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WIDER Working Paper 2022/102

A model to explain the impact of government revenue on the quality of governance and the SDGs

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September 2022

United Nations University World Institute for Development Economics Research
wider.unu.edu

Abstract: This paper empirically investigates the link between the level of government revenue per capita and six indicators of quality of governance in an unbalanced panel data set consisting of all countries in the world (217) using data from 1980 to 2020. It uses single-equation GMM techniques and a VAR and VECM approach to investigate this link. The results show a strong effect over time whereby an increase in government revenue leads to a steady improvement in governance. These findings suggest an important virtuous circle between government revenue and governance, indicating that additional government revenue can significantly impact the Sustainable Development Goals more than our previous work has suggested.

Key words: corruption, GMM, ECM, SDGs

JEL classification: I10, C01, C13, C20

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This study has been prepared within the UNU-WIDER project GRD – Government Revenue Dataset. It is part of UNU-WIDER's Domestic Revenue Mobilization (DRM) programme, which is financed through specific contributions by the Norwegian Agency for Development Cooperation (Norad).

Information and requests: publications@wider.unu.edu

ISSN 1798-7237 ISBN 978-92-9267-236-2

https://doi.org/10.35188/UNU-WIDER/2022/236-2

Typescript prepared by Joseph Laredo.

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The Institute is funded through income from an endowment fund with additional contributions to its work programme from Finland, Sweden, and the United Kingdom as well as earmarked contributions for specific projects from a variety of donors.

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1 Introduction

In September 2015, world leaders agreed on a road map to a more equitable and sustainable future and adopted an agenda for sustainable development and 17 Sustainable Development Goals (SDGs) with 169 targets. The SDGs are grounded in human rights law and are a unique opportunity to advance the realization of those rights (United Nations Office of the High Commissioner of Human Rights 2021). However, many low- and lower-middle-income (hereafter lower-income) countries are unlikely to reach the SDGs, especially the targets on safe sanitation (SDG 6) and secondary school completion (SDG 4). Most premature deaths result from inadequate access to critical determinants of health: clean water, sanitation, education, gender equality, and healthcare (SDGs 3, 4, 5, and 6) (Kuruvilla et al. 2014; Moyer and Hedden 2020). In the same year, heads of state and governments gathered in Addis Ababa to affirm their commitment to act in partnership to achieve the SDGs. They acknowledged that there must be a credible way of financing the goals through increased government revenues. The General Assembly reiterated that each country has primary responsibility for its own economic development, that increased domestic resource mobilization will be critical, and that there needs to be an enabling global economic environment for individual countries to operate within.

When governments have more revenue, they spend more on public services. Multiple studies demonstrate that increased government spending on public services drives progress towards the SDGs (Anyanwu and Erhijakpor 2009; Gupta et al. 2002; Haile and Niño-Zarazúa 2018; Sanoussi and Boukari 2020). Notably, the relative increase in spending on public services is more significant in lower-income countries than in upper-middle and high-income (hereafter higher-income) countries (Miller and Long 2017; Reeves et al. 2015; Tamarappoo et al. 2016). In addition, the impact of government revenue and spending on progress towards the SDGs is non-linear, with lower-income countries achieving higher benefits from marginal increases in government revenue than higher-income countries (Hall, Illian, Makuta et al. 2020). This impact translates to a more significant potential for lower-income countries to catch up with higher-income countries, conditional on increasing government revenue. Government revenue reflects governments' ability to spend across the many sectors that will impact progress towards the SDGs. In addition, as the policies and practices of global actors influence government revenue, quantifying the impact of government revenue on governance and, therefore, on the SDGs may highlight the vast potential for curbing leaks from government revenue envelopes.

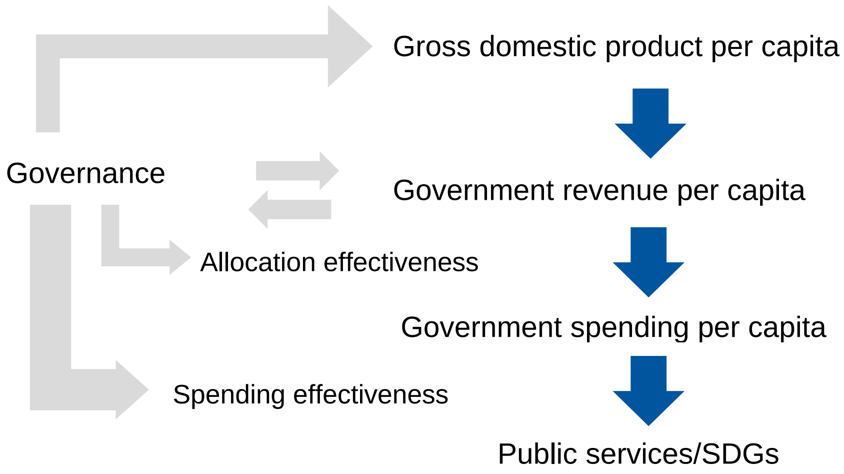
In O'Hare and Hall (2022), we modelled the effect of government revenue and governance on eight of the SDGs (under-five mortality, maternal death rates in childbirth, basic water supply, safe water supply, basic sanitation, safe sanitation, percentage schooling, and immunization rates). We found that an increase in government revenues positively affects all these SDGs but is highly non-linear, with a much more significant effect in lower-income countries than in higher-income countries. We also found that this relationship is strongly affected by a range of quality of governance indicators. A weakness of this work is that we treated the governance indicators as exogenous variables. However, we believe that governance will also respond to economic development. By ignoring this effect, we may be underestimating the impact on the SDG indicators of an increase in government revenue. Thus, an increase in government revenue will directly impact the SDGs, but it will also have an indirect effect through an improvement in governance. In this paper, we investigate the importance of this route with the aim of combining these sets of equations in a single model that will capture both effects.

