ISSN No. 2454 - 1427

CDE
December 2025

Does E-Government Reduce Corruption in Sub-Saharan Africa? A Theoretical and Empirical Analysis

S. Benson Simwanza
Email: benson@econdse.org
Department of Economics
Delhi School of Economics
University of Delhi

Dibyendu Maiti
Email: dibyendu@econdse.org
Department of Economics
Delhi School of Economics
University of Delhi

Working Paper No. 357

Centre for Development Economics
Delhi School of Economics
Delhi- 110007

Does E-Government Reduce Corruption in Sub-Saharan Africa? A Theoretical and Empirical Analysis *

S. Benson Simwanza[1] and Dibyendu Maiti[1]

[1]Delhi School of Economics, University of Delhi, India

Abstract

The paper investigates whether the thriving application of ICTs, e-government, reduces the level of corruption within nations in Sub-Saharan Africa. Using a simple Ramsey model, it models the tax evasion in the presence of ICTs and demonstrates how the level of digital-institutional quality that improves digitalisation strengthens institutions, reduces corruption, and thereby enhances growth. Not digitalisation, but digitalisation with institutional quality matters most. Furthermore, this study empirically explores the nexus between perceived corruption and e-government using a panel data set for 44 Sub-Saharan African countries during the period 2003-2022 using various methods of estimation: OLS, IV, FE, and GMM methods. The regional e-government development index (EGDI) average is below the global average. The findings indicate that e-government does not lessen the corruption perception index across all indicators. E-government is robust in reducing the perceived corruption index when full interactions between government effectiveness and e-government, as well as between government effectiveness and economic prosperity, are introduced into the models.

JEL Code: O33, O44, O57

Key words: Corruption, E-government, IV–2SLS, Dynamic Panel GMM

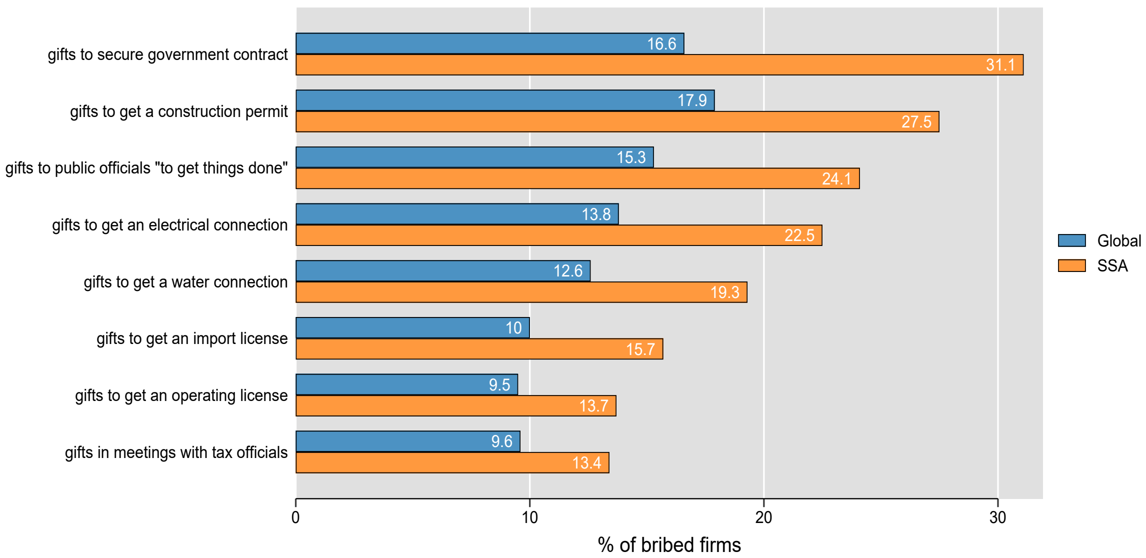
---

*Thanks for the feedback from the DSE Winter School (2024) and DSE Young Scholar Seminar (2025).
Address for correspondence: Delhi School of Economics, Delhi University, North Campus, New Delhi - 110007, India; email: benson@econdse.org

1 Introduction

Corruption is considered the most prevalent and persistent challenge to eradicating uttermost poverty and collective wealth among a vast number of people growing in transition and developing countries [Grey and Kaufmann, 1998] and is a fundamental obstacle to reaching the Sustainable Development Goals (SDG) [Mayanja and Nkata, 2019, Ouedraogo and Sy, 2020]. Corruption is not one-of-a-kind to developing economies and exists in all nations in different forms, such as embezzlement, clientelism, patronage, bribery, and lobbying. Such problems persist in Sub-Saharan Africa to a severe extent, with some variations between countries. For example, Figure 1 shows the percentage of firms that are likely to pay gifts to civil servants in order to operate their economic activities in Sub-Saharan Africa [Myint, 2000, Delavallade, 2012]. The number of firms that are expected to pay bribes is above the global average in the cases presented in the graph. The drivers of corruption differ in relation to the degree of advancement. In Sub-Saharan African countries, there could be a lack of accountability, the unimplemented rule of law, bribery of civil servants for private benefits, low payments for civil servants, and no transparency in public sector prosecutions. The consequences of corruption appear to be a greater problem, particularly with regard to sustainable economic development and inclusive growth [Mishra and Bisht, 2013, Ojo et al., 2013, Alkemade and Suurs, 2012]. For example, corruption creates mistrust between public officials, politicians, and citizens, lowering the individual living standard and hindering the effective delivery of public service provisions and socioeconomic outcomes. In most developing countries around the world, including Sub-Saharan African countries, the level of corruption perception is quite high, and there is a strong belief that corruption practices bring the biggest impediments to the overall provision of public goods, cause economic inefficiency due to misallocation of scarce resources, and result in an unequal allocation of income and wealth within a community, broadening the disparity between those who have resources and those who do not. The ability of digital technologies to expose the level of corruption encourages the government to apply such advancements for the delivery of public goods and services effectively, known as e-governance. The revelation of corruption among the general public, facilitated by various digital innovations and platforms, has put pressure on incumbents to adopt corrective measures in a democratic setting [Maiti and Khari, 2025]. Therefore, it is believed that e-governance must reduce the level of corruption. The main thrust of this study is to determine whether the modern digital revolution can mitigate the negative impacts of corruption by reducing its prevalence in Sub-Saharan African countries.

