second step, the effect of commodity price volatility is estimated using a fractional regression model (FRM).

4.1 Step 1 : Estimating technical efficiency

In this subsection, we describe the indicators used in our study to determine public sector performance indices and discuss the methodology used to calculate public expenditure efficiency scores.

4.1.1 Public sector performance indices (PSP)

The performance indicators chosen in this study are based on the work of [Afonso et al. \(2005\)](#). Following this methodology, we first calculate a composite public sector performance indicator (PSP), which comprises seven socio-economic areas of government activity, called PSP sub-indicators. These sub-indicators are grouped into two categories. On the one hand, those called opportunity indicators, comprising four sectors, namely health, education, infrastructure and administration, identify these sectors as strategic for economic and social development. The second category takes into account the Musgrave model, which refers to the three traditional functions of the state : allocation (economic performance), distribution and stabilisation of resources. The precise choice of indicators within each category is based on previous work by ([Afonso et al. \(2005\)](#)); [Afonso and Fraga \(2024\)](#) and on the availability of data. The aim is to select indicators that are both theoretically relevant and empirically measurable. This two-category methodology aims to provide a comprehensive understanding of the economic and social role of the state, by

combining indicators that reflect both its traditional missions and its impact on long-term development.

The health sector performance indicator comprises two sub-indicators : the under-5 mortality rate (per 1,000 live births), the adolescent fertility rate (births per 1,000 women aged 15-19) and the maternal mortality ratio (per 100,000 live births). The education sector performance indicator includes secondary school enrolment and the quality of the education system. For the infrastructure sector outcome indicator, we consider the overall infrastructure quality indicator from The Global Competitiveness Index Historical. Finally, we have selected four sub-indicators for public administration, namely freedom of expression, rule of law, quality of regulation and effectiveness of public authorities. On the input side, we consider public spending on education (as a percentage of GDP) for the education sector, public spending on health (as a percentage of GDP) for the health sector, public capital stock (as a percentage of GDP) and public-private partnership stock (as a percentage of GDP) for infrastructure, and public spending on final consumption (as a percentage of GDP).

As mentioned earlier, we also consider the so-called Musgravian indicators, which comprise three sub-indicators, namely distribution, stability and economic performance. The outcome indicator for distribution is captured by the Gini index. For the stability sub-indicators, we use the standard deviation of the five-year moving average of GDP growth and inflation. To measure economic performance, we consider GDP per capita, GDP growth (5-year average) and the unemployment rate (5-year average). We use total public expenditure (as a percentage of GDP) as an input for stability, distribution and economic performance (as a percentage of GDP). Then, to capture the common characteristics of the performance sub-indicators used, we measure a composite index for each sector according to [Anderson \(2008\)](#). On the one hand, this method gives less weight to highly correlated indicators and conversely more weight to uncorrelated indicators, as they could provide new information. On the other hand, the method also takes into account variables with missing data, which gives them less weight than variables with complete data.

4.1.2 Calculation of efficiency scores

The econometric model described in this work for estimating efficiency scores is that of [Kumbhakar et al. \(2014\)](#). It is specified as follows :

$$y_{it} = \theta_0 + x_{it}^T \theta + c_i - \theta_i + v_{it} - u_{it}, \quad (1)$$

where :

$$\begin{aligned}
c_i &\overset{\text{i.i.d.}}{\sim} \mathcal{N}(0, \sigma_c^2), \\
\theta_i &\overset{\text{i.i.d.}}{\sim} \mathcal{N}^+(0, \sigma_\theta^2), \\
v_{it} &\overset{\text{i.i.d.}}{\sim} \mathcal{N}(0, \sigma_v^2), \\
u_{it} &\overset{\text{i.i.d.}}{\sim} \mathcal{N}^+(0, \sigma_u^2),
\end{aligned}$$

The model explains the performance of the public sector Y_{it} in country i in year t as a function of inputs X_{it} and four error components : c_i which represents unobserved individual heterogeneity, θ_i which represents persistent inefficiency, u_{it} transient inefficiency, and v_{it} which is regular disturbance. The model in (1) can be estimated using a single-step maximum likelihood method (Colombi et al., 2014) or a multi-step procedure (Kumbhakar et al., 2014). Although the multi-step procedure is less efficient than single-step maximum likelihood estimation, it is simpler and easier to implement. In the multi-step procedure, the model in (1) can be rewritten as follows :

$$y_{it} = \theta_0 + x_{it}^T \theta + \lambda_i + \epsilon_{it}, \quad (2)$$

where

$$\theta_0 = \theta_0 - E[\theta_i] - E[u_{it}], \quad (3)$$

$$\lambda_i = c_i - \theta_i + E(\theta_i), \quad (4)$$

$$\epsilon_{it} = v_{it} - u_{it} + E[u_{it}]. \quad (5)$$

The model in (2) turns out to be a standard panel data model and can be estimated using standard panel data estimation methods. After estimating (2), we can obtain the predicted values of θ_i and ϵ_{it} , $\hat{\theta}_i$ and $\hat{\epsilon}_{it}$, then the persistent and transitory efficiency components are estimated by applying standard stochastic frontier techniques to (4) and (5) with θ_i and ϵ_{it} replaced by $\hat{\theta}_i$ and $\hat{\epsilon}_{it}$.

The persistent efficiency for the country is given by :

$$PE_i = E[\exp(\theta_i)]$$

The transient efficiency for the country in the year tested is given by :

$$TE_{it} = E[\exp(u_{it})]$$

Given that θ_i and u_{it} are distributed¹, the total efficiency is then written :

1. θ_i and u_{it} distributed means that the distribution of θ_i does not depend on that of u_{it} and vice versa. In other words, they are independent random variables. The consequence of this assumption of independence is that we can break down the expectation of a function of θ_i and u_{it} as the product of the individual expectations. This property follows from the independence between θ_i and u_{it} , allowing the expectation of a joint function to be factored as the product of the individual expectations

$$TE_{it} = PE_i \times TE_{it}$$

With :

$$PE_i = \frac{1}{\sigma_\theta}$$

$$TE_{it} = \frac{1}{\sigma_u}$$

Where σ_θ and σ_u are always the increased standard deviations of θ_i and u_{it} .

4.2 Step 2 : Estimating the effects of commodity price volatility on the efficiency of public spending

In this second step, the previously calculated production efficiency score is regressed on exogenous variables using a fractional regression model (FRM) proposed by [Papke and Wooldridge \(1996\)](#). The reason for using this type of model is the limited value of efficiency scores and, in some cases, production scores. The literature emphasises that, unlike traditional linear regression, the FRM is based on a transformation of the dependent variable via a fractional link function, typically a logistic or fractional probit function ([Baum \(2008\)](#); [Ramalho et al. \(2011\)](#)). This approach better captures underlying dynamic processes where the dependent variable follows a fractional diffusion ([Meerschaert \(2013\)](#)). It is also more flexible because it adapts to a wide range of distributions of the dependent variable ([Cook et al. \(2008\)](#)). The FRM highlights the limitations of linear regressions in estimating the second stage after the efficiency score. For example, the standard linear regression model is considered inappropriate because it does not guarantee that the predicted values of the dependent variable are limited to the unit interval ([Armstrong et al. \(2012\)](#)). Furthermore, as the dependent variable is strictly limited to the interval $]0;1]$, it is generally unreasonable to assume that the effect of an explanatory variable is constant over its time interval ([Ramalho et al. \(2011\)](#)). The Tobit approach is also commonly used to estimate efficiency scores bounded by an interval. However, this method has certain limitations in the specific case of data defined on $[0,1]$. Firstly, the short-tailed Tobit model only restricts predictions within the interval $[0,1]$, which is problematic when observations lie outside these bounds. Secondly, although the Tobit model is well suited to data bounded by $[0,1]$, it seems inappropriate for data defined only on $[0,1]$. Finally, the Tobit model is based on strong assumptions of normality and homoscedasticity, which are not always verified in practice ([Ramalho et al. \(2011\)](#)). Consequently, the estimation of a fractional regression model (FRM) requires the use of a quasi maximum likelihood (QML) estimator as proposed by [Papke and Wooldridge \(1996\)](#). Indeed, the application of the FRM method requires only one assumption, namely a functional form constraining the conditional mechanism of the dependent variable as follows :

$$E(y|x) = G(x\omega) \tag{6}$$

where $G(\cdot)$ is a nonlinear function satisfying $0 \leq G(\cdot) \leq 1$.

It is crucial to point out that the estimation of equation 1 can be carried out through nonlinear least squares estimation or maximum likelihood estimation. However, it should be noted that the latter, in addition to being less efficient than QML estimation, also requires the specification of the conditional distribution of y at x . For these reasons, [Papke and Wooldridge \(1996\)](#) have suggested using QML estimation to estimate the MFR, based on the Bernoulli model (log-likelihood function). The log-likelihood function is written as follows :

$$\mathcal{LL}_i(\omega) = y_i \log[G(x_i\omega)] + (1 - y_i) \log[1 - G(x_i\omega)] \quad (7)$$

With the QML estimator of ω defined by :

$$\hat{\omega} \equiv \arg \max_{\omega} \sum_{i=1}^N \mathcal{LL}_i(\omega) \quad (8)$$

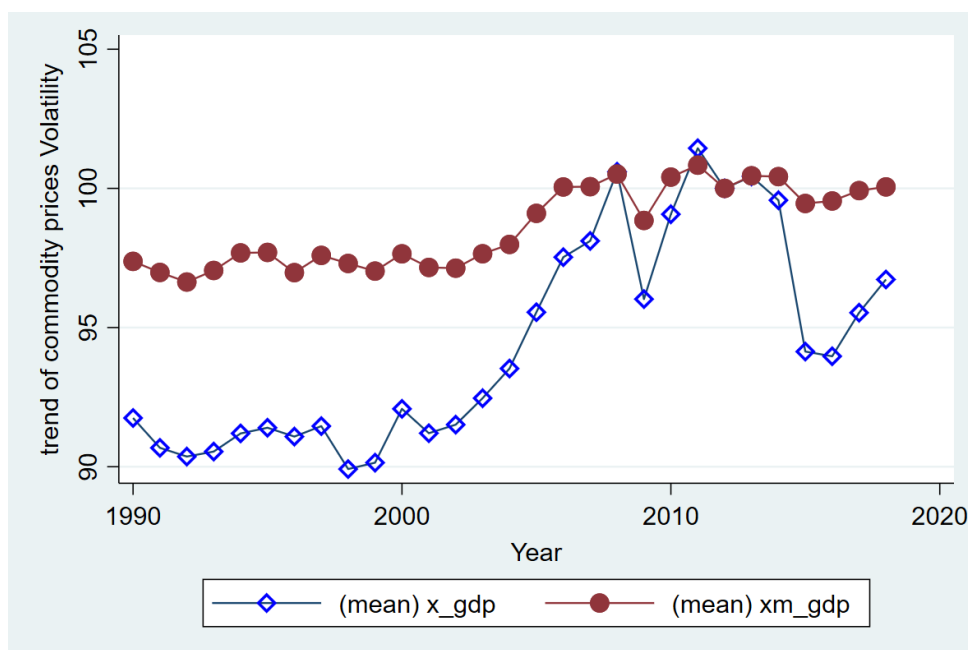
If equation 1 is well specified, $\hat{\omega}$ will be systematically and asymptotically normal, whatever the distribution of y over x ([Gourieroux et al. \(1984\)](#)).