1.1 The governance, revenue, and SDGs nexus

The Gross Domestic Product (GDP) per capita in 2018 in lower-income countries was on average US$750 compared with US$40,000 in higher-income countries. The government revenue/GDP ratio is much smaller in lower-income countries (13 per cent) than in higher-income countries (35 per cent). In lower-income countries, government revenue per capita is US$100 compared with US$14,000 in higher-income countries (O'Hare et al. 2020). To increase government revenue for the SDGs, both the size of the pie (GDP) and the size of the slice of the pie (tax/GDP) will need to increase. Furthermore, increasing the size of the slice is likely to drive an increase in the size of the pie. Indeed, Gaspar et al. (2016) argue that there is a tax/GDP tipping point, a minimum ratio, above which there is a sharp rise in GDP growth. They found this ratio to be 13.75 per cent.

There are several steps, acting in both directions, along the pathway from GDP to tax revenue mobilization and achievement of the SDGs, all of which are influenced by governance (O'Hare and Hall 2022). Here we briefly summarize the literature on each step with an overview shown in Figure 1.

Figure 1: The governance, tax revenue, and SDG nexus



Source: authors' construction.

The impact of governance on economic growth

Multiple researchers have shown the positive impact of governance on economic growth. For example, Ugur (2014) used a meta-regression analysis on 327 estimates of corruption's effect on economic growth and demonstrated that a reduction in corruption would positively impact long-run economic growth in lower-income countries. Since that publication, Chan et al. (2017) have empirically shown that efficient government spending and transparent tax administrations increase economic growth. In addition, Factor and Kang (2015) show, using structural equation modelling, that lower corruption levels are associated with economic growth.

Good governance stimulates economic growth, drives up households' income, and improves institutions. In turn, improved institutions result in better critical services, allowing households to divert precious resources towards other social goods, which is especially important for low-income families (Chong and Calderón 2000). Moreover, governance impacts non-income pathways critical to economic growth, including peace and stability and the effective regulation of critical sectors including health and education (Langnel and Buracom 2020).

The impact of governance on revenue generation

Several studies empirically demonstrate that the tax/GDP ratio improves with good governance and tax administration. Gupta (2007) finds that corruption negatively affects tax revenue. Ajaz and Ahmad (2010) studied 25 low- and middle-income countries and found that good governance and a reduction in corruption positively impact tax revenue. Arif and Rawat (2018) studied 10 emerging economies and found that tax revenue generation increases if there is a reduction in corruption and good governance. Other researchers use empirical methods to confirm this (e.g. Igbinovia and Ekwueme 2020). Jahnke (2017) shows that a lower perception of corruption is associated with higher tax compliance using Afro barometer survey results. In addition, governments responsive to their citizens are more stable, are less likely to be toppled, and can focus public spending on productive sectors that generate higher revenues and on social goods that will increase future revenue (Acemoglu and Robinson 2012; Cooray et al. 2017).

The impact of revenue on governance

Baskaran and Bigsten (2013) empirically studied the impact of increased tax revenue on governance. They used the tax/GDP ratio from the World Development Indicators dataset for tax revenue, corruption and government efficiency indicators from the Worldwide Governance Indicators (WGI) project, and, for democracy, Polity IV's democracy score. They studied 31 sub-Saharan African countries between 1990 and 2005 and showed that a 1 per cent increase in the tax/GDP ratio reduces corruption by 0.04–0.08 points (measured on a scale of 0–6). However, there is no significant increase in democracy. They control for endogeneity using instrumental variables.

There are two channels by which an increase in revenue might impact governance: 1. More revenue means improved services, e.g. better salaries for staff and reduced corruption; 2. Citizens demand better governance if they carry a fiscal burden, i.e. a solid fiscal contract.

1. More revenue means improved services

Baskaran and Bigsten (2013) consider the hypothesis that if governments have more revenue, this will allow them to, for example, pay civil servants higher salaries and reduce the motivation for corruption. However, a high tax/GDP ratio may result from a large manufacturing base or service industry, but it may also result from taxes on natural resources and indicate not strong fiscal capacity but rather an easily accessible source of revenue. If revenue increases by this channel, then resource rent and aid should display the same effect on governance. Baskaran and Bigsten control for natural resource rents and aid as a share of GDP and find that the tax/GDP ratio continues to be positively associated with governance, but resource rent and aid have no effect. They therefore dismiss 'more revenue means better services' as the likely channel by which an increase in tax revenue might impact governance. Others concur with this; many lower-income countries derive tax revenue from natural resources and aid and are less dependent on a solid fiscal contract for tax revenue. Moore (2007) argues that governments are less accountable when dependent on non-tax incomes, such as from the extractives or aid sectors.

2. Citizens demand better governance (with a solid fiscal contract)

Political scientists have long argued that improved fiscal capacity improves governance and that governments are more accountable to their citizens when dependent on them for tax revenue (Moore 2007). Empirical work supports this by showing that the higher the tax/GDP level, the lower the perceived level of corruption (Besley and Persson 2014; Cooray et al. 2017; Gupta 2007).

Governance and allocation

Governance impacts the volume of revenue, its allocation, and spending effectiveness. For example, an empirical study of 64 countries showed that corruption results in less spending on social sectors (Delavallade 2006). Conversely, a reduction in corruption results in increased spending on education (Mauro 1998; Nyamongo and Schoeman 2010).

Governance and the effectiveness of public spending

Good governance impacts the effectiveness of government spending and thus enhances the quality of critical services. Researchers have studied the interaction between governance and health expenditure to demonstrate this (Farag et al. 2013; Makuta and O'Hare 2015; Rajkumar and Swaroop 2008). Others confirm these findings (Baldacci et al. 2008; Çevik and Okan Taşar 2013; Dhrifi 2020; Hanf et al. 2013; Murshed and Ahmed 2018; Nketiah-Amponsah 2019). Thus, good governance is vital in translating public spending into progress toward the SDGs (Hu and Mendoza 2013).

In summary, improved governance increases GDP and the ability to generate, allocate, and effectively use revenue.

We have shown that additional government revenue and spending stimulate progress towards the SDGs. However, this progress is non-linear, with lower-income countries achieving higher benefits from marginal increases in government revenue than higher-income countries. We have also demonstrated that an increase in the quality of governance would amplify the impact of any additional government revenue, and that this is critical when government revenue levels are below US$5,000 per capita (Hall, Illian, Makuta et al. 2020; Hall et al. 2021; O'Hare and Hall 2022). However, our model may not capture the full effect of an increase in government revenue improving the quality of governance over time and thus the effectiveness of government spending, and may therefore underestimate the importance of curtailing revenue losses and inefficiencies.