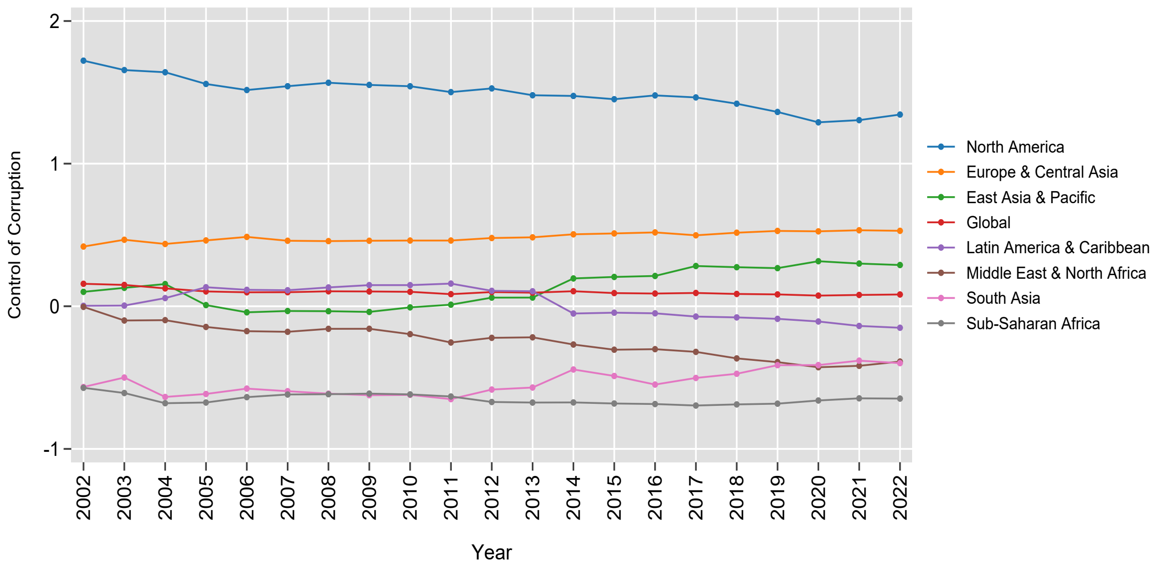
Figure 1: Percentage of firms expected to pay bribes as gifts



Source: The World Bank

Some drivers of corruption in nations of Sub-Saharan Africa include: first, a lack of transparency, which is common to nearly all Sub-Saharan African governments; for example, the likelihood of corruption occurring through tax depends on the tax law interpretations and the closeness between taxpayers and tax auditors. The probability of corruption is generally low or less likely to occur if the tax and customs laws are clear and do not require contact between tax investigators and taxpayers [Tanzi, 1998]. Corruption is more likely to exist if tax and customs laws are misinterpreted by taxpayers. Given that the payment of taxes requires regular communication between taxpayers and tax officials, and if the wages of tax officers are low, corruption is expected to be high [Tanzi, 1998]. Moreover, Tanzi [1998] argues that at one time in some countries, corruption became so endemic among tax officers (like in Uganda and Peru) that it compelled the government to shut down the current tax offices and substitute them with new ones. In addition to that, tax officers are not audited, and in developing countries, including Sub-Saharan African countries, they provide poor services to taxpayers by planting ignorance in them, which finally exacerbates corruption and weakens the ultimate objective of combating corruption. Secondly, the government steps into the market, which is done when the government pursues the offering of consumable resources and commodities at below market prices, which creates excess demand in comparison to supply. The clearing price is not automatically adjusted due to the government influence, and the users of the commodities will be required to pay a kickback to acquire offers from the government [Knack and Keefer, 1995]. Third, in terms of government size and bureaucracy, Seldadyo and De Haan [2005] believes that citizens are tempted to bribe public officials to eliminate their suspensions and advance the queue if the ratio of public service outlets per capita is small, and the larger the government, the greater the likelihood of corrupt habits. It seems to be suggesting that the more efficient the institutions, the lower the level of corruption.

Figure 2: Corruption Control by Region



Source: Worldwide Governance Indicators (2023)