5 Stylized facts

5.1 Commodity prices

Changes in commodity prices are a determining factor for African economies, which are highly dependent on exports of these natural resources. Graph 1 illustrating the data for the period 1990-2018 effectively shows an upward trend in prices, for both the export price index (x_gdp) and the terms of trade index (xm_gdp). More specifically, the x_gdp index rose from a value of 91.8 in 1990 to 96.7 in 2018, with an average increase of 0.5 points per year. There were two very sharp peaks in 2008 and 2011, when the index reached 100.6 and 101.4 respectively, reflecting the surge in world prices in those years. Conversely, the low point was in 1998-1999, when the index fell below 90 (89.9 in 1998), reflecting the fall in commodity prices. Between these extremes, the x_gdp index has fluctuated in line with economic cycles, while following a long-term upward trend. This overall rise reflects an improvement in the world prices of raw materials exported by Africa, such as oil, metals and agricultural products ([Arezki et al., 2014](#)). It can be explained by the rapid industrialisation and urbanisation of emerging countries such as China, which have stimulated demand ([Erten and Ocampo, 2013](#)). The peaks observed in 2008 and 2011 correspond to the all-time highs reached on the markets at that time. However, this favourable trend masks major fluctuations. The trough at the end of the 1990s, when x_gdp fell below 90, refers to the Asian crisis of 1997-1998, which depressed world prices ([Cashin and McDermott, 2002](#)). More moderate variations have also been observed in line

FIGURE 1 – Evolution of the Terms of Export and the Terms of Trade for Commodities in Africa from 1990 to 2018



Source : Author’s construction based on data from Gruss and Kebhaj (2019)

with economic cycles. The increased volatility of commodity prices since the early 2000s has also been highlighted by other studies (De V. Cavalcanti et al., 2015).

These fluctuations have had a direct impact on the budgets of African governments, whose revenues are heavily dependent on commodity exports (Mansour, 2014). The peaks may have generated exceptional revenues, but the troughs have also caused deficits when public spending has been maintained at a high level (Van der Ploeg and Venables, 2011). There has even been talk of a veritable "resource curse" linked to the mismanagement of this financial windfall (Frankel, 2010). However, despite a long-term upward trend, the uneven evolution of commodity prices represents a permanent challenge for African public finances.

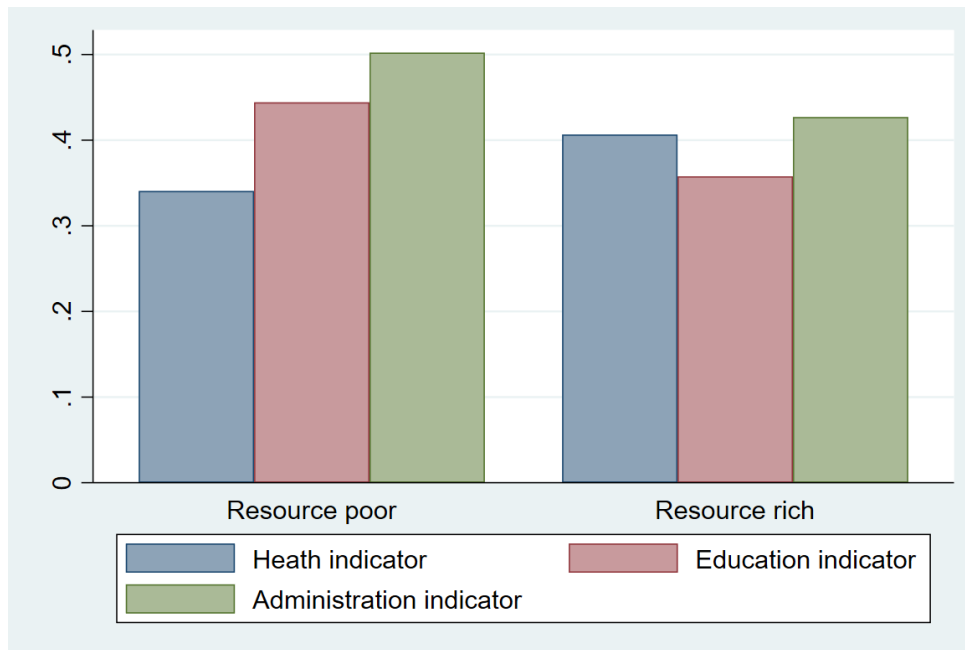
5.2 Public sector performance (PSP)

5.2.1 Analysis of opportunity indicators : health, education, infrastructure and administration

In this section, we present the calculated public sector performance indices. These indices take into account the information contained in the sub-indicators used to construct them. Figures 2 and 3 present the various opportunity indicators, namely the performance indices for health, education, infrastructure and administration. In Figure 2, the values of the indices range from 0 to 1, while in Figure 3, the value of the infrastructure performance index ranges from 1 to 7.

Analysis of Figure 2 reveals a wide disparity between African countries in terms of health indicators, which combine infant mortality rate, adolescent fertility rate and maternal mortality. The best-performing countries are Tunisia, Algeria, Mauritius and Seychelles, with an indicator below 0.1. These countries appear to have relatively well-developed health systems that are effective in reducing infant and maternal mortality. They also have low adolescent fertility rates. At the bottom of the ranking are countries such as the Central African Republic, Sierra Leone, Niger and Chad, with an indicator above 0.6. These countries still have very high infant and maternal mortality rates, linked to inadequate access to primary healthcare and high adolescent fertility rates.

FIGURE 2 – Average performance indicator for health, education and administration



Source : Author's construction

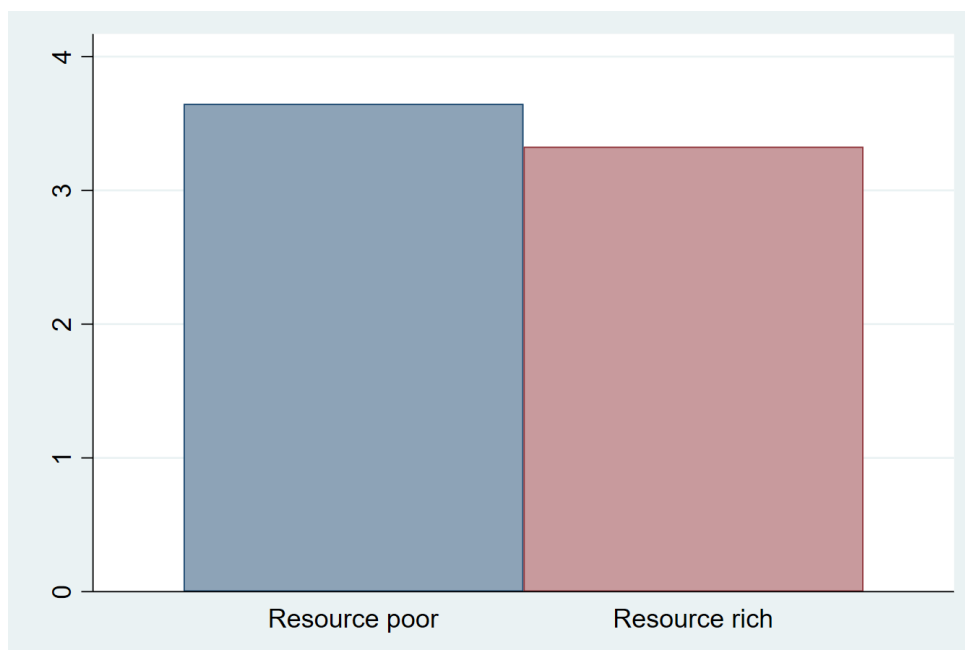
In the education sector, the best-performing countries are Mauritius, Seychelles, Cape Verde, Tunisia and Botswana, with an indicator above 0.65. These countries manage to enroll a large proportion of their population in secondary education while maintaining a high standard of teaching. At the bottom of the ranking are Chad, the Central African Republic, Niger and Mauritania, with an indicator below 0.2. These countries have very low rates of access to secondary education and poor quality education systems. It can also be observed that countries rich in natural resources tend to perform worse in education, perhaps because the income from these resources is not sufficiently reinvested in education.

The performance indicator for the administration sector shows wide disparities between countries. The best performances are achieved by Mauritius, Botswana, South Africa, Namibia, Cape Verde and Seychelles, with indicators above 0.7. These countries stand out for their stable political systems, solid institutions, efficient bureaucracies and respect for the rule of law. At the bottom of the ranking are Eritrea, the Central African Republic,

Chad and the Republic of Congo, with indicators below 0.3. These countries suffer from weak institutions, endemic corruption and a lack of political transparency. Resource-rich countries perform less well on average. Commodity revenues can lead to weak governance and rent capture by elites.

Regarding infrastructure, Figure 3 shows that there are major disparities between countries. The top-ranked countries are Mauritius, Seychelles, Morocco and Namibia, with an indicator above 4.5. They benefit from good quality transport, electricity and telecommunications infrastructure. South Africa, Botswana, Ghana and Senegal are in the middle range, with indicators between 3.5 and 4.5. The quality of infrastructure has improved in these countries, but there are still shortcomings, particularly in rural areas. At the bottom of the ranking are the Democratic Republic of Congo, Guinea, Chad and Angola, with indicators below 2.5. These countries suffer from a major infrastructure deficit that is holding back their economic development. Once again, resource-rich countries have, on average, poorer quality infrastructure. Revenues from raw materials do not seem to be sufficiently invested in this strategic sector.