Our objective is to model the impact of government revenue on the quality of governance over time and on progress towards the SDGs.

The plan for the rest of this paper is as follows: Section 2 outlines the research question, the broad methods, and the data we will use. Section 3 explains the econometric analysis and results, and Section 4 gives our conclusions and highlights policy implications.

2 Research question, methods, and data

What impact does government revenue have on the quality of governance over time and SDG progress?

2.1 Methods

We have built a detailed model of SDG indicators as a function of government revenue using the UNU-WIDER Government Revenue Dataset (GRD) (UNU-WIDER 2020) and six dimensions of the quality of governance of a country using the World Bank World Governance Indicators (Kaufmann et al. 2013) and World Development Indicators for SDG indicators (World Bank 2021)—see Appendix A. This work used data for every country in the world (217) over the period 1996–2019 (depending on availability).

To help users visualize the human impact of government revenue losses, we have developed the modelling into a cutting-edge, interactive online tool called the Government Revenue and Development Estimations (GRADE) (O'Hare et al. 2020). This provides precise and realistic estimates of how many more (adults, women, and children) will attend school, drink clean water, and survive if revenue increases. The tool also allows users to visualize the estimations if governance were to 'improve' and the impacts amplified dramatically.

We treated governance as an exogenous input to health outcomes in that work. This is a reasonable assumption from an econometric point of view as, at least in the short run, the quality of governance would not be easily changed by an increase in government revenues. However, this will probably not be the case over time, so when we calculate the long-run impact of a change in government revenues, we miss an important transmission channel.

2.2 Data

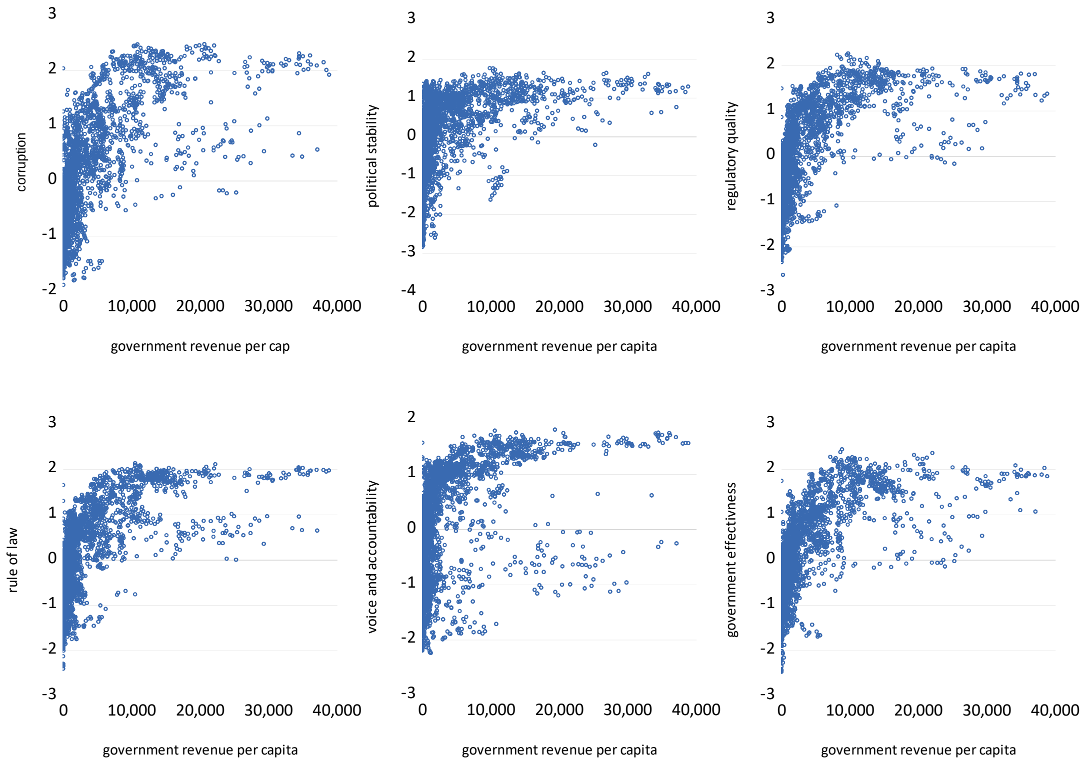
Like others, we wished to use measures of tax that reflect a solid fiscal contract. For example, Besley and Persson (2009) argued that the proportion of direct taxes (income taxes, payroll taxes, and social security contributions) is a better measure of fiscal capacity and the strength of the fiscal contract than the overall tax/GDP ratio. Others argue that tax effort (the ratio of what could be raised to what is raised) is the best measure of state capacity (Mkandawire 2009). However, Baskaran and Bigsten (2013) argue that the total tax/GDP ratio is the optimal measure because the direct tax/GDP ratio could reflect an increase in income inequality. They also argue that tax effort is subject to measurement errors and reflects the state's extractive capacity. Based on these arguments, we use the tax/GDP ratio.

We used the latest update of the GRD. The dataset has both general and central government revenue data, and we used the latter. Data that include and exclude grants are available, and we use total general government revenue, excluding grants, as this variable better reflects the capacity of domestic revenue. For the same reason, we used data that include social contributions, even though they may be incomplete. The GRD expresses all data as a percentage of GDP taken from the World Economic Outlook (WEO) in Local Currency Units (IMF 2018). We convert government revenue as a percentage of GDP into government revenue per capita and, as before, use the six dimensions of the quality of governance of a country, using the WGI (see Appendix A for definitions; also Kaufmann et al. 2013).

Figure 2 shows the scatter plots of the relationship between government revenue per capita and the various governance measures.

These scatter plots clearly show a strong positive relationship between government revenue per capita and the various governance indicators. However, there is also clearly a group of countries where the level of government revenue seems to have little effect on the quality of governance. This trend appears to be particularly strong for voice and accountability. This is echoed in our results (see below).