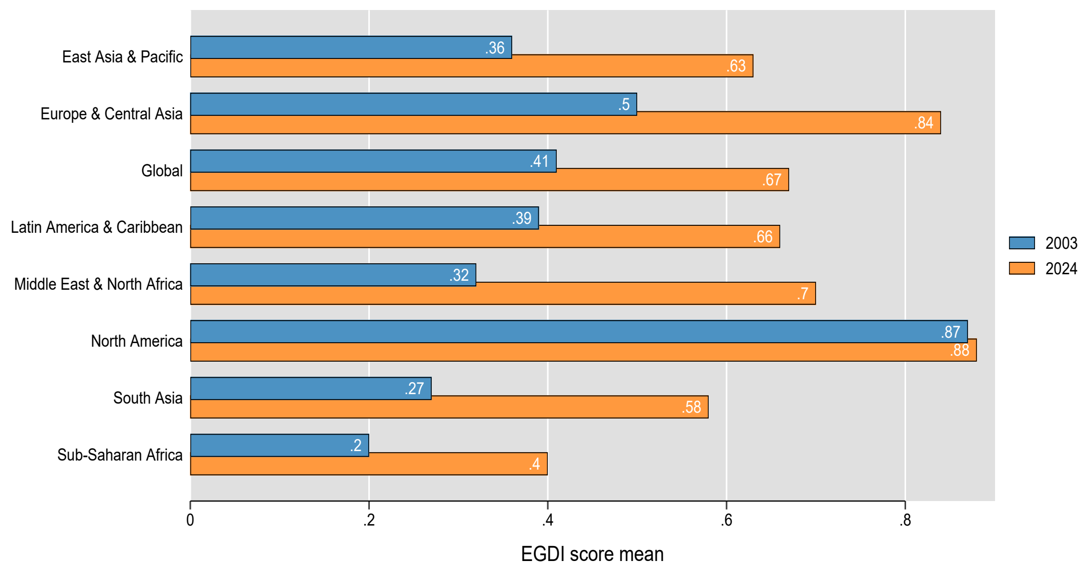
The harmful consequences of corruption on development and growth led governments to establish anti-corruption initiatives and commissions to use traditional methods, which directly or indirectly reduce the amount of corruption. For example, reducing frequent contact between the public and the government representatives responsible for implementing particular tasks, for instance, tax collection. Some of the drawbacks of these measures were: a lack of quantification, transparency, and political favour still exists, as well as the immeasurable closeness between tax officers and taxpayers, which adversely affects fiscal health, etc. Figure 2 shows the average strengths of effective policies in corruption control by region, whose values range from -2.5 (unsuitable policy) to 2.5 (suitable policy). North America is the best-performing region, which shows the policy effectiveness is strong enough in curbing corruption, followed by Europe & Central Asia and East Asia & the Pacific, which have been above zero from 2012 to date. The Middle East & North Africa, South Asia, and Sub-Saharan Africa are all below zero, representing an ineffective policy towards curbing corruption; however, Sub-Saharan Africa ranks as the least successful region compared to others. With regard to this regional corruption comparison, no region is clean at the 100% level, signifying that each nation experiences a sort of corruption. The degree of corruption combating among sub-Saharan African countries varies from less effective policies to more effective policies [Aborisade and Aliyyu, 2017].

The weaknesses of traditional methods for combating corruption, adopted by governments, have led to a consensus among researchers advising countries to utilise digital means to deliver their services. Many economies adopted the modernization of government through the performance of digital means, as they believed that it would help curb and reduce corruption opportunities in the public sector of developing countries by implementing automation in the delivery of public services. In the digital era, governments can use information technology to reduce crime and increase government transparency, accountability, quality of public goods, efficiency, citizen participation, and facilitate advocacy [Mykhalchenko, 2022]. The ongoing digital revolution has transformed politics, human rights, and public administration by introducing new technological solutions for digitalisation, and the participating population has increased annually. Countries that do not prioritise the integration of their services to digital technology at all levels always suffer. The relationship between corruption and technology, and how the former can be affected by the latter, has been established over time [Danowski et al., 2023]. Hence, digital transformation allows service users to be part of the solution. However, researchers argue that, when government systems are digitalised, corruption practice relocates from an offline pattern to an online exercise such as cybercrime, and cases regarding this practice are also evidenced in Sub-Saharan African countries [van Vuuren et al., 2020, Snail ka Mtuze and Musoni, 2023, Adewopo et al., 2024].

The degree of e-government varies from one region to another. For instance, Figure 3 represents the reports of the e-government survey of 2003 and 2024, published biennially by the Economic and Social Affairs Department of the United Nations (UNDESA). By 2024, the EGDI means of North America (0.88), Europe & Central Asia (0.84), and the Middle East & North Africa (0.7) were above the global average, while by 2003, only Europe & Central Asia and North America were above the global average. However, the Middle East and North Africa had improved their EGDI average in 2024. Above the global average, indicating that a country and its citizens have substantially devoted themselves to policies that purposefully support the significant achievements of missions and targets of using ICTs and other adaptable technologies, this initiative supports growth and inclusive development, and minimises the digital divide. Despite being positioned beneath the global average, from 2003 to 2024, the e-government of Sub-Saharan Africa grew by 100%.

According to this United Nations (2024) website, the first three best countries leading the development of e-government in Sub-Saharan Africa are: South Africa (0.8616), Mauritius (0.7506), and Seychelles (0.6773), and the last three countries with the lowest e-government are: Somalia (0.1468), South Sudan (0.1191) and the Central African Republic (0.0947). In 2003, the global average was 51% more than the Sub-Saharan African average, while in 2024 the global average was 40% more than the Sub-Saharan African average. This shows that Sub-Saharan Africa has decreased the gap with regard to the average of global average by about 11%. The region's EGDI averages below the global average and experiences obstacles when implementing the ICT policies, such as political, financial, technical, organisational, and social and cultural barriers.

Figure 3: EGDI by Region



Source: United Nations Department of Economic and Social Affairs (2024)

By referring to transparency as the principle mechanism behind flourishing digital anticorruption. Transparency can be either upward or downward. Upward transparency facilitates the government to get feedback from the citizens and learn about the responsibilities of lower-class bureaucrats. This makes senior government employees observe those in the junior ranks to check corruption and misconduct using online reporting systems, crowdsourcing, automated service delivery, and social media platforms. Downward transparency easy flow of information from the government to the public. This expands freedom of information by making data available to citizens through online documents and open data portals. But, greater transparency can simply lead the public officials to hide corrupt activities slightly rather than reducing corruption. Disclosed data bear fruitful conflicts with the privacy against people's rights. For those who are unfamiliar with information communication technology (ICT), they can face difficulties in accessing the digital public services, and hence leads to the expansion of the digital divide. If security measures are not properly secured, whistleblowing sites can jeopardise users. Likewise, blockchain technology raises questions about data protection and regulatory proceedings. No matter the risks associated with the roles of digitalisation. Nevertheless, the e-government tools reduce waiting times, efficiently offer some public services accessible around the clock, and make the services affordable remotely [Ndou et al., 2004]. People can use electronic devices such as smartphones and computers or e-government terminals to submit appeals or requests for public services online. This potentially cuts corruption opportunities and bias from public officials [Elbahnasawy, 2014]. Also, e-government makes it easier to get updates on the accomplishments of public officials and examine the facts on public service delivery.