FIGURE 3 – Average infrastructure performance indicator



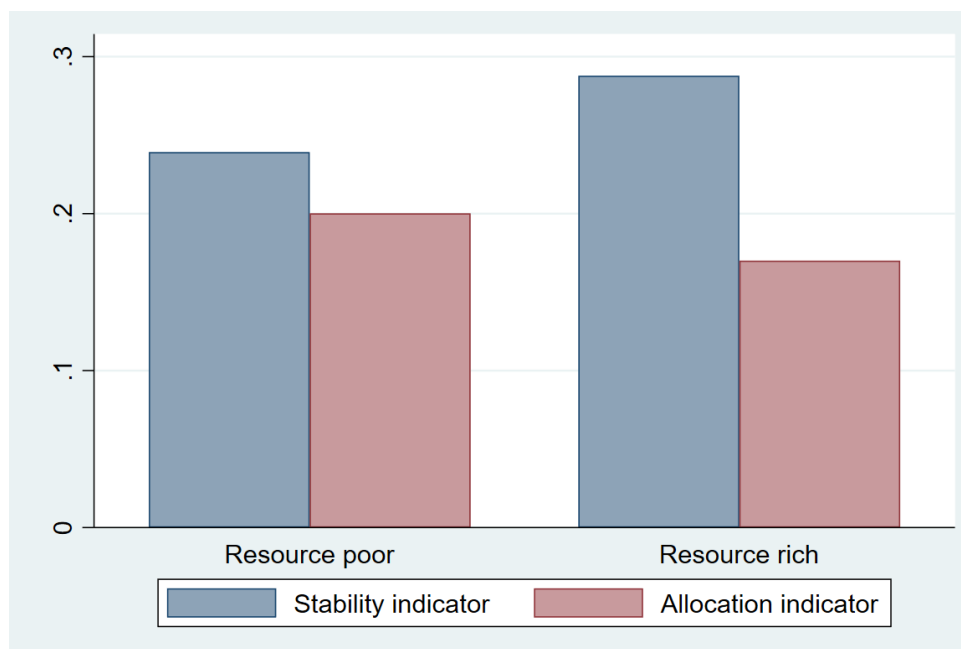
Source : Author's construction

5.2.2 Analysis of musgravian performance indicators : economic stability, economic performance and income distribution

Figure 4 shows average values of 0.26 and 0.19 for the result indicators of economic stability and economic performance respectively. As far as economic stability is concerned, the best-performing countries are the Seychelles, Morocco, Tunisia and Botswana, with an indicator of less than 0.25. These countries manage to maintain stable inflation and

sustained growth. The least stable countries are Ethiopia, Chad, DRC and Ghana, with indicators above 0.4. They have experienced high inflation or erratic growth over the period.

FIGURE 4 – Average of stability and allocation result indicators



Source : Author's construction

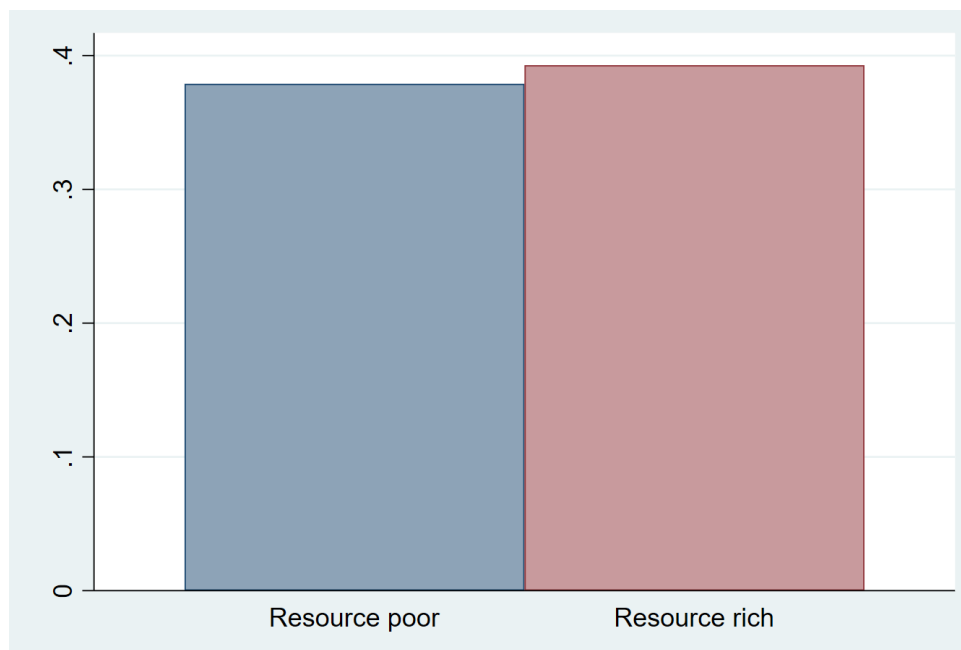
In terms of economic performance, the best results come from the Seychelles, Mauritius, Botswana and South Africa, with indicators above 0.4. These countries combine relatively high GDP per capita with low unemployment rates. Most African countries have very weak economic performances, with indicators below 0.2. Their GDP per capita and employability rates are low. Only a few countries rich in natural resources, such as Gabon and Congo, are exceptions.

Figure 5 shows the average of the distribution result indicator. There are huge disparities between countries in terms of income inequality. The countries with the lowest inequality are Namibia, Eswatini, South Africa and Botswana, with indices above 0.8. The distribution of wealth is relatively egalitarian in these countries. The countries with the most glaring inequalities are Ethiopia, Mali and Algeria, with a Gini index of less than 0.2. There is an extreme concentration of wealth in these nations. Countries rich in natural resources tend to have higher levels of inequality, due to the capture of mining or oil revenues by an elite.

5.2.3 Analysis of the composite public sector performance indicator

As previously mentioned, the composite public sector performance indicator, which aggregates performance indicators for health, education, governance, infrastructure, economic stability, and inequality, reveals significant disparities. The best performers are

FIGURE 5 – Average of the distribution result indicator



Source : Author's construction

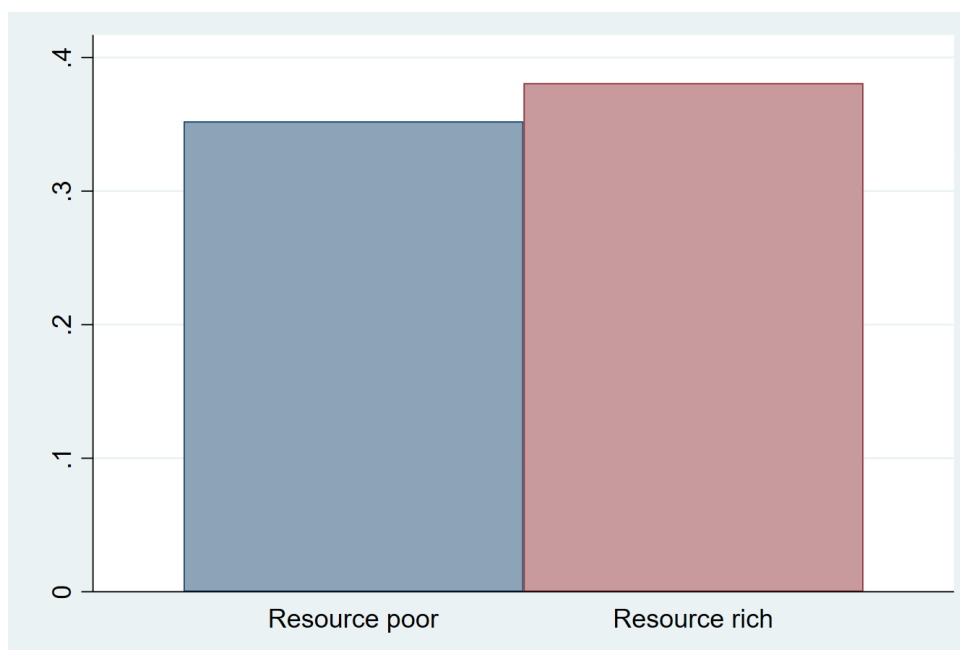
Tunisia, Morocco, Mauritius, and Cape Verde, with indicators below 0.3. These countries combine good results across most of the dimensions studied. These findings align with the Ibrahim Index of African Governance ([Mo Ibrahim Foundation, 2020](#)). The report highlights the importance these countries place on quality education and widespread access to healthcare. Botswana, Kenya, Senegal, and Ghana are in the middle range, with indicators between 0.3 and 0.4. Overall, their results are good, but there is room for improvement. At the bottom of the ranking are Sierra Leone, the Democratic Republic of Congo, Chad, and Niger, with indicators above 0.45. These countries perform poorly on most fronts, revealing structural deficiencies in the public sector. According to the African Development Bank ([Outlook, 2021](#)), their poor performance can be attributed to chronic underinvestment in essential public services such as health and education, as well as poor governance. These gaps in public sector performance have a direct impact on human development in Africa. Countries with poor public services lag significantly behind in terms of life expectancy, education levels, and per capita income.

Moreover, Figure 6 shows that resource-rich countries have the lowest average values. Rent-seeking appears to be detrimental to the quality of public policies.