Figure 2: Government revenue per capita in US$ and governance indicators



Source: authors' construction.

2.3 Strategy

This study explores the critical relationship between government revenue and quality of governance over time. We use a panel database involving every country in the world over a long period. We explore a range of techniques, as in applied econometric work, since it is often impossible to know a priori which approach will prove the most effective. First, we consider the broad properties of our data and ask whether the analysis should be carried out in level or difference form. The data are unusual in that the governance indicators all lie within a range from -2.5 to +2.5 and thus do not meet the normal requirements for testing stationarity. We ensure that we have either stationary data or that we have cointegration. We begin by using a single-equation approach to the issue using a single-equation equilibrium correction model (ECM) for each governance measure and government revenue. This needs to allow for the endogeneity of government revenue, so we use an estimation technique that can deal with this: a panel instrumental variable estimator generalized method of moments (GMM). We then check the robustness of these results by using a completely different approach, a vector autoregressive (VAR) analysis, looking at the dynamic interactions between government revenue and each of the six dimensions of governance quality. This allows a complex and possibly slow interaction between the two to be explored. We can then build a panel vector equilibrium correction model (VECM), which allows us to fully model the dynamic adjustment towards the long-run equilibrium. We are then able to contrast the adjustment process for the two approaches.

Finally, we combine this model with our existing model for SDG 4, 5, and 6 indicators to capture not only the direct effect of government revenue and quality of governance on progress towards the SDGs, but also the important indirect effect of an increase in government revenue on the quality of governance over time and thus the effectiveness of government spending on the SDG indicators.

3 The econometric analysis and results

Modern time-series econometrics emphasises the importance of the stationarity and cointegration properties of data for valid estimation work (Asteriou and Hall 2021: 31). Over the last 10 to 15 years, this analysis has been extended to a panel data setting, and it is now well understood that even in a panel context these issues cannot be ignored. However, the data we are dealing with here do not easily fit into the standard I(1) or I(0) framework; all the governance variables we have are bounded between -2.5 and +2.5 and therefore cannot be random walk variables, although it is still possible that they are not weakly stationary. Applying the standard panel stationarity tests here is therefore not sensible, as they are all based on the null hypothesis of a unit root random walk. For completeness, however, we give the results of a standard set of panel stationarity tests in Table B1 in Appendix B.

The strict interpretation of these results is that we reject the null of a unit root for all the governance indicators while accepting the null for government revenue. However, we question the relevance of these results to the issue of non-stationarity, which is the important factor. The key issue for estimation is therefore that if the variables are not weakly stationary, we need to know that they cointegrate; if they are weakly stationary, then we may proceed anyway. So, if they either are weakly stationary or cointegrate, the appropriate modelling strategy is to keep the variables in level form. Therefore, we begin by testing for bivariate cointegration between government revenue per capita and each of the governance variables. Here we perform three Engle–Granger-based panel cointegration tests: the Kao (1999) and two versions of the combined Johansen test based on the Fisher (1925) procedure of averaging the individual test statistics. The results are shown in Table 1.

Table 1: Panel cointegration tests between government revenue per capita and each of the governance variables

	Control of corruption	Government effectiveness	Political stability	Regulatory quality	Rule of law	Voice and accountability
Kao test (null unit root)	0.0	0.0	0.0	0.0	0.0	0.0
Fisher trace test (null 0 coint. vectors)	0.0	0.0	0.0	0.0	0.0	0.0
Fisher max. eigen. test (null 0 coint. vectors)	0.0	0.0	0.0	0.0	0.0	0.0

Note: the table shows probability values that the null of no cointegration is correct in each case. A value of less than 0.05 would therefore reject the null at a 5 per cent critical value, and we accept cointegration.

Source: authors' construction.

As Table 1 shows, in every case the null hypothesis of no cointegration is rejected by all three tests. We can therefore proceed to estimation in a valid way, as either the data may be regarded as stationary or they convincingly cointegrate and therefore, following the Granger representation theorem, valid estimation is possible.

We begin by estimating a set of single-equation relationships between each of our governance indicators and the logarithm of government revenue per capita (lgovrev). There are several difficulties with estimating a relationship between these two. First, we cannot assume that government revenue is independent of quality of governance—in econometric terms, that it is weakly exogenous. Second, it is fairly obvious that quality of governance is going to be affected by government revenue only slowly over time, so our specification has to allow for a gradual adjustment of the governance indicators to an increase in government revenue. This implies that the model we use must be dynamic (Asteriou and Hall 2021). However, as we are using a panel data set, it also implies that standard ordinary least squares (OLS) estimation would give biased results, as it is well known that OLS is not a consistent estimator of dynamic panel data models. Therefore, we employ a GMM estimator that deals with both the possible endogeneity of government revenue and the bias that might come from a dynamic panel under OLS. GMM is an estimation procedure that uses variables called instruments, which are exogenous but correlated with the independent variables to purge the potential bias of OLS.

The general structure of each equation takes the form of a bivariate dynamic equilibrium correction model with up to a two-year lag structure. The general model is therefore:

$$\Delta GI_{it} = \alpha_{i0} + \alpha_1 \Delta\, lg\, o\, v_{it} + \alpha_2 \Delta\, lg\, o\, v_{it-1} + \alpha_3 \Delta GI_{it-1} + \alpha_4 GI_{it-1} + \alpha_5\, lg\, o\, v_{it-1} + \varepsilon_{it} \qquad (1)$$

Where Δ is the first difference operator, GI is one of the governance indicators, α_{i0} is a fixed effect which varies for each country in order to allow for non-time varying differences between countries, $\alpha_1 ... \alpha_5$ are parameters, and $\varepsilon_{it} \sim N(0, \sigma^2)$ is the error term. For stability in the long run, we require that $-1 < \alpha_4 < 0$ where this parameter also governs the speed of adjustment so that a value close to -1 would imply a rapid adjustment process and a value close to 0 would imply slow adjustment. The long-run total effect on GI is given by $GI = -(\alpha_5 / \alpha_4) \lg ov$ so that $(-\alpha_5 / \alpha_4)/100$ is the long run semi-elasticity of GI with respect to lgov.