In the context of anticorruption and good governance prospects, digitalisation has become increasingly revolutionary in the work of all actors and is significantly considered a key in the battle against corruption: public institutions, private sectors, civil society organisations, the media, and civic movements. Many of these actors work beyond distinct stakeholders and sight to prompt these dissimilar actors together. As there are multiple approaches from different departments and activities, the digitalisation can detect corruption and help to elevate income and welfare. In these developments, African countries are progressively seeing digitalisation as a significant tool for detection, prevention, and prosecution [Monitor]. Recently, Sub-Saharan African countries have followed digital innovation in tax administrations to trim bureaucracy and control corruption amongst tax officials. Digitalisation is progressively transforming the operations of tax administrations in innumerable ways, serving to advance processes efficiently and service delivery and trim the degree of corruption through mobilisation and enhancing public participation [Gupta et al., 2017]. For the most corrupt countries, digitalisation collates inbuilt corruption control, thus increasing indirect tax collection as it streamlines the interactions between servers and customers [Monitor, 2019].

The research results stress the worthiness of adopting e-government in the prevention of corruption. From the perspectives of public policy, e-government is an unmatched tool for anti-corruption actions and initiatives that need to be potentially realised by policymakers in addressing public troubles. This paper intends to offer a review of relevant and recent studies on how the digitalisation of the public sector can cut down corruption and possibly promote more sustainable economic advancement and inclusive progress in developing and emerging economies. The task at hand gives analyses on the link between digitalisation (e-government) and perceived corruption, focusing on corruption in the provision of public goods and services, and the resulting implications for sustainability in reducing corruption across the region. To deeply emphasise the analysis of this study with more clarity, this study focuses on e-government, which is, on certain occasions, confused with the term "e-governance," and whether Sub-Saharan African nations gain the most advantages from the increased implementation of e-government of ICT. E-government is the use of digital platforms through technology devices (e.g., computers and the internet) that smoothly increase the manner in which public services are provided to individuals, organizations, businesses, and other people in a country or region [Marche and McNiven, 2003]. Finally, this study examines the strength of the nexus between corruption and e-government using four different econometric models: the generalised method of moments, fixed effects approach, random effects models, and ordinary least squares. These models consider dependent and explanatory variables from 2003 to 2022.

In contrast to the existing research contributions, which merely experimentally demonstrate the connection between corruption and digitization, like those by Ouedraogo and Sy [2020], Paul and Adams [2024], and Kanyam et al. [2017]. This study adds to the existing literature in both theoretical and empirical aspects. Theoretically, this document illustrates how the sophisticated power of digital institutional quality can be leveraged as a modern resource to combat corruption. In addition, the theoretical model discusses the significant interactional behaviours between taxpayers, tax auditors, and tax administrators that influence the degree of corruption. Maiti and Khari [2025] corruption and the size of informality. However, they did not deal with tax evasion, which is much prevalent in Sub-Saharan Africa. This paper reveals that the level of digital-institutional quality determines the growth. The lower the digital-institutional quality and the higher the corruption, the lower the growth. Mere digitalisation is not sufficient for growth unless the institution is better. Empirically, it employs multiple techniques to demonstrate the relationships between the explained and explanatory variables, yielding robust results for macro-policy dynamics. For example, it draws a clear conclusion by comparing the elasticities of ordinary least squares (pooled OLS), instrumental variable (IV–2SLS), fixed effects model (FE) and the generalised method of moments (GMM) for Sub-Saharan African countries, which brings flexibility in policy design, especially for the nexus between corruption and digitalisation in low-income countries whose e-government index is weak, and corruption perception index scores fall below the global average. Secondly, several previous and current studies on the corruption-digitalisation nexus fail to use and recognise the significance of interaction among the regressors, which clearly helps in strengthening policy design. Hence, this study fills the gap by incorporating the interaction between independent and control variables that statistically improves the power of estimators.

We organise the remaining part of this paper as follows: The second section evaluates the main findings from the empirical research by exploring the roles of e-government in cutting down corruption in both low-income and advanced economies, and the challenges of this methodology. The third section presents a basic model that explains the nexus between digital-institutional quality and corruption. The fourth part outlines the data, its sources, and a statistical summary. The fifth section introduces empirical econometric estimations using four different techniques. The sixth part covers the findings, while the seventh part wraps up the research with policy recommendations, limitations, and suggests future research for the gaps found in this study.

2 Literature Review

No definition of corruption is simple, but this paper refers to various definitions that have common characteristics from different scholars and international organisations. For example, corruption is the misuse of entrusted authority for personal gain in violation of rules, UNDP [India] said. Jain [2001], Tanzi [1998], and others have defined it as "the misuse of public authority for private gain" [Rose-Ackerman and Palifka, 2016]. Corrupt acts can be practised in different forms, including theft, embezzlement, bribery, favouritism, clientelism, extortion, lobbying, discretionary abuse, inappropriate political donations, and exploiting conflicting interests [TOOLKIT, 2004, Anokhin and Schulze, 2009]. Tanzi [1998] defines the meaning of corruption as the ill-treatment of public authority or power for personal gain. So, one cannot finalise with certainty that corruption is absent in the private sector. Additionally, Tanzi [1998] examined the prevalence of corruption in large private sectors, particularly in hiring and procurement contexts. In the public sector, it increases public expenditure and reduces tax collection, which adversely affects financial health and also produces macroeconomic dynamics [Mauro, 1995, Bhargava and Bolongaita, 2004]. Previously, scholars studied illegal practices, including corruption. [Ades and Di Tella, 1999, Aidt, 2003, Elliott, 1997, Jain, 2001, Mauro, 1995, Svensson, 2005, Tanzi, 1998] have confirmed that corruption limits economic growth, discourages investment, changes the structure of government expenditure, and usually underscores the goal of a country of reducing poverty and threatening the improvements of welfare and quality of life for rural and underprivileged populations in developing and emerging economies [Bhargava and Bolongaita, 2004]. The use of government corruption indexes in combination with country-level economic data showed that the level of corruption was negatively related to investments and economic growth [Mauro, 1995]. Those analyses also show that a one-standard-deviation improvement in the CP drives a rise in the investment rate of the country by over 4 percentage points and in the annual GDP per capita growth by more than half a percentage point.