5.3 Efficiency of public spending (PSE)

An analysis of the average total public sector efficiency scores for African countries (Figure 7) shows that there are significant variations between countries in terms of the effectiveness with which public spending translates into tangible results in terms of health,

FIGURE 6 – Average composite public sector performance indicator by natural resource wealth

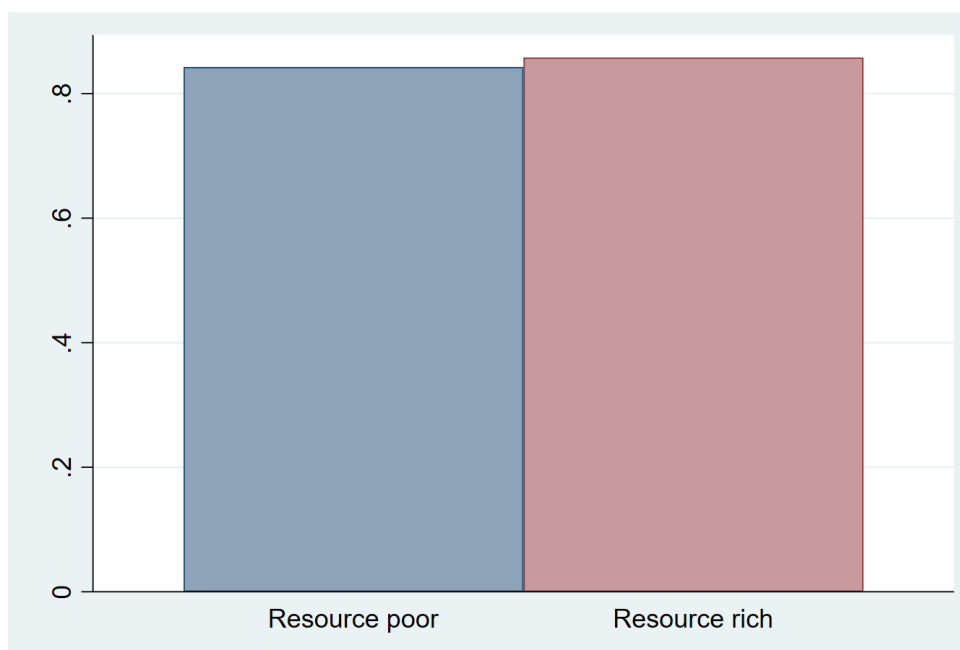


Source : Author's construction

education, infrastructure, etc. The top-performing countries are Sierra Leone (0.9559), Mali (0.9475), Niger (0.9400), Lesotho (0.9381), Chad (0.9359), Seychelles (0.9299) and Ethiopia (0.9244) with scores above 0.92. Despite limited resources, these countries manage to maximize the impact of their public spending. According to [Zeufack et al. \(2021\)](#), these high performances can be attributed to budgetary and financial reforms that have improved public finance management. Indeed, the report highlights in particular Ethiopia's progress in multi-year investment planning, wage bill management and performance audits ([Bank, 2020](#)). [IMF \(2018\)](#) also highlights the strengthening of budgetary institutions in Mali since 2013, with the adoption of tax rules, a performance-based remuneration policy for civil servants and a public finance transparency code. Middle-income countries such as South Africa (0.8954), Botswana (0.8905), and Namibia (0.9070) are in the upper-middle range, with scores between 0.89 and 0.91. Their public spending generates satisfactory results, but there is room for improvement. [Fall \(2022\)](#) highlights that South Africa could enhance its spending efficiency by strengthening governance and combating corruption.

At the bottom of the ranking are Algeria (0.6052), Comoros (0.6384), and Mauritania (0.7008), with scores below 0.71. The effectiveness of their public policies appears inadequate relative to the resources mobilized. [IMF \(2023\)](#) highlights the governance challenges and the need for structural reforms in Algeria to improve public spending efficiency. Interestingly, some resource-rich countries, such as Angola (0.9122) and Gabon (0.8070), show contrasting levels of efficiency. This could be explained by differences in rent management

FIGURE 7 – Average public sector efficiency score by natural resource wealth over the period 1998-2018.



Source : Author's construction

and governance quality. [NRGI \(2021\)](#) emphasizes the importance of transparency and accountability in managing natural resource revenues to improve public spending efficiency. Looking at [Figure 7](#), we can say that although a comparison of efficiency averages between resource-rich and non-resource-rich countries might suggest a moderate gap, a more detailed analysis reveals significant disparities within each group.

6 Data and descriptive statistics

Our study looks at the effectiveness of public spending in 44 African countries between 1998 and 2018. This broad sample makes it possible to analyse the dynamics at work across the continent, including countries at different levels of development. Many African economies are heavily dependent on commodity exports and are therefore vulnerable to fluctuations in world prices. Analysing different national contexts sheds light on the repercussions of this dependence on public finances.

The period 1998-2018 offers a perspective over 21 years, i.e. two full decades. This is long enough to identify long-term trends ([Collier and Goderis \(2012\)](#)). What's more, these years include periods of major price instability, such as in the 2000s, when their peak caused destabilising effects in Africa ([Guillaumont Jeanneney and Hua \(2015\)](#)). Starting the analysis in 1998 is justified by the improved availability and reliability of macroeconomic data from the 1990s in sub-Saharan Africa ([Jerven and Johnston \(2015\)](#)). Obtaining longer time series was not possible given the concern to balance our panel

dataset.

In this study, our dependent variable is represented by the efficiency scores calculated above, which have values between 0 and 1. Our independent variable is the country-specific CTOT (Commodity Terms of Trade) volatility, which we refer to as commodity price volatility. This index captures the exceptional gains and losses linked to fluctuations in the world prices of exported commodities. CTOT is calculated by weighting the price variations of a basket of 45 commodities, using national trade data (Gruss and Kebhaj (2019)). The weight of each product in the basket depends on the share of net exports of that product in national production. Thus, a rise (or fall) in CTOT indicates an increase (or decrease) in export earnings for commodities, reflecting gains (or losses) in terms of income for the country. The CTOT data come from the IMF's World Economic Outlook (2019). We assume that CTOT is exogenous for African countries, which do not significantly influence world prices given their small share in exports (Katoka and Dostal (2022); Gruss and Kebhaj (2019); Ferraro and Peretto (2018)).

To estimate the volatility of commodity prices, we use the standard deviation of the cyclical component of prices over 5-year sub-periods, a method also used by Combes and Ebeke (2011) and Apeti (2023). This approach makes it possible to capture medium-term fluctuations by filtering out short-term variations. In concrete terms, the volatility of CTOT commodity prices for the country in the year is calculated as follows :

$$CTOTvolatility_{it} = \sqrt{\frac{1}{5} \sum_{j=1}^5 (\varepsilon_{it} - \bar{\varepsilon}_{it})^2}$$

Where ε_{it} represents the cyclical component of estimated prices and $\bar{\varepsilon}_{it}$ the average of ε_{it} over the 5-year sub-period. The term $(\varepsilon_{it} - \bar{\varepsilon}_{it})$ thus captures the deviation from the trend over the period, the square root of the mean of the squares of which is taken to obtain the standard deviation as a measure of volatility. This sub-period approach makes it possible to take into account changes in commodity price volatility over time, unlike a measure over the entire period, which would be static (Arezki et al. (2014)).

6.1 Control variables

The efficiency of public spending, particularly in African countries, can be influenced by various macroeconomic, institutional, and structural variables. Among these, natural gas rents can have an ambivalent impact. Specifically, these are defined as the difference between the value of natural gas production at world prices and total production costs. The impact of such rents can be twofold. On one hand, these additional revenues can allow governments to increase productive investments and social spending, potentially improving spending efficiency (Ross, 2015). On the other hand, however, the phenomenon of the "resource curse" can lead to poor governance and reduce spending efficiency (Venables, 2016). Furthermore, the level of corruption control is also a key factor. This

variable measures the perception of the extent to which public power is used for private gain. Consequently, a low-corruption environment promotes better resource allocation and transparent use of public funds, thus increasing spending efficiency [Bosco \(2016\)](#). Conversely, corruption diverts spending towards private interests and distorts investment priorities, thereby reducing efficiency ([Cooray and Dzhumashev, 2018](#)). In addition, external debt, which represents debt owed to non-resident creditors repayable in foreign currency, plays a significant role. It can have negative effects if it becomes too burdensome, constraining productive spending in favor of debt service, thus reducing efficiency ([Presbitero, 2016](#)). Nevertheless, moderate indebtedness can finance profitable investments when domestic resources are insufficient, potentially improving efficiency ([Eberhardt and Presbitero, 2015](#)). Moreover, government effectiveness, which reflects the quality of public services, the competence of the administration, and its independence from political pressures, is crucial. A competent administration ensures better planning and execution of spending programs, thereby increasing efficiency ([Afonso et al., 2021](#)). Conversely, an inefficient bureaucracy leads to waste and poor service delivery, thus reducing efficiency ([Baum et al., 2017](#); [Chugunov and Markuts, 2019](#)). Additionally, skilled labor, generally measured by the enrollment rate in higher education, is an important factor. It can promote optimal use of public investments, improving their efficiency. However, an unskilled workforce can compromise these benefits ([Hanushek and Woessmann, 2023](#)). Inflation, measured by the annual variation in the consumer price index, also impacts spending efficiency. High inflation can reduce the real value of spending, thereby decreasing its efficiency ([Ha et al., 2019](#)). Nonetheless, a moderate rate can sometimes reflect sustained demand and be favorable to the impact of spending ([Vinayagathan, 2013](#)). Furthermore, political stability and absence of violence, which measures the likelihood of destabilization or overthrow of the government by unconstitutional or violent means, is a critical factor. Political stability encourages consistent implementation of long-term programs, thus increasing spending efficiency ([Aisen and Veiga, 2013](#)). In contrast, conflicts can divert resources towards security at the expense of other sectors, consequently reducing efficiency ([Mueller and Tobias, 2016](#)). Lastly, the exchange rate, generally measured by the real effective exchange rate, plays a significant role. It influences the costs of imports necessary for investments and can affect exports, public revenues, and the attractiveness of projects to foreign investors. As a result, a stable or slightly undervalued exchange rate can promote competitiveness and efficiency of public spending, while overvaluation can have the opposite effect ([Rodrik, 2008](#); [Habib et al., 2017](#)).

TABLE 1 – Summary Statistics of variables.

Variable	Obs	Mean	Std. dev.	Min	Max
Public Sector Efficiency	592	0.850	0.080	0.605	0.956
Log of CTOT volatility	742	4.601	0.094	3.865	4.780
Natural gas rents (% of GDP)	892	0.165	0.698	0	6.773
Corruption control	836	-0.535	0.600	-1.597	1.245
log of external debt	882	21.764	1.393	18.369	25.603
Government effectiveness	834	-0.655	0.612	-1.879	1.150
log of labour force	903	14.889	1.437	11.676	17.782
inflation	924	8.327	28.395	-14.401	550
polity2	903	1.847	5.238	-7	10
log of exchange rate	924	4.840	2.317	-1.116	9.459

6.2 Descriptive statistics

7 Results

The main objective of this study is to deeply analyze the effects of commodity price volatility on the efficiency of public expenditures in a representative sample of 44 African countries. The results of econometric estimations are presented in detail in table 2. The primary goal is to rigorously assess the significant impact of global commodity price volatility, a macroeconomic phenomenon of crucial importance for many African countries, on a strategic variable of public finances, namely the efficiency of public expenditures.

The coefficient associated with the logarithm of commodity terms of trade volatility is negative and statistically highly significant at the 1% level (-1.535, $p=0.002$). This negative and significant coefficient confirms the conclusions of previous studies on the negative impact of high dependence on commodity exports on the efficiency of public expenditures. Specifically, the negative coefficient of -1.535 indicates that a 1% increase in commodity price volatility is associated with a substantial decrease of 0.015 points in the total public expenditure efficiency index, holding all other variables constant. This detrimental effect is explained by the high volatility of basic commodity prices, which disrupts medium/long-term budgeting and planning.