We begin with this general model and then remove any insignificant effects to achieve a parsimonious model in a standard general to a specific methodology. Table 2 shows the parsimonious estimates for each of the GMM estimates for each governance indicator.

Table 2: GMM estimation of the equilibrium correction models for governance indicators

	Control of corruption	Government effectiveness	Political stability	Regulatory quality	Rule of law	Voice and accountability
α_1	-	-	-	-	-0.04 (3.0)	-
α_2	-	-	-	-	-	-
α_3	-	-	-	-0.06 (3.3)	0.036 (1.9)	0.13 (7.0)
α_4	-0.26 (19.5)	-0.3 (19.9)	-0.24 (18.2)	-0.24 (17.1)	-0.25 (18.5)	-0.25 (19.7)
α_5	0.038 (4.1)	0.04 (4.5)	0.024 (1.6)	0.04 (4.1)	0.028 (3.5)	0.0025 (0.3)
$(-\alpha_5 / \alpha_4)/1$	0.0015	0.013	0.001	0.0017	0.001	0.001
J-statistic p-value	0.26	0.8	0.72	0.34	0.71	0.63

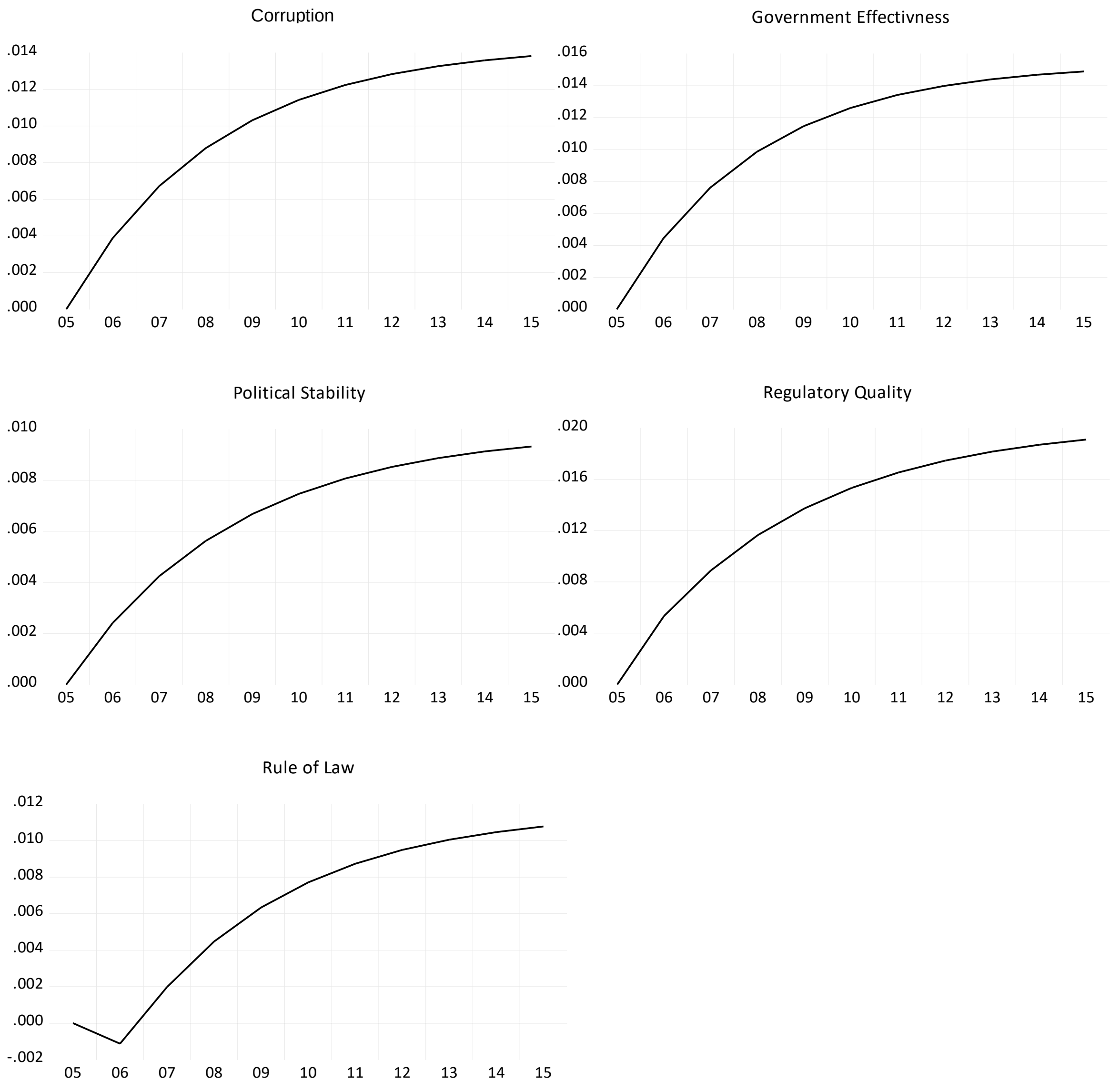
Note: student 't' statistic in parentheses. Fixed effects included but not reported. This is a single-equation panel GMM estimator using the following instruments: governance indicator lagged 1–3; government revenue lagged 1–3 with fixed effects.

Source: authors' construction.

Five of the six models perform well: α_4 and α_5 are significant and correctly signed in all the models except voice, where a_5 is not significant although still correctly signed. This suggests that, apart from voice, there is a significant and important link between government revenue and the governance indicators. The first three models have dropped the dynamic terms, which suggests that the adjustment process is very smooth. The last three have some dynamic terms but these are small, suggesting again that the governance indicators are quite smooth with only small perturbations around the smooth path. α_4 is a very similar order of magnitude in all cases, which suggests that the speed of adjustment is very similar across the indicators.

We performed a simple simulation exercise to give a clearer idea of the speed of adjustment of the governance indicators. We simulated a fixed 10 per cent increase in government revenue per capita over 10 years and graphed the adjustment process for each of the five indicators with significant effects (not voice). This is shown in Figure 3.