Klitgaard [1988] viewed corruption as an issue of unequal information and incentives, illustrated using a basic principal-agent-client framework. In this context, elected officials act as principals for the nation and its clients, and since they cannot personally provide all services themselves, they hire a cadre of civil servants—the agents—including teachers, doctors, labour inspectors, and tax officials to perform public services on their behalf. But because agents know more about the administration than the principals and clients, unequal access to information means corruption occurs when agents opportunistically abuse the power bestowed upon them by corrupt means—usually bribery, nepotism, extortion, fraud, or other means—and exploit that power for themselves. And corruption tends to proliferate, especially in environments characterised by inadequate accountability and transparency [Lio et al., 2011].

Likewise, corruption worsens income inequality and accelerates poverty, which is evidenced by the country data analysis from the world organisations like the International Monetary Fund (IMF) and the World Bank [Gupta et al., 2002, Bhargava and Bolongaita, 2004, Tanzi, 1998] and mostly distorts the poor's lifestyle. Even though the statement that bribery is seen as a means to enhance acceleration and efficiency for the wealthy, in nations with widespread corruption, those without resources are compelled to pay bribes, which are free and provided by the government. Since a greater share of their incomes goes to bribes, which worsens income inequality [Vittal, 2003]. Therefore, as noted by Bhargava and Bolongaita [2004], curbing corruption is essential for furthering economic prosperity, improving social conditions, increasing country competitiveness, and alleviating poverty. Nevertheless, controlling corruption is a hard task, and over the past decades, to address corruption, the responsible bodies or organisations typically started by addressing its underlying causes or drivers of corruption. For example, Kaufmann et al. [1999] identified one of the drivers for corruption as public officials not being accountable and transparent over the mandates that enable them to exploit their authority. The intervention of the government means that its officials make decisions about access to the country's economic resources and opportunities. This shows that the success of individuals or firms does not rely on the market forces of demand and supply but rather on the ability to influence government officials, which adds value to the prevailing corruption [Shabbir and Anwar, 2007].

Shleifer and Vishny [1993] found that corruption is, unfortunately, both widespread and important in all economies, but with significant margins. Rose-Ackerman and Palifka [2016] believes that corruption might have a negative effect on governments and countries, and undermines the legitimacy of a government; reforms to a corrupt government or judicial system are very difficult. Furthermore, corruption creates mistrust between a government and its people and brings unmatched efforts to combat political instability or even the eradication of corruption, nearly impossible [Damania et al., 2004]. Also, the outcome of the bribery mechanism is by no means optimal when the goals of enterprises and politicians do not align with those of maximisation of social welfare [Shleifer and Vishny, 1993]. Wei [1997, 2000] argued that corruption carries a tax effect that weakens the willingness to invest abroad. As per empirical research, Mauro [1995] used data for 58 countries to analyse the nexus between economic expansion and corruption. The result showed that GDP growth and investment have been significantly negatively impacted by the level of corruption. Mo [2001] applied multinational data spanning 1970-1985 and reported that corruption directly leads to a decline in human capital, a cut down in investment, and political misunderstandings, and therefore indirectly impedes economic development. Pellegrini and Gerlagh [2004] contended that corruption impacts inclusive prosperity through trade policies and investment. Notwithstanding, some scholars argue that corruption decelerates economic prosperity by affecting taxes [Imam and Jacobs, 2014]. Also, Gründler and Potrafke [2019] showed the link between corruption and economic growth across 175 nations from 2012 to 2018 by using the index of corruption perceptions (CPI) data constructed by Transparency International. Their analysis indicated that the consequence of corruption on prosperity is mostly perceived in autocratic economies and is transferred to economic prosperity via a worsening in Foreign Direct Investment (FDI) and a rise in inflation.

Corruption is termed as an everlasting threat to human development and economic growth, and examining the perspectives of anti-corruption initiatives seems to be significant with reference to the adopted approach towards the efforts of raising economic prosperity and development [Mutungi et al., 2019]. Existing literature typically dictates either direct or indirect measures or both, but this paper will discuss the studies connected to ICT measures of corruption, which are prevalent with the recent trends of digital society.

However, transforming societies from traditional to digital (modern) has been a priority for nations that are both in development and those that are already developed [Barcevičius et al., 2019]. In this case, combating the expansion of corruption has been fruitful through various means of ICTs and digital tools. The modern technology of curbing corruption comes with both advantages and disadvantages [Drew, 2011], but studies still find more advantages than disadvantages. For instance, the cost of anti-corruption supervision through these means becomes easier, but the expenses of obtaining and installing ICT are extremely elevated for developing countries to afford. Other benefits are increased efficiency of government agencies in processing data; decrease in the time, effort, and expenses of customers and organisations; enhanced public good provisions and citizens' satisfaction; reduction of corruption by promoting transparency that increases the rate of detection in governance; opening government data to public scrutiny; and creation of new business and work opportunities by streamlining governmental procedures, limiting the latitude of officials, and reducing citizens' engagement with intermediaries. Basic services can be provided more efficiently. Allows easy access to information exchanged by government bodies, ministries, and the public. Promote collaborative government—citizen and private governance. Allows monitoring and evaluation of government economic performance, and this naturally heightens public confidence in the government [Maiti and Awasthi, 2020, Batool et al., 2021, Liva et al., 2020, Sharma et al., 2021].