The coefficient associated with natural gas rents as a percentage of GDP is negative and highly significant (-0.424, $p<0.001$). This indicates that a one percentage point increase in the share of gas rents in GDP is associated with a very robust decrease of 0.424 points in the total public expenditure efficiency index, all else being equal. This result corroborates the analysis of Arezki and Ismail (2013), which generally found that prosperous periods

for natural resources such as gas tend to significantly reduce the efficiency of public expenditures. Conversely, the coefficient on the estimation of government effectiveness is positive and significant at the 5% level (0.192, $p=0.027$). This means that a one-point increase in this governance indicator is robustly associated with a 0.192-point increase in the efficiency index of expenditures, consistent with the findings of Hauner and Kyobe (2010). The quality of public institutions and governance thus appears to be a key factor in significantly increasing the efficiency of public expenditures.

TABLE 2 – Effects of commodities prices volatility on the efficiency of public spending in African countries

Variables	Baseline	Std. Err.
Log of CTOT volatility	-1.534 ^{***}	0.505
Natural gas rents (% of GDP)	-0.424 ^{***}	0.0338
Corruption control	0.0320	0.0842
Log of external debt	-0.0229	0.0297
Government effectiveness	0.192 ^{**}	0.0869
Log labour force	0.108 ^{***}	0.0267
Inflation	0.0139 ^{***}	0.00499
Polity2	0.0172 ^{***}	0.00574
Log of exchange rate	0.0290 ^{**}	0.0139
Constant	7.578 ^{***}	2.499
Observations	498	

Note : Estimation method : fractional logistic regression. The dependent variable is the technical efficiency score estimated in the table.

Counterintuitively, the coefficient on inflation is positive and statistically significant (0.014, $p=0.005$). This suggests that a one percentage point increase in the inflation rate is associated with a 0.014-point increase in the total public expenditure efficiency index, all else being equal. This result contradicts some previous studies like Herrera and Ouedraogo (2018) which highlighted the adverse effects of a high and unstable inflation environment on expenditure efficiency. Similarly, the coefficient on the logarithm of the exchange rate is positive and significant (0.029, $p=0.037$), indicating that a 1% depreciation of the nominal exchange rate is associated with a 0.029-point increase in efficiency index. Although counterintuitive, this result could be explained by the benefits of price competitiveness accruing to the export sector following depreciation.

In contrast, the coefficients associated with the size of the active population (\log_labor_force) and the score on the Political Stability/Absence of Violence index

(polity2) are positive and highly significant, consistent with theoretical predictions. Specifically, a 1% increase in the active population leads to a robust increase of 0.108 points in the efficiency index ($p < 0.001$). And a one-point higher score on the polity2 index of political stability/absence of violence is associated with a gain of 0.017 points ($p = 0.003$), highlighting the benefits of a more stable and peaceful political environment for expenditure efficiency.

Thus, although inflation and exchange rate depreciation paradoxically appear to be associated with greater efficiency of public expenditures in this sample, the positive and highly robust effects of a large active population and better political stability on efficiency are consistent with established economic theory. In fact, counterintuitively, the results indicate that higher inflation and exchange rate depreciation are linked to an increase in the efficiency index of public expenditures. This goes against what would normally be expected, as high inflation and depreciated currency are generally considered detrimental to sound public finance management. However, the estimations show very significant positive effects statistically for two other variables : the size of the active population and the level of political stability/absence of violence measured by the polity2 index. A larger active population indeed allows for better allocation of public resources in various productive sectors. And a peaceful political climate, free from violence and instability, is more conducive to effective management of long-term public investments. These two results - the beneficial effects of a large workforce and a stable environment - are consistent with predictions of traditional economic theory. They point towards better efficiency when basic conditions are met in terms of available human capital and institutional stability. The counterintuitive links with inflation and exchange rate, on the other hand, could be explained by sample specificities.

However, contrary to some expectations, control of corruption does not have a significant impact on efficiency according to these estimations. This could be explained by measurement issues or the fact that other institutional factors like political stability play a more determining role.

8 Robustness Checks

8.1 Alternative measure of efficiency scores

This section examines the robustness of the results by considering an alternative measure of the dependent variable. To do this, we consider the approach of [Greene \(2005b\)](#). Table 3 presents the results with the alternative measure in column [2], while column [1] reports those of the basic model. The base model estimates public expenditure efficiency scores according to [Kumbhakar et al. \(2014\)](#). In addition to accounting for unobserved heterogeneity across countries, this method decomposes inefficiency into persistent (long-

run) and transitory (short-run) components, requiring a two-stage estimation procedure. [Greene \(2005b\)](#) approach, while not allowing this decomposition, incorporates unobserved heterogeneity between countries and offers a one-stage specification, allowing greater econometric flexibility. In column [2] of Table 3, the outcome variable is regressed on the original sample, using [Greene \(2005b\)](#) approach to estimating efficiency scores. The results remain stable.

TABLE 3 – Effects of commodity price volatility on the efficiency of public spending in Africa with an alternative measure of efficiency.

	Kumbhakar(2014)		Green (2005a,b)	
	Coefficient	std. err.	Coefficient	std. err.
Log of CTOT volatility	-1.534***	0.505	-0.00490***	0.00150
Natural gas rents (% of GDP)	-0.424***	0.0338	-0.00114***	0.000116
Corruption control	0.0320	0.0842	-0.000104	0.000196
Log of external debt	-0.0229	0.0297	-0.000203**	8.15e-05
Government effectiveness	0.192**	0.0869	0.000984***	0.000206
Log labour force	0.108***	0.0267	0.000318***	7.03e-05
Inflation	0.0139***	0.00499	2.55e-05**	1.15e-05
Polity2	0.0172***	0.00574	3.64e-05***	1.31e-05
Log of exchange rate	0.0290**	0.0139	-3.03e-06	3.45e-05
Constant	7.578***	2.499	7.986***	0.00723
Observations	498		498	

8.2 Alternative estimation method

In order to estimate the impact of commodity price volatility on the efficiency of public spending, we use a fractional regression model on a panel of data from African countries over the period 1998-2018. Recent studies on similar issues have favoured it ([Gupta et al. \(2014\)](#); [Clements et al. \(2015\)](#)). This model is suitable for modelling a dependent variable, which takes values between 0 and 1 (the efficiency of public spending in our case). It uses logit and probit models to estimate the relationship between public spending efficiency and its determinants ([Ramalho et al. \(2010\)](#)). The regressions in our study were all carried out using a fractional logit model. To check the robustness of our basic model, we estimate it using a fractional probit regression that takes heteroscedasticity into account. The results are presented in Table 4.

TABLE 4 – Robustness of the results after using an alternative estimation method

Variables	Probit model	Std. Err.
log_xm_gdp5	-0.00490***	0.00150
NaturalgasrentsofGDPNY	-0.00114***	0.000116
ControlofCorruptionEstimate	-0.000104	0.000196
log_external_debt	-0.000203**	8.15e-05
GovernmentEffectivenessEstima	0.000984***	0.000206
log_labor_force	0.000318***	7.03e-05
inflation	2.55e-05**	1.15e-05
polity2	3.64e-05***	1.31e-05
log_exch_rate	-3.03e-06	3.45e-05
Constant	7.986***	0.00723
Observations	498	

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

8.3 Additional controls

The main model is also extended by including additional covariates. In columns [1]-[9] of Table 5, we complement our main specification with the following variables : GDP growth (annual %), Total natural resources rents (% of GDP), age dependency ratio, regulatory quality, Political Stability and Absence of Violence/Terrorism, democracy (democ), Climatic vulnerability score, financial openness (kaopen), Domestic credit to private sector by banks (% of GDP). This enrichment of the basic specification aims to control for additional factors that could affect the relationship between commodity price volatility and the effectiveness of public spending in African countries. In particular, the inclusion of political-institutional variables makes it possible to take account of the institutional environment. The results suggest that the negative impact of price volatility is a robust result.

TABLE 5 – Robustness with the addition of relevant controls

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Log of CTOT volatility	-1.485*** (0.503)	-1.178** (0.585)	-1.406* (0.735)	-1.350* (0.705)	-1.405** (0.704)	-1.426** (0.717)	-1.538** (0.735)	-1.659** (0.746)	-2.094*** (0.717)
GDP growth annual	0.00541 (0.00581)	0.00414 (0.00588)	7.23e-05 (0.00640)	-0.000518 (0.00632)	0.000268 (0.00612)	-0.000202 (0.00633)	-0.00280 (0.00594)	-0.00300 (0.00605)	-0.00789 (0.00622)
Total natural resources rents		0.00439 (0.00399)	0.000392 (0.00433)	-0.000862 (0.00432)	-0.000602 (0.00448)	-0.000691 (0.00454)	0.00115 (0.00450)	-0.00122 (0.00471)	-0.00196 (0.00444)
Age dependency ratio			2.668*** (0.302)	2.689*** (0.306)	2.719*** (0.305)	2.728*** (0.304)	1.776*** (0.408)	1.828*** (0.400)	1.437*** (0.413)
Regulatory quality				-1.649*** (0.609)	-1.492** (0.622)	-1.476** (0.628)	-1.655*** (0.627)	-1.347* (0.758)	-0.152 (0.725)
Political stability					-0.0713 (0.0479)	-0.0793* (0.0462)	-0.0417 (0.0468)	-0.0467 (0.0487)	-0.0661 (0.0477)
Democracy						0.000693 (0.00171)	0.000238 (0.00161)	0.000391 (0.00173)	0.000589 (0.00159)
Climatic vulnerability score							2.413*** (0.768)	2.433*** (0.801)	2.118*** (0.789)
Financial openness								-0.0757*** (0.0219)	-0.0871*** (0.0210)
Log of domestic credit									-0.224*** (0.0608)
Constant	7.356*** (2.491)	5.940** (2.834)	5.261 (3.555)	5.472 (3.351)	5.809* (3.346)	5.868* (3.383)	5.246 (3.392)	5.975* (3.521)	8.922*** (3.452)
Observations	497	497	449	449	449	449	449	435	426
Robust standard errors in parentheses : *** p<0.01, ** p<0.05, * p<0.1									

9 Heterogeneity

The effect of commodity price volatility on the efficiency of public spending is likely to vary according to certain characteristics of African countries. This section examines the heterogeneity associated with the size of the economy, natural resource wealth and the presence of sovereign wealth funds. Large economies can be expected to have a greater capacity to absorb price shocks through diversification; countries rich in oil, gas and mining are more exposed to volatility. Finally, sovereign wealth funds help to smooth resource revenues and can mitigate the effects of volatility on public finances.