Figure 3: The adjustment process implied by the GMM estimates to a 10 per cent increase in government revenue per capita



Source: authors' construction.

This figure illustrates the smooth transition in response to a 10 per cent increase in government revenue per capita for each of the five governance indicators that have a significant effect. They all show a smooth transition except for a very small initial negative effect in the rule of law, which is rapidly eliminated.

While these results seem very satisfactory, we felt that it would be worth checking their robustness by using a completely different methodology. We therefore now turn to an investigation of the same question but using a panel VAR model. A VAR model avoids the problem of endogeneity of some of the variables by treating all variables in an equivalent manner—that is, as endogenous. So we begin by estimating a series of bivariate VAR models between each of our governance indicators and government revenue. We then go on to estimate a single VAR for all five indicators that work well (again, not voice) and government revenue.

A standard VAR may be expressed in the following general way

$$X_{it} = \Pi(L)X_{it} + w_{it} \tag{2}$$

Where X_{it} is a vector of n variables for each country i and over t time periods and $\Pi(L)$ is a matrix lag polynomial. In our initial VARs n=2, that is each of our measures of governance and government revenue. In the final VAR n=6 for the five measures of governance together and government revenue. One of the advantages of the VAR methodology is that the investigator only has to make a limited range of decisions. First, the investigator has to choose the variables of interest. The only other choice is the number of lags in the matrix lag polynomial. We have chosen to base this on a range of information criteria. In particular, we use the final prediction error (FPE) criterion, the Akaike information criterion (AIC), the Schwarz information (SC) criterion, and the Hannan–Quinn (HQ) information criterion. Table 3 shows the recommended lag length by each of these criteria for each of the VARs, along with our final decision.

Table 3: The choice of lag length for each VAR

	FPE	AIC	SC	HQ	Chosen
Corruption	7	7	1	1	1
Government effectiveness	7	7	1	1	1
Political stability	8	8	1	1	1
Regulatory quality	7	7	1	2	1
Rule of law	7	7	1	1	1
Voice	7	7	2	2	2
All except voice	2	2	1	1	2

Source: authors' construction.

The first six rows show the chosen number of lags for each measure of governance with government revenue for each of the four information criteria and the choice of lags we have made based on this. Generally speaking, the FPE and AIC chose quite a long lag length of around 7, while the SC and HQ criteria chose a much shorter lag length of 1 or 2. Given the well known result that SC and HQ often perform better in Monte Carlo studies and our general preference for a shorter VAR length (as this usually produces smoother responses), our chosen number of lags is in each case 1 or 2. Row 7 shows the results for a single VAR containing all the governance indicators except voice (where the VAR proved to be unsatisfactory, matching the GMM results) and government revenue.

So that we might interpret the results of the VAR estimation more easily, we chose to reparametrize the VAR into a vector error correction model (VECM) in the following way.

$$\Delta X_{it} = \Pi * (L)\Delta X_{it} + \alpha'\beta X_{it-1} + w_{it} \tag{3}$$

This is simply a generalization of the equilibrium correction model to a vector setting. The key vectors of parameters of interest here are α, which controls the speed of adjustment to the equilibrium (α_1 is the effect in the governance equation and α_2 is the effect in the government revenue equation) and β, which shows the long-run relationship between the variables. For the two variable cases, we normalize $\beta_1 = 1$ so that $-\beta_2$ is the long-run effect of government revenue on each of the governance indicators (as government revenue is in logs, we divide $-\beta_2$ by 100 so that we may interpret the effect as a response to a 1 per cent change in government revenue). While the general condition for stability in this model is complex, a sufficient condition is that $\alpha_1 < 0 \, and \, \alpha_2 > 0$. The estimated values of the dynamic parameters of the system $(\Pi^*(L))$ are of little interest, so we do not report these, although we will show some simulations of each equation that contain the full dynamic specification of the VECM. Table 4 reports the key parameters of interest.

Table 4: The key parameters for the six bivariate VECMs

	$-\beta_2$	α_1	α_2
Corruption	0.015(11.4)	-0.0006(0.5)	0.12(8.6)
Government effectiveness	0.0084(15.3)	-0.01(4.9)	0.03(8.3)
Political stability	0.0073(13.1)	-0.18(4.9)	0.02(8.3)
Regulatory quality	0.016(10.6)	-0.0012(1.1)	0.01(8.12)
Rule of law	0.0135(11.5)	0.00017(0.13)	0.014(8.3)
Voice and accountability	0.0265(10.6)	0.002(4.3)	0.005(7.8)

Note: student 't' statistics in parentheses.

Source: authors' construction.