In this context, the paper highlights studies that have used ICTs and digital tools, especially e-governance, to combat corruption. For example, Kim et al. [2009] used electronic governmental data from South Korea between 1999 and 2007 and concluded that wider application of e-government services reduced corruption by increasing transparency and enhancing accountability within the public sector and generating public opposition against corruption. Nevertheless, the adoption of ICTs was equilibrated with a social initiative aimed at raising public consciousness about corruption, intensifying efforts to monitor and report corrupt practices, committing resources to control corruption, and terminating public officials involved in corruption. Bhuiyan [2011] studied that the expansion of e-governance in Bangladesh not only potentially reduces corruption and alleviates poverty but also offers opportunities for cost-effective solutions for enhancing services to citizens. Exploring numerous cases of construction-related corruption underneath the umbrella of huge economic prosperity in the construction projects within Spanish municipalities, Muñoz-Cañavate and Hípola [2011] observed that the employment of e-administration services helped to land several corrupt politicians in prison. Also, they found that the wider use of e-administrative services means increased monetary savings through reductions in public spending.

In analysing the connection between corruption and information and communication technology (ICT), Andersen [2009] employed panel data from 149 nations with two-time observations (t = 1996, 2006) to estimate the consequence of digitalisation on corruption control and demonstrate that increased e-government adoptions can significantly assist in cutting down corruption through a first-differenced estimator that gives nonnegative and statistically economically interesting results. Lio et al. [2011] applied dynamic panel data modelling with Granger causality tests from a panel dataset comprising 70 economies from 1998 to 2005 and revealed that the degree of Internet adoption in an economy significantly reduced the extent of corruption. Bertot et al. [2012] examined how connectivity among collaborative e-government, ICT, and social media fosters transparency and illustrated that the utilisation of e-government services stepped up public transparency and diminished corruption, and also indicated that corruption levels were significantly higher in nations that valued in-person or phone interactions over e-government. Charoensukmongkol and Moqbel [2014] showed that the government's investment in ICT reduces or increases the levels of corruption. However, the expansion in ICT investment allows for technological infrastructures that effectively boost supervision and cut down corruption, but the excess investment may bring a new opportunity for corruption. Some work examines how online perceptions of a government influence corruption perceptions; for instance, Garcia-Murillo [2013] analysed a panel data set of six years from 2002 to 2005 and 2008 for 208 economies. His examination reveals that the presence of government websites has contributed to a global decline in perceptions of corruption and provided a case study of countries that used internet gateways to reduce perceptions of corruption. Using cross-country panel data, Agarwal and Maiti [2019] revealed that digitalisation does not automatically enhance governance unless the judiciary system is effective.

In summary, while numerous studies have empirically demonstrated the link between digitalisation and corruption without considering the effectiveness of institutions in speeding up the detection of corruption, relatively few studies have also demonstrated the theoretical relationship between digitalisation and corruption without taking into account the possible mechanisms of institutions that are prevalent in Sub-Saharan Africa. Due to this disparity, this paper examines how effectively digital tools and institutional quality complement each other to mitigate corruption.

3 A simple model

We use a simple Ramsey-Cass-Koopmans model enhanced by integrating the influence of corruption within the public sector institutions responsible for tax collection and the delivery of public goods, which are carried out by government employees, either in a corrupt environment or through rent-seeking habits in the presence of e-governance. More precisely, the level of e-governance influences the transactions of firms under the scanner of government compliance. A tax auditor may enter into an agreement to hide tax evasion for payments made as bribes by identified tax evaders. If the tax auditor is honest, they may neither conceal tax evasion nor accept bribes; in this case, tax revenue would not be affected. But if the tax auditor is not honest, they may conceal tax evasion and accept bribes, which decreases tax revenue and reduces the tax burden on taxpayers, and restricts the quantity of public goods accessible to the private sector. Still, dishonest public officials may abuse the entrusted authority at the moment of public services provision by imposing unnecessary, excessive red tape that reduces the productivity of private firms. The firms are supposed to incur costs in order to obtain the indispensable public input. Nevertheless, the degree of corruption varies with respect to the strength of the digital-institutional quality. If an economy has a strong digital-institutional quality, the degree of corruption will be small via the discovery of tax evasion, and a significant amount of tax revenue will be secured; conversely, this is true. This exercise aims to model this behaviour. The model includes three sets of agents - households, firms, and government.

3.1 Households

The representative household-producer with infinite life, willing to maximize utility, expressed as:

$$U = \int_0^\infty u[c(t)]e^{-\rho t}\, dt \tag{1}$$

The variable $c(t)$ is consumption, the parameter $\rho > 0$ is the preference for constant time rate, and $u(c)$ has the normal characteristics of positive and decreasing return, $u'(c) > 0$ and $u''(c) < 0$, and satisfies Inada requirements, $\lim\limits_{c\to\infty} u'(c) \to 0$ and $\lim\limits_{c\to 0} u'(c) \to \infty$. We do not assume that the government service directly affects the utility, as in Maiti and Khari [2025]. The population that corresponds to the number of consumers remains unchanged. We consider the isoelastic utility function as follows:

$$u(c) = \frac{C^{1-\sigma} - 1}{1-\sigma} \tag{2}$$

where $\sigma > 0$ captures the intertemporal substitution effect[1]. A fraction of households work for the government; the rest work for private firms under a continuum of firms, given the government policies. The household owns firms and inelastically supplies an amount of labour and capital to them. Following Barro [1990], we assume that the firms have the subsequent Cobb-Douglas production function:

$$y = f(k, \mathrm{g}) = Ak^{1-\alpha}\mathrm{g}^{\alpha} \tag{3}$$

where $0 < \alpha < 1$, A is the productivity of the exogenously total factor, y is the output per capita, and demonstrates constant scale returns in k and g collectively, yet only shows diminishing returns in k. Here, k is the amount of capital per capita of the producer, and g measures the amount per capita purchased by the government[2].