9.1 Economy size

Here, following [Sawadogo \(2020\)](#), we distinguish between small and large economies using a dichotomous variable based on country GDP. This variable takes the value 1 for countries whose GDP is below the sample average, and 0 otherwise. The aim is to examine the heterogeneity of results between these two groups with different economic structures ([Table 6](#)). By analysing the separate regressions for rich (column 1) and poor (column 2) countries, we note striking differences in the differential impact of shocks according to country size. Firstly, price volatility ($\log CTOT$) has a negative and marginally significant impact (at the 10% threshold) on the effectiveness of public spending in poor countries, but not in rich countries. An increase in volatility reduces efficiency by 0.68 percentage points in poor countries. This can be explained by their lower diversification and macroeconomic resilience to external shocks, as shown by [Haddad et al. \(2013\)](#). Secondly, gas rents penalise rich countries more, with a coefficient of -0.33 compared with -0.28 (insignificant) for poor countries. The concentration of exports on gas increases the vulnerability of large economies, a result consistent with [Van der Ploeg and Venables \(2011\)](#) analysis of the natural resource curse. Furthermore, the control of corruption has an opposite impact on the efficiency of public spending between the two groups of countries. Better control of corruption significantly improves efficiency in rich countries (+0.28) but worsens it in poor countries (-0.24). In addition, government effectiveness significantly improves the efficiency of public spending in both rich countries (+0.19 at the 5% threshold) and poor countries (+0.18 at the 10% threshold). Administrative capacity and the quality of public management therefore appear to be crucial, whatever the country's level of development. Finally, a more favourable working population and political regime increase efficiency only in poor countries. However, inflation and a stronger currency improve spending efficiency more in rich countries, which could be explained by their greater monetary credibility, as suggested by [Aisen and Veiga \(2013\)](#).

TABLE 6 – Heterogeneous effect of variables on the efficiency of public spending according to country size.

Variables	[1]	[2]
Log CTOT volatility	-0.683* (0.350)	-0.171 (0.809)
Natural gas rents	-0.282 (0.202)	-0.334*** (0.0637)
Corruption control	-0.239*** (0.0891)	0.280*** (0.0928)
Log of external debt	0.0272 (0.0427)	0.0293 (0.0578)
Gouvernment effectiveness	0.177* (0.106)	0.191** (0.0927)
Log of Labour force	0.209*** (0.0373)	-0.0284 (0.0577)
Inflation	-0.00353 (0.00590)	0.0560*** (0.0124)
Polity2	0.0193*** (0.00561)	0.00282 (0.00592)
Log of exchange rate	-0.0958*** (0.0166)	0.144*** (0.0207)
Constant	1.707 (1.883)	1.585 (3.796)
Observations	339	159
Robust standard deviations in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Poor countries [1], Rich countries [2]		

9.2 Resource rich

The results in Table 7 highlight significant disparities in the determinants of public spending efficiency between resource-rich and resource-poor African countries.

Firstly, the volatility of commodity prices, measured by the logarithm of the CTOT index, has a negative and statistically significant impact on the efficiency of public spending in both groups of countries. However, this effect is more marked for resource-poor countries, suggesting that these economies are more vulnerable to the volatility of world prices. A 10% increase in price volatility would lead to a reduction of around 27% in the effectiveness of public spending in resource-poor countries (Coefficient = -2.70, $p < 0.01$), compared with 9% in rich countries (Coefficient = -0.91, $p < 0.01$). This difference could be attributed to less diversification of budget revenues and greater sensitivity to fluctuations in world prices in economies less well endowed with natural resources. Second, gas rents, expressed as a percentage of GDP, have a significant negative impact on the efficiency of public spending in both groups of countries, but the impact is more pronounced for resource-poor countries (Coefficient = -0.88, $p < 0.01$). This suggests additional challenges for these economies in allocating resource revenues efficiently.

Third, controlling corruption has a significant effect on the efficiency of public spending, but in opposite ways across country groups. While in resource-rich countries better control of corruption appears to reduce the efficiency of public spending (Coefficient = -0.57, $p < 0.01$), in resource-poor countries it improves this efficiency (Coefficient = 0.42, $p < 0.01$). This dynamic could reflect differences in the way corruption interferes with governance and the use of public resources in these specific contexts.

In addition, factors such as an efficient public administration (Coefficient = 0.31, $p < 0.05$), an active labour force (Coefficient = 0.26 for rich countries, 0.11 for poor countries, $p < 0.05$), moderate inflation (Coefficient = 0.015, $p < 0.05$) and a stable political environment (Coefficient = 0.049, $p < 0.05$) have differential effects on the efficiency of public spending depending on countries' natural resource endowments. These results underline the importance of differentiated strategies to improve the efficiency of public spending in Africa, taking into account the economic and institutional specificities of each group of countries.

In conclusion, these findings highlight the need for appropriate policy and institutional approaches to optimise the use of public resources in African countries, particularly with regard to the management of natural resource revenues and the fight against corruption.

9.3 Sovereign wealth funds (SWFs)

The analysis of heterogeneity (Table 8) according to whether or not a country has a sovereign wealth fund reveals contrasting results regarding the impact of commodity price volatility on the effectiveness of public spending in African countries.

TABLE 7 – Results of heterogeneity according to natural resource wealth.

	(1)	(2)
VARIABLES		
Log CTOT volatility	-0.915*** (0.276)	-2.702** (1.050)
Natural gas rents	-0.499*** (0.0331)	-0.878** (0.355)
Corruption control	-0.567*** (0.0953)	0.422*** (0.0984)
Log external debt	-0.0407 (0.0310)	-0.0565 (0.0512)
Government effectiveness	0.314** (0.135)	0.140 (0.110)
Log of labour force	0.257*** (0.0330)	0.107** (0.0448)
Inflation	0.0147*** (0.00447)	0.000932 (0.00920)
Polity2	0.0485*** (0.00490)	-0.00257 (0.00764)
Log exchange rate	0.0226* (0.0130)	0.0601*** (0.0160)
Constant	2.613* (1.491)	13.82*** (4.930)
Observations	227	271
Robust standard errors		
*** p<0.01, ** p<0.05, * p<0.1		

Note : Column [1] shows the results of the estimate based on the country being rich in natural resources, while column 2 shows the results of the estimate based on the country not being rich in natural resources.

For countries with sovereign wealth funds, the estimated coefficient of -0.7639 for \log_CTOT is not statistically significant, suggesting that price volatility does not significantly affect the efficiency of public spending in these countries. However, the natural gas rent ($NaturalgasrentsofGDPNY$) has a significant negative effect, with a coefficient of -0.3164 (significant at the 1% level).

TABLE 8 – Impact of commodity price volatility on the efficiency of public spending according to sovereign wealth fund holdings.

VARIABLES	(1)	(2)
Log of CTOT	-0.764 (0.721)	-1.796*** (0.657)
Natural gas rents	-0.316*** (0.0876)	-0.286*** (0.0574)
Corruption control	0.156 (0.223)	0.00507 (0.0921)
Log external debt	0.114 (0.0723)	-0.0439 (0.0413)
Government effectiveness	0.215 (0.227)	0.217** (0.0964)
Log labor force	0.0205 (0.0800)	0.0942*** (0.0330)
Inflation	0.0448*** (0.00682)	0.00992* (0.00541)
Polity2	0.0357 (0.0217)	0.0172*** (0.00615)
Log of exchange rate	0.0442* (0.0262)	0.0352** (0.0145)
Constant	1.880 (3.453)	9.427*** (3.249)
Observations	70	428
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Note : Column [1] shows the results of the estimate according to whether the country has a sovereign wealth fund, while column [2] shows the results of the estimate according to whether the country does not.

Conversely, for countries without sovereign wealth funds, price volatility has a negative and highly significant impact on the effectiveness of public spending. The estimated coefficient of -1.7956, statistically significant at the 1% level, implies that a one-point

increase in this volatility is associated with a 1.7956-point drop in the effectiveness of spending. This high degree of vulnerability illustrates the phenomenon of the 'natural resource curse', where the abundance of these resources can paradoxically hamper economic development in the absence of adequate mitigation mechanisms. These results reveal a striking contrast. While holding a sovereign wealth fund seems to protect countries from the negative impact of commodity price volatility on the efficiency of public spending, countries without such funds appear to be highly vulnerable to this volatility. This highlights the crucial importance of SWFs as instruments for smoothing price fluctuations and mitigating the 'Dutch disease' syndrome, where a sudden influx of foreign currency linked to the exploitation of natural resources can lead to an appreciation of the real exchange rate and a loss of competitiveness in other sectors. However, the presence of a sovereign wealth fund does not prevent the damaging effect of over-dependence on rents from natural gas resources on the efficiency of public spending. This raises questions about the governance and effective use of these funds in the management of revenues from natural resources, and their ability to truly counter the harmful effects of an economy overly dependent on revenues from raw materials. In addition to these commodity-related factors, other macroeconomic and institutional variables have a significant impact. The inflation rate has a positive effect on the efficiency of public spending, both for countries with and without SWFs. This counter-intuitive result can be explained by the fact that, in an inflationary context, governments have an incentive to allocate their spending more efficiently in order to preserve purchasing power. In addition, a moderate level of inflation can stimulate economic growth and thus improve the collection of public revenues, allowing for a better allocation. In addition, for countries without sovereign wealth funds, two key institutional factors positively influence the efficiency of public spending. On the one hand, government efficiency has a significant positive impact, with an estimated coefficient of 0.2171 (significant at the 5% level). This implies that a one-point improvement in the government efficiency index is associated with a 0.2171-point increase in the efficiency of public spending. On the other hand, the level of democracy (polity2) also exerts a significant positive effect, with an estimated coefficient of 0.0172 (significant at the 1% level) indicating that a more democratic regime tends to favour more efficient public spending. These results highlight the crucial importance of the quality of institutions and governance for the optimal allocation of public resources, particularly for countries that do not benefit from the presence of a sovereign wealth fund to cushion external shocks. Effective government and democratic decision-making processes appear to facilitate more judicious management of public spending in the absence of such mitigation mechanisms.

In sum, the analysis confirms the central role played by sovereign wealth funds in mitigating the negative impact of commodity price volatility on the effectiveness of public spending in African countries. However, it also highlights the persistent challenges posed by over-dependence on natural resource rents, even when a SWFs is present. Furthermore,

these results reinforce the crucial importance of macroeconomic factors such as inflation control, as well as strong governance institutions and effective democracy, for the optimal use of public resources and sustainable economic development, whether or not countries have a SWFs.