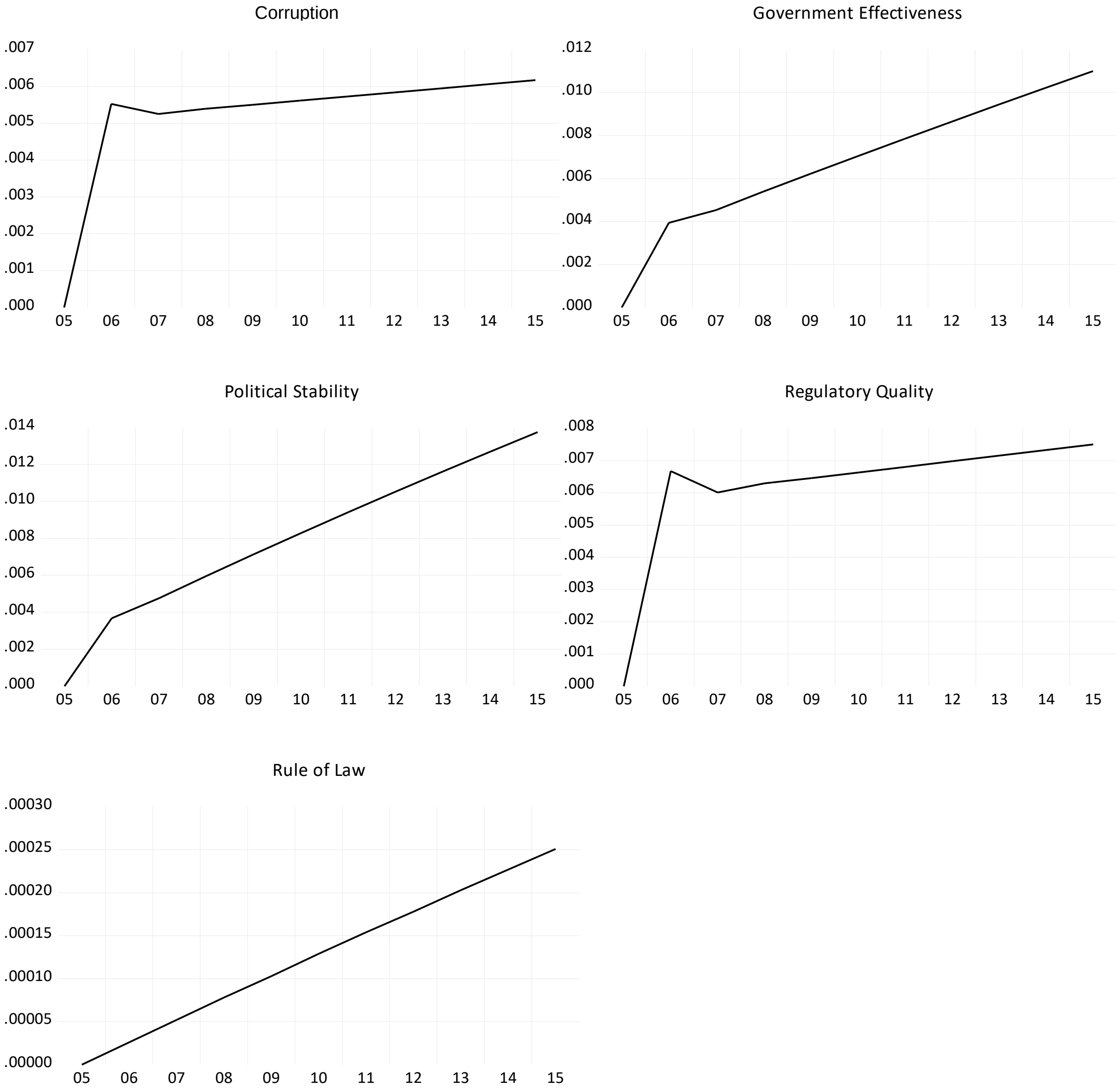
The coefficient for the long-run effect of government revenue on the quality of governance indicators is generally significant and of the same order of magnitude, as shown in Table 2. However, the two parameters that govern the rate of adjustment towards this long-run equilibrium are smaller and, in two cases (rule of law and voice), are actually the wrong sign for α_1, which could imply that the model does not move towards this long-run effect at all. All the adjustment coefficients for government revenue are correctly signed and significant, although they are still small. This suggests that there is a strong long-run effect of changes in the governance indicators on increasing government revenue but, again, it is a slow effect. This emphasizes the important simultaneity that links government revenue and governance. In these results, there is again an incorrect sign in the adjustment coefficient on voice, so in a similar result to the GMM results, voice does not seem to be affected by government revenue.

The picture given by these results is fairly clear: (i) there is a very strong bi-directional link between government revenue and governance; (ii) there is a similar order of magnitude in the long-run link between the two here and in the GMM results. It is reasonable to assume that the adjustment process over a 10-year horizon will be very similar; we will confirm this conjecture below.

We then estimated a five-variable VECM involving corruption, government effectiveness, political stability, regulatory quality, and rule of law (we did not include voice and accountability, as the bivariate model performed so poorly). All the long-run coefficients were significant, as were the adjustment coefficients, but for space reasons, and because they add little to the analysis, we do not report these results here.

The next step in a standard VAR is to carry out an impulse response analysis—that is, to shock the residuals of the VAR or VECM to see how the system adjusts to a shock. The shock is usually set at one standard deviation of the variables in question and is usually only a one-period shock, but it can be set as a permanent change by cumulating the impulse responses over time. We have decided to depart from the standard procedure for a two main reasons: (i) the standard shock of one standard deviation calculated across all the countries in our sample would represent a shock to government revenue of over 40 per cent, which is unreasonably large; (ii) because government revenue is a part of the model, it also reacts to the shock, so that government revenue continues to rise dramatically. Hence the effect on the governance indicators would become much larger than the initial effect would have been and would then be difficult to interpret. For these reasons, we decided to perform a different set of simulations that are more comparable to those shown in Figure 3. We take the estimated VECM and treat government revenue as exogenous, then increase government revenue by 10 per cent and then solve for the increase in each of the governance indicators. Figure 4 shows the effects of this simulation experiment.

Figure 4: The effect within the bivariate VECMs of a 10 per cent increase in per capita government revenue



Source: authors' construction.

Comparing Figure 4 with Figure 3, we see that the two sets of results are quite similar in the response over a 10-year horizon. The bivariate results are not quite as smooth as the GMM results, because the dynamic effects in the VECM have not been removed when they are insignificant (as is standard in VAR analysis), but the main point is that both techniques find a very similar adjustment profile.

4 Conclusions, policy implications, and limitations

In O'Hare and Hall (2022), we modelled the effect of government revenue and governance on eight of the SDGs (under-five mortality, maternal death rates in childbirth, basic water supply, safe water supply, basic sanitation, safe sanitation, percentage schooling, and immunization rates). We found that an increase in government revenues has a positive effect on these SDGs and it is highly non-linear, with a much bigger impact in lower-income countries than in higher-income countries. We also found that this relationship is strongly affected by a range of quality of governance indicators. A weakness of this work is that we treated the governance indicators as exogenous variables. We believe that governance will also respond to economic development, and by ignoring this effect we may be underestimating the impact of an increase in government revenue on the SDG indicators. Thus, an increase in government revenue will directly impact the SDGs, but it will also have an indirect effect through an improvement in governance. In the present study, we investigated the importance of this route with the aim of combining these sets of equations in a single model that would capture both effects.