We assume that the government neither produces nor owns capital. So, the government merely uses the tax revenues collected to provide the productive inputs to the private sector. We consider the role of goods and services supplied by the public sector as a factor in private production, creating a possible connection between government, growth, and development [Aschauer, 1989]. The firms obtain these public goods through the overwhelming bureaucracy established by the dishonest officials. Firms report only a fraction of their actual earnings (profits), $(1 - b)y$, for assessment to the tax authority to maximize after-tax income, where b $(0 \leq b < 1)$ denotes the rate of tax evasion, expressed as the proportion of declared earnings to the actual amount. Consequently, each firm pays an income tax amounting to $(1 - b)\tau y$, which is less than the true tax, τy, where τ $(0 < \tau < 1)$ is the tax rate. In this presentation, tax revenue is directly proportional to firm income, i.e., $T(y) = \tau y$. However, the penalty rate represented by $\lambda > 1$ is the punishment policy against tax evasion.

3.2 Government

The government detects tax evaders through regular and random audits of taxpayers. The probability of detection (η) depends on tax evasion (b) and the quality of the digital institution ω $(\omega > 0)$ that captures the power of the tax authority. Mathematically, this probability can be presented as follows:

[1]Barro and i Martin [1992]. explained the intertemporal substitution effect as the trade-off between future consumption in relation to current consumption motivated by the change in relative prices; However, this parameter reflects the Euler approach, which is based on the first-order estimation conditions associated with intertemporal optimisation.

[2]This is different from Maiti and Khari [2025]. The production function they considered is independent of the government investment.

$$\eta = b\omega \tag{4}$$

where $\omega = d\upsilon$, d $(0 < d < 1)$ stands for the level of e-government that conveys digital means of picturing and recording corruption practices, υ $(\upsilon > 1)$ stands for institutional quality (e.g., auditors, inspectors, police forces, legal officers and practitioners, and anti-corruption committees and initiatives). It represents the level of digital-institutional quality. The argument behind this combination is that e-government cannot work alone without the ambitious architect of institutions that bring technical support in exercising corruption detection. However, the performance of the e-government becomes thoroughly effective and more suitable if agreements or corruption are made through ICT devices (e.g., phones, laptops, tablets, fax machines, network cards, audiovisual equipment, etc.).

Furthermore, the workability of this digital-institutional quality depends on the number of cases detected at the given threshold and can be expressed in respect of its strength, given by the following relationship:

$$\kappa = \frac{\omega}{n} = \frac{d\upsilon}{n} = q; \text{(say)} \tag{5}$$

where κ stands for the strength of digital-institutional quality, n stands for the number of cases detected, and q stands for the target (threshold). In the early decades, before the invention of e-government, only institutional quality was used to detect corruption, with the achievements falling below post-e-government. The varying degrees of damaging consequences of corruption depend on the strength of digital-institutional quality that determines the tenacity of the spread and persistence of corruption adoption. The relation stated in expression (5) is strongly argued in the following three scenarios:

Case 1: If $\kappa > q$ indicates that detection has achieved more than the given threshold, it proves that the strength of digital-institutional quality is strong enough to report corruption cases than the target plotted. The low corruption practice happens because the governments and their citizens take actions to devote themselves against corruption. The investment in digital-institutional quality in the countries portraying this behaviour is so high that it neutralises the concealment costs of corruption; the government replies to suspected queries, pending cases, and corruption rumours. For example, this experience of battling corruption can be evidenced by high-income countries that consistently appear to implement corruption policies to the greatest degree. The contact between a taxpayer and a civil servant has been replaced by digital tech innovation.

Case 2: If $\kappa = q$ indicates that the detection has exactly achieved the given threshold, and shows that the strength of digital institution quality is moderate enough to report the same corruption cases as the target plotted. Additionally, this is achieved by countries with stable economies that consistently implement a mission to moderately control corruption activities. Positioning $\kappa \geq q$ does not signify that these countries are purely clean. There are exceptions everywhere, regardless of huge digital investment, free expression, and a strong bond between people and their governments. For example, in advanced economies such as the United States, Rose-Ackerman [2013] asserted that drug dealers and gamblers had to impose entry restrictions or raid competitors by paying bribes to officials or the police department.

Case 3: If $\kappa < q$ indicates that detection has achieved less than the given threshold and proves that the strength of digital-institutional quality is weak enough to report corruption cases than the target plotted. It can happen because the investment in and effort put into the digital-institutional quality is smaller than the concealment cost of practising corruption. However, this case of corruption combat appears to be so irrelevant in low-income economies [Bardhan, 2017], where the systems of achieving the ends of the countries are particularly unproductive, there is weak democratic oversight by civilians regarding governmental actions, and bureaucratic civil servants possess extensive discretionary authority over the provision of public input to private firms (private sectors) [Azariadis and Lahiri, 2002]. In this context, the information gap between agents and their governments is the basic assumption that lies behind this relationship, and more corruption cases create disincentives in investment, weaken economic growth, and result in unnecessary recession. In support of the true consensus behind this scenario $\kappa < q$, the official and private representatives concur to generate revenue from an absence of information controlled by unstable digital-institutional quality, even if their actions are destructive to the well-being of the community, and little voice from the majority is raised against unlawful practice that eventually cannot cure corrupt chronic behaviour.