10 Transmission channels

All econometric analyzes carried out previously highlight a marked and robust negative impact of the volatility of world commodity prices on the effectiveness of public spending in African countries. This finding remains consistent whether we consider the main model presented in Table 1 or whether we make distinctions according to natural resource wealth, the size of the economy or the holding of sovereign wealth funds. In all cases, volatility significantly reduces the efficient allocation of public resources in economies that are vulnerable to erratic price fluctuations. However, beyond this direct deleterious effect, this section identifies the indirect transmission channels through which volatility impacts public spending. In particular, mediation tests highlight the role of three factors as potential channels responsible for the negative impact of volatile commodity prices : the reduction in the available labor force, the weakening of democratic institutions, .

By considering democracy (polity2) as a potential mediator, the results in table 9 are particularly interesting. There is a positive indirect effect (mediation) that is statistically significant at the 5% level (coefficient = 0.019). This suggests that greater commodity price volatility is associated with a higher level of democracy in the countries studied. And this greater democracy then tends to improve the efficiency of public spending. This result can be explained by the fact that the positive income shocks generated by volatility create an additional 'rent' that interest groups are encouraged to compete for. This heightened competition for resources tends to encourage the emergence of checks and balances and demands for transparency and democratic control on the part of civil society, to prevent the capture of resources by a narrow elite. A more democratic environment, with greater civil liberties and institutional controls, would ultimately lead to better allocation and management of public spending. However, despite this positive indirect effect of democracy, the direct effect of price volatility on efficiency, once controlled for the level of democracy, remains negative and highly significant at the 1% level (coefficient = -0.185). This direct effect probably captures the unfavourable impacts of macroeconomic instability and harmful external shocks induced by volatility. The total effect combining the direct and indirect effects is therefore ultimately negative and statistically significant at 5% (coefficient = -0.166). Despite the positive channel through democracy, the deleterious effect of macro instability prevails overall.

With inflation as a potential mediator, we still obtain results (table 10) that highlight a harmful transmission channel from commodity price volatility to the effectiveness of public

TABLE 9 – IV mediation with Polity2

Variables	Coefficient	Std. Err.	z	$P > z $	[95% <i>Conf.Interval</i>]
<code>_bs_1</code>	0.019**	0.009	2.20	0.028	0.002 - 0.037
<code>_bs_2</code>	-0.185***	0.065	-2.85	0.004	-0.313 - -0.058
<code>_bs_3</code>	-0.166**	0.065	-2.56	0.010	-0.292 - -0.039

Note : `_bs_1` (indirect effect), `_bs_2` (direct effect) and `_bs_3` (total effect)

spending. The indirect effect (mediation) is negative and statistically significant at the 10% level (coefficient = -0.020). This indicates that greater volatility in commodity prices tends to be associated with higher levels of inflation in the countries studied. And this higher inflation, in turn, worsens the efficiency with which public spending is allocated and used. This result can be explained by the fact that the positive income shocks generated by price peaks tend to fuel inflationary pressures through a demand effect. Furthermore, the macroeconomic uncertainty and instability induced by price volatility complicate the conduct of effective countercyclical monetary policies to curb inflation. High inflation erodes purchasing power, distorts relative prices and undermines predictability, having a negative impact on the quality of public budget management. Beyond this harmful indirect effect via inflation, the direct effect of price volatility on the effectiveness of spending, once inflation is controlled, remains robust, negative and highly significant at the 1% threshold (coefficient = -0.185). This direct effect probably captures other unfavourable channels such as overall macroeconomic instability. Thus, the total effect combining the direct and indirect effects is negative and highly statistically significant (coefficient = -0.206). The inflation transmission mechanism considerably amplifies the adverse effects of price volatility on the efficiency of public spending.

TABLE 10 – IV mediation with inflation

Variables	Coefficient	Std. Err.	z	$P > z $	[95% <i>Conf.Interval</i>]
<code>_bs_1</code>	-0.020*	0.012	-1.66	0.098	-0.045 - 0.004
<code>_bs_2</code>	-0.185***	0.063	-2.95	0.003	-0.308 - -0.062
<code>_bs_3</code>	-0.206***	0.066	-3.12	0.002	-0.335 - -0.077

Note : `_bs_1` (indirect effect), `_bs_2` (direct effect) and `_bs_3` (total effect)

Taking labour force as a potential mediator, the results in table 11 show a positive indirect effect that is statistically significant at the 1% level (coefficient = 0.051). This suggests that higher levels of commodity price volatility are associated with a larger workforce in the countries studied. And this increased workforce then tends to improve the efficiency with which public spending is allocated and used. This result can be explained

by the fact that the positive income shocks generated by commodity price rises stimulate economic activity and create employment opportunities, attracting more labour. A larger workforce can then enable better implementation of public investment projects and spending programmes. Human resources are a key factor in effective public management. However, despite this positive indirect effect via the workforce, the negative direct effect of price volatility on spending efficiency, once the workforce is controlled for, remains very robust and significant at the 1% level (coefficient = -0.185). This unfavourable direct effect probably captures other harmful channels such as the overall macroeconomic instability induced by volatility. In the end, the total effect combining the direct and indirect effects remains negative and statistically significant at the 5% level (coefficient = -0.134). Although the transmission channel through labour is beneficial, it does not fully compensate for the direct negative impacts of price instability on public expenditure management.

TABLE 11 – IV mediation with labour force

Variables	Coefficient	Std. Err.	z	$P > z $	[95% <i>Conf.Interval</i>]
<code>_bs_1</code>	0.051***	0.018	2.78	0.006	0.015 - 0.087
<code>_bs_2</code>	-0.185***	0.065	-2.85	0.004	-0.313 - -0.058
<code>_bs_3</code>	-0.134**	0.060	-2.25	0.024	-0.251 - -0.017

Note : `_bs_1` (indirect effect), `_bs_2` (direct effect) and `_bs_3` (total effect)

We also examine the potential role of income inequality, measured by the Gini coefficient, as a transmission mechanism for the effect of commodity price volatility on the efficiency of public spending. The results (table 12) show a negative indirect effect (mediation) that is statistically significant at the 5% level (coefficient = -0.029). This indicates that greater price volatility tends to be associated with higher levels of income inequality. And these higher inequalities, in turn, deteriorate the efficiency with which public spending is allocated and used. This suggests that positive income shocks from price rises disproportionately benefit the richest segments of the population, exacerbating inequality. High levels of inequality can then undermine efficiency through a number of channels : divergent social demands, elite capture of resources, socio-political tensions, and so on. Beyond this adverse indirect effect via the inequality channel, the negative direct effect of volatility on efficiency, once inequality has been controlled for, remains very robust and significant at the 1% level (coefficient = -0.177). The total effect combining the direct and indirect effects is therefore negative and highly significant (coefficient = -0.206). The transmission mechanism through income inequality considerably amplifies the harmful effects of price volatility on the efficient management of public spending. These results highlight an additional channel through which price volatility can cause harm, by fueling inequalities that act as a brake on the efficiency of public policies. This highlights

the importance of putting in place institutional mechanisms that allow the benefits of commodity price rises to be redistributed fairly.

TABLE 12 – IV mediation with gini indicator

Variables	Coefficient	Std. Err.	z	$P > z $	[95% <i>Conf.Interval</i>]
_bs_1	-0.029**	0.013	-2.22	0.026	-0.054 - -0.003
_bs_2	-0.177***	0.069	-2.57	0.010	-0.312 - -0.042
_bs_3	-0.206***	0.073	-2.83	0.005	-0.348 - -0.063

Note : _bs_1 (indirect effect), _bs_2 (direct effect) and _bs_3 (total effect)

These analyses show that in African countries, commodity price volatility appears to be a key factor impacting the efficiency of public expenditure management, through a variety of often contradictory forces. While some channels, such as democracy and labour, appear to play a positive role, others, such as inflation and inequality, have a very negative impact. And the direct effect of macroeconomic instability associated with volatility predominates, exerting significant downward pressure on the efficiency of public management. This analysis calls for institutional mechanisms and public policies to be put in place to mitigate the unfavourable consequences of volatility (fighting inflation, redistributing rents fairly, stabilising the macroeconomic environment) while strengthening the virtuous channels such as democracy and the development of human resources.

11 Conclusions and policy implications

The objective of this study was to analyze the effects of commodity price volatility on the efficiency of public expenditure in a sample of 44 African countries over the period 1998-2018. Econometric estimations show that a 1% increase in commodity terms of trade volatility is associated with a 1.5-point decrease in the index of public expenditure efficiency, all else being equal. This result is robust across different specifications. The analysis shows that small economies and countries rich in natural resources are most affected by erratic fluctuations in global prices. The lower the level of economic diversification, the more detrimental the effect of dependence. Similarly, dependence on gas revenues increases budgetary vulnerability. However, the significance of the working-age population, institutional quality, degree of democracy, and possession of sovereign wealth funds mitigate the adverse effects of commodity price instability. Mediation tests have identified four main transmission channels : the level of inequality through the Gini index, the proportion of the working-age population, inflation, and political stability/absence of violence. The potential decrease in efficiency is mediated through increased income inequality, reduced labor force, high inflation eroding purchasing power, and weakened political stability.

Furthermore, exacerbated inequalities undermine efficiency through divergent social demands, resource capture by elites, or socio-political tensions. These results underscore the dangers of many African countries' dependence on highly volatile commodities. Optimal allocation of public resources proves to be complex. Even though the magnitude of effects differs across national contexts, price volatility represents a structural challenge for the continent's development. Ultimately, transforming the "curse" of natural resources into an opportunity for sustainable development will be a formidable challenge. This study has several policy implications :

- Introducing counter-cyclical budgetary rules (precautionary savings, stabilization funds) seems essential to smooth commodity revenues and isolate public budgets from exogenous fluctuations. Chile and Norway demonstrate that prudent macroeconomic policies can mitigate destabilizing effects.
- Economic diversification, to reduce dependence on a few commodities for exports and public revenues, reduces vulnerability to global prices. Industrialization and high value-added services should be encouraged.
- In countries rich in natural resources, combating corruption and promoting pluralistic democratic institutions appear as essential levers to improve the quality of public policies. The capture of rents related to commodities must be limited.
- Developing human capital through education and training strengthens economic resilience. A skilled and flexible workforce facilitates adaptation to external shocks.
- Regional cooperation, through integrated markets and macroeconomic coordination, allows pooling resources to finance large infrastructure projects. A larger scale would favor counter-cyclical policies.
- Good governance and effective state institutions remain indispensable conditions for optimal use of public funds, especially in a volatile environment.