We employed two contrasting econometric methodologies to quantify the effects of an increase in the log of government revenues per capita on various indicators of governance quality (single equation GMM and a VECM). Both models show significant effects on the governance indicators of increasing government revenues. The estimates of the long-run effects are of a similar order of magnitude, as is the speed of adjustment to this equilibrium. This yields a remarkably consistent picture over a 10-year horizon, as shown in Figures 3 and 4.

The important insight gained from the VECM is that, generally, we should not treat government revenue per capita as an exogenous variable. There is an important feedback from governance to government revenue as well as from government revenue to governance. The simulations we presented treat government revenue as an exogenous process and simply add a fixed amount to it to investigate the effect on governance. However, the VECM results suggest that this is not the end of the story. Over time, as governance improves, there will be further increases in government revenue, which will further improve governance and so on, forming an important virtuous circle.

Expected limitations of this study are that data for government revenue from the GRD are not available before 1980 and data on the quality of governance from the World Governance Indicators are not available before 1996.

We have previously shown that the impact of government revenue and spending on progress towards the SDGs is non-linear, with lower-income countries achieving higher benefits from marginal increases in government revenue than higher-income countries (Hall, Lopez, McNabb et al. 2020; Hall et al. 2021). These models show that an increase in government revenue has a much more significant impact on progress towards the SDGs—through its effects on improving the quality of governance over time. This is a slow effect that builds up in a very important way. Thus, identifying sources of lost revenues and inefficiencies could hold enormous potential for progress towards the SDGs.

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Appendix A: Definitions

Worldwide Governance Indicators

The WGI reports aggregate and individual governance indicators for over 200 countries and territories over the period 1996–2019 for the six dimensions of governance described below (see also Table 3). These are composite indicators, based on more than 30 data sources. First, individual questions from the underlying sources are assigned to one of the aggregate indicators. The compilers then rescale the data to make them comparable across sources using the unobserved components model. The resulting composite measures are in units of a standard normal distribution with mean zero running from -2.5 to +2.5, higher values corresponding to better governance (Kaufmann and Aart Kraay 2020; Kaufmann et al. 2010).

Control of corruption: perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests

Government effectiveness: perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies

Political stability: perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically motivated violence and terrorism

Regulatory quality: perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development

Rule of law: perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence

Voice and accountability: perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and free media

SDG indicators[1]

Basic drinking water services: the percentage of the population drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip. Improved water sources include piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water.

Safely managed drinking water services: the percentage of the population using drinking water from an improved source that is accessible on premises, available when needed, and free from faecal and chemical contamination

[1] World Bank (2021).

Basic sanitation services: the percentage of the population using sanitation facilities that are not shared with other households and where excreta are not hygienically separated from human contact

Improved sanitation services: the percentage of the population using sanitation facilities that are not shared with other households and where excreta are hygienically separated from human contact. Improved sanitation facilities include flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, compositing toilets, and pit latrines with slabs.

Safely managed sanitation services: the percentage of the population using improved sanitation facilities where excreta are treated and disposed of in situ, stored temporarily and then emptied and treated off-site, or transported through a sewer with wastewater and then treated off-site

Child immunization: the percentage of children aged 12–23 months who received diphtheria, pertussis (or whooping cough), and tetanus (DPT) vaccinations before 12 months or at any time before the survey. A child is considered adequately immunized against DPT after receiving three doses of vaccine.

School life expectancy (primary and secondary), both sexes (years): the number of years a person of school entrance age can expect to spend within the specified level of education. For children of a certain age, school life expectancy (SLE) is calculated as the sum of the age-specific enrolment rates for the levels of education specified. The part of the enrolment that is not distributed by age is divided by the school-age population for the level of education they are enrolled in and multiplied by the duration of that level of education. The result is then added to the sum of the age-specific enrolment rates. A relatively high SLE indicates a greater probability of children spending more years in education and higher overall retention within the education system. It must be noted that the expected number of years does not necessarily coincide with the expected number of grades of education completed, because of repetition. Since SLE is an average based on participation in different levels of education, the expected number of years of schooling may be pulled down by the magnitude of children who never go to school. Those children who are in school may benefit from many more years of education than the average. Here education is shown as the percentage of the maximum SLE, both primary and secondary, both sexes, globally, which is 17 years.

Appendix B: Panel stationarity tests for the variables

Table B1: Results of panel stationarity tests for the variables

	Levin, Lin and Chu	Im, Pessaran and Shin	ADF-Fisher Chi-Square	Phillips and Peron Chi-Sq
Corruption	-7.7 (0.0)	-5.3(0.0)	637.6(0.0)	620.6(0.0)
Government effectiveness	-10.7(0.0)	-7.4(0.0)	794.3(0.0)	694.6(0.0)
Political stability	-11.7(0.0)	-11.8(0.0)	838.7(0.0)	861.7(0.0)
Regulatory quality	-13.0(0.0)	-7.6(0.0)	719.5(0.0)	689.3(0.0)
Rule of law	-9.8(0.0)	-6.7(0.0)	641.7(0.0)	639.5(0.0)
Voice	-9.3(0.0)	-8.2(0.0)	731.5(0.0)	665.7(0.0)
Government revenue per capita	4.4(1.0)	6.8(1.0)	188.9(0.95)	188.4(0.95)

Note: significance values (p-values) in parentheses. Null hypothesis for all tests is a unit root.

Source: authors' construction.

The formal interpretation of these results is quite clear: in the case of all the governance indicators we can reject the null hypothesis of a unit root, while in the case of government revenue per capita we cannot reject this hypothesis. However, there are a number of reasons to question the implication that the governance indicators are stationary:

1. Given the nature of the governance indicators, which are bounded between -2.5 and +2.5, it is clear they cannot be a unit root, although this does not mean that they are stationary. A unit root is non-stationary but there are many other processes that are not unit roots which do not meet the requirement of weak stationarity that the first two moments of a series are constant.
2. Some of the individual cross-sections are very short, as the panel is unbalanced, and this may lead to a bias in the tests.
3. Looking at individual country governance indicators, we see that they often show an increase over time, suggesting that they are not mean reverting.

Taking all this into account, and despite the formal tests, we believe it is important to allow for the possibility that the governance indicators are in fact non-stationary.