These various policies should contribute to building the resilience of African economies to chronic instability in global commodity prices, thereby preserving governments' ability to pursue effective public policies for development. The implications of this study highlight the magnitude of the challenge of gradually decoupling African growth from the rise in commodity prices, which remains unresolved.

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Appendix

A- Classification of Resource-Rich Countries

Classifying countries based on their natural resource wealth is a complex exercise that lacks consensus in the literature (Ross, 2015). Various approaches are used, notably based on the share of commodity exports in total exports or GDP (monétaire international, 2012), or on the share of the active population employed in extractive sectors (Sachs and Warner, 2001).

For our analysis, we adopted an approach inspired by the UNCTAD methodology (Ferdowsi, 2010), classifying commodity exports into three categories :

- **Hydrocarbons** : crude oil, natural gas, and refined petroleum products
- **Minerals** : iron, copper, gold, diamonds, uranium, and other metallic and non-metallic minerals
- **Agricultural products** : food products, beverages, agricultural raw materials

A country is considered resource-rich if at least one product from the hydrocarbons or minerals categories represents 25% or more of its total merchandise exports, on average over the period 1995-2019. This 25% threshold is commonly used in the literature (Venables, 2016).

The following formula was applied :

$$\text{Resource_Wealth}_i = 100 \times \frac{\text{NR_Exports}_i}{\text{Total_Exports}_i} \quad (9)$$

Where :

- Resource_Wealth_i is the ratio of natural resource exports to total exports for country i
- NR_Exports_i represents the value of exports of products from the hydrocarbons and minerals categories for country i
- Total_Exports_i represents the value of total merchandise exports for country i

This approach allows us to capture the relative dependence of economies on non-renewable natural resources, while taking into account the specificities of sub-Saharan Africa, where most countries are dependent on commodities to varying degrees (on Trade and Development, 2019).

B- Anderson's (2008) Method for Calculating Standardized Weighted Index

In this study, we used [Anderson \(2008\)](#) method to calculate the standardized weighted index. This method, which employs a Generalized Least Squares (GLS) approach, comprises several steps :

1. Selection of relevant indicators for the outcome under study.
2. Adjustment of signs so that the positive direction always indicates a better outcome.
3. Normalization of indicators by centering and converting them to effect sizes.
4. Construction of weights using the inverse of the covariance matrix of normalized indicators.
5. Calculation of the index as a weighted average of normalized indicators using GLS estimation.
6. Final normalization of the index to obtain a distribution with a mean of zero and a standard deviation of one in the reference group.

The normalization of indicators, the construction of weights, and the use of GLS estimation are crucial steps in this method.

- **Normalization of Indicators** Normalization is done by subtracting the mean of the indicator in the reference group, then dividing by the standard deviation of the reference group.
- **Construction of Weights** Weights are calculated from the inverse of the covariance matrix (Σ^{-1}) of normalized indicators. The weight of each indicator is the sum of the entries in its row in Σ^{-1} .
- **Calculation of the Final Index using GLS** The final index is calculated as a weighted average using GLS estimation. This approach accounts for the correlation structure among the indicators, providing an efficient estimator. The index s_i for each observation i is calculated according to the formula :

$$s_i = (1'\Sigma^{-1}1)^{-1}(1'\Sigma^{-1}ey_i)$$

where 1 is a column vector of 1s and ey_i is a column vector of all normalized outcomes for observation i . This formula represents an efficient GLS estimator.

- **Final Normalization** The final normalization of the index is done by subtracting the mean of the index in the reference group and dividing by the standard deviation of the reference group.

TABLE 13 – Resource-Rich Countries

Country	ISO Code
Algeria	DZA
Angola	AGO
Cameroon	CMR
Chad	TCD
Democratic Republic of Congo	COD
Egypt	EGY
Eritrea	ERI
Gabon	GAB
Ghana	GHA
Guinea	GIN
Mauritania	MRT
Namibia	NAM
Niger	NER
Republic of Congo	COG
Rwanda	RWA
Senegal	SEN
Sierra Leone	SLE
South Africa	ZAF
Tanzania	TZA
Togo	TGO
Zambia	ZMB

Note : Countries classified as resource-rich according to the method described in Appendix A.

TABLE 14 – African Countries with Sovereign Wealth Funds (SWFs)

Country	Year of Implementation	ISO Code
Angola	2012	AGO
Botswana	1998	BWA
Algeria	2000	DZA
Gabon	2012	GAB
Ghana	2012	GHA
Mauritania	2006	MRT
Senegal	2012	SEN
South Africa	1998	ZAF

Note : Countries listed have implemented Sovereign Wealth Funds as of the years indicated according [Yonga \(2012\)](#).

TABLE 15 – Average Public Spending Efficiency (PSE) Scores by Country : 1998-2018

Rank	Country	ISO	PSE score	Rank	Country	ISO	PSE score
1	Sierra Leone	SLE	0.9559	23	Cameroon	CMR	0.8577
2	Mali	MLI	0.9475	24	Côte d'Ivoire	CIV	0.8478
3	Niger	NER	0.9400	25	Burkina Faso	BFA	0.8449
4	Lesotho	LSO	0.9381	26	Republic of Congo	COG	0.8427
5	Chad	TCD	0.9359	27	Senegal	SEN	0.8380
6	Seychelles	SYC	0.9299	28	Guinea-Bissau	GNB	0.8294
7	Ethiopia	ETH	0.9245	29	Uganda	UGA	0.8277
8	Ghana	GHA	0.9152	30	The Gambia	GMB	0.8271
9	Guinea	GIN	0.9135	31	Madagascar	MDG	0.8201
10	Angola	AGO	0.9122	32	Gabon	GAB	0.8070
11	Zambia	ZMB	0.9113	33	Eritrea	ERI	0.7921
12	Namibia	NAM	0.9070	34	Rwanda	RWA	0.7855
13	Mauritius	MUS	0.9051	35	Egypt	EGY	0.7588
14	Kenya	KEN	0.8969	36	Tunisia	TUN	0.7489
15	Eswatini	SWZ	0.8957	37	Togo	TGO	0.7426
16	South Africa	ZAF	0.8954	38	Djibouti	DJI	0.7271
17	Cabo Verde	CPV	0.8927	39	El Salvador	SLV	0.7254
18	Botswana	BWA	0.8905	40	Burundi	BDI	0.7023
19	Tanzania	TZA	0.8832	41	Morocco	MAR	0.7011
20	Dem. Rep. of the Congo	COD	0.8778	42	Mauritania	MRT	0.7008
21	Central African Republic	CAF	0.8668	43	Comoros	COM	0.6384
22	Benin	BEN	0.8615	44	Algeria	DZA	0.6052

Note : By way of illustration, a score of 0.7 for a given country means that this country could, on average, improve its efficiency by 30% while maintaining the same level of resources to achieve the targets set. The closer the score is to 1, the higher the efficiency of the country's public spending.

TABLE 16 – Sources of variables for the calculation of efficiency scores

Variables	Nature	Sources
1. Public expenditures variables (Inputs) :		
Public spending on education (% of GDP)	Continuous	Public Expenditures for Economic Development (SPEED)
Public spending on health (% of GDP)	Continuous	SPEED
Total investment	Continuous	World Economic Outlook (WEO)
Public spending on final consumption (% of GDP)	Continuous	World Development Indicators (WDI)
Total public expenditure (% of GDP)	Continuous	WDI
2. Sectorial performance indices (outcomes)		
<i>Health :</i>		
• Under-5 mortality rate (per 1,000 live births)	Continuous	WDI
• Adolescent fertility rate (births per 1,000 women aged 15-19)	Continuous	WDI
• Maternal mortality ratio (per 100,000 live births)	Continuous	WDI
<i>Education :</i>		
• Secondary school enrolment	Continuous	WDI
• Quality of education system	Continuous	Global Competiveness Index (GCI)
<i>Infrastructure :</i>		
• Overall infrastructure quality indicator	Continuous	GCI
<i>Public Administration :</i>		
• Freedom of expression	Continuous	Teorell et al. (2021)
• Rule of law	Continuous	Teorell et al. (2021)
• Quality of regulation	Continuous	Teorell et al. (2021)
• Effectiveness of public authorities	Continuous	Teorell et al. (2021)
<i>Distribution :</i>		
• Gini index	Continuous	Standardized World Income Inequality Database (SWIID)
<i>Stability :</i>		
• Standard deviation of the five-year moving average of GDP growth	Continuous	Authors from WDI
• Standard deviation of the five-year moving average of inflation	Continuous	Authors from WDI
<i>Economic Performance :</i>		
• GDP per capita	Continuous	Authors from WDI
• GDP growth (5-year average)	Continuous	Authors from WDI
• Unemployment rate (5-year average)	Continuous	Authors from WDI

TABLE 17 – Commodity prices and expenditure efficiency : sources of variables

Variables	Nature	Sources
1. Main model variables		
Public Sector Efficiency	Scores ranging from 0 to 1	Authors, from data in Table 16
Commodity price volatility	Continuous	Authors, from Gruss and Kebhaj (2019)
Natural gas rents (% of GDP)	Continuous	World Development Indicators (WDI)
Corruption control	Index ranging from 0 to 100	World Governance Indicators database (Kaufmann et al., 2011)
External debt	Continuous	WDI
Government effectiveness	Index ranging from -2.5 to 2.5	World Governance Indicators database
Labour force	Continuous	WDI
Inflation	Continuous	WDI
Polity2	Index ranging from -10 to 10	Marshall and Gurr (2020)
Exchange rate	Continuous	WDI
2. Additional variables		
GDP growth (annual %)	Continuous	WDI
Total natural resources rents (% of GDP)	Continuous	WDI
Age dependency ratio	Continuous	WDI
Regulatory quality	Index ranging from -2.5 to 2.5	World Governance Indicators database
Political Stability and Absence of Violence/Terrorism	Index ranging from -2.5 to 2.5	World Governance Indicators database
Democracy	Index ranging from 0 to 10	Marshall and Gurr (2020)
Climatic vulnerability score	Index	Goujon (2006)
Financial openness (kaopen)	Index ranging approximately from -2 to 2	Chinn and Ito (2008)
Domestic credit to private sector by banks (% of GDP)	Continuous	World Governance Indicators (WGI)