When the taxpayer is completely detected for evasion, a fine equal to $\lambda\tau by$ is charged. However, if the information of the amount evaded is partial, then the taxpayer will be expected to be charged with the random penalty rate $\overline{m}$ on the evasion revealed as expressed in equation (7). However, the detected tax evader pays a bribe to a corrupt tax auditor to conceal the practice of tax evasion. The corrupt bureaucrats misuse a part of the tax revenues collected through the creation of excessive bureaucratic hurdles and rent-seeking behaviour, and by leveraging the discretionary authority granted to impose barriers on companies seeking to access public goods. The corruption of public officials and the digital-institutional capacity (or quality) determine the magnitude of these extortions.

The implication of this message is that, at any given size of the government, the lower the digital-institutional quality, the higher the magnitude of corruption and tax evasion, and vice versa holds true. We also express the probability of corruption as:

$$p = p(\omega, \epsilon) \tag{6}$$

where p is a twice differentiable and increasing function in the digital-institutional quality parameter ω, $\partial p(\omega, \epsilon)/\partial\omega > 0$ and a decreasing function of corrupt public officials ϵ, $\partial p(\omega, \epsilon)/\partial\epsilon < 0$. The randomness of the penalty rate λ depends on the likelihood of corruption. Similarly, the adjustment of the penalty rate λ depends on the probability of corruption, such as:

$$m = \begin{cases} \lambda = 0 & \text{if not detected with probability } p = 0 \\ \lambda > 1 & \text{if detected with probability } p\ (0 < p < 1) \\ x < \lambda & \text{if detected with probability } 1 - p \end{cases} \tag{7}$$

where x is the bribe rate. And, x is less than the penalty rate, signifying that the legal penalty rate λ is higher than the expected penalty rate $\overline{\lambda}$.

Following equation (7), due to an unknown amount evading, it is to whether the taxpayer is under-reporting their income or over-reporting purchases. In this attempt, the expected random penalty rate is assigned by the following equation:

$$\overline{m} = \lambda p + x(1 - p) \tag{8}$$

For a rational taxpayer, the choice to evade or not to evade is based on the anticipated gains or losses associated with the decision made, subject to detection [Tanzi and Shome, 1993]. This behaviour of the taxpayer is discussed as a kind of game theory in a classical theory paper written by [Allingham and Sandmo, 1972]. The net income of taxpayers after audit and before the random penalty rate is expressed by the following three outcomes.

$$y_\tau = \begin{cases} (1-\tau)y + \tau b y & \text{if the evasion is not detected by the authority} \\ (1-\tau)y + (1-\lambda)\tau b y & \text{if the evasion is detected and penalty is paid to the authority} \\ (1-\tau)y + (1-x)\tau b y & \text{if the evasion is detected but the bribe is paid to the authority} \end{cases} \tag{9}$$

A theoretical underpinning to this information is that a rational tax auditor can detect the true amount evaded by using a suitable digital-institutional quality that identifies the information gap between the reported amount and the actual amount evaded. Through a remarkable information gap, a tax auditor can truly assign a penalty rate λ or receive a bribe x from the taxpayer.

Lemma 1: *Undetected taxpayer income is higher than bribed income after detection, i.e., $\tau by > (1-x)\tau by$*

Proof: Let us consider the net income of a taxpayer after auditing and comparing two cases: if the evasion is not detected by the tax auditor, and if the evasion is detected, but the bribe is paid to the tax auditor, that is $(1-\tau)y + \tau by > (1-\tau)y + (1-x)\tau by$ that finally gives the following inequality:

$$\tau by > (1-x)\tau by \tag{10}$$

The expression on the left-hand side is the evaded tax amount, and the right-hand side is the bribed tax amount, given that $b > x$, and this becomes true if and only if this condition holds, $x > 0$.

However, applying the random penalty after the tax audit, the net income is expressed by the following results:

$$\overline{y}_\tau = \begin{cases} (1-\tau)y + \tau by & \text{with probability } \eta = 0 \\ (1-\tau)y + (1-\overline{m})\tau by & \text{with probability } \eta \ (0 < \eta < 1) \\ (1-\tau)y + (1-x)\tau by & \text{with probability } 1-\eta \end{cases} \tag{11}$$

In fiscal policy and tax administration, the random penalty rate is expected to be implemented due to discrepancies in the information gap between the reported amount and the unreported amount. From the income schemes presented in equation (11), this paper considers the optimal expected after-income tax of the taxpayer as $\overline{y}_\tau = (1-\tau)y + (1-\eta\overline{m})\tau by$, and abbreviating $\pi = 1 - b(1-\eta\overline{m})$. Then, the government can collect tax revenue that is equal to:

$$R = \pi\tau y \tag{12}$$

where, π $(0 < \pi < 1)$ measures the efficiency of tax collection. Under the balanced budget scheme, the revenue collected is divided between the production of public services and the generation of bureaucratic obstacles, written as:

$$\mathrm{g} + f + z = R \tag{13}$$

where g represents the productive public factor that shows development projects and f is the transfer payments, which refers to the negative taxes that are equivalent to fiscal subsidies. They include the income redistribution made by the government to its individuals or community groups without receiving goods or services in return. The fiscal capacities determine the degree of transfer payments, and the degree of transfer payment is essentially subject to the former earnings of the beneficiaries. For instance, the benefits of social security (e.g., compensation for unemployment, senior citizens' insurance, civil services pensions, survivors' benefits, and supplemental security income) and in-kind benefits such as nutrition assistance. However, fiscal transfer is considered a loss of government revenue; hence, it is represented as a part of the tax collected as follows:

$$f = \varepsilon R \Longrightarrow f = \varepsilon \pi \tau y \tag{14}$$

where ε ($\varepsilon > 1$) is the rate of transfer that reflects the size of f. I assume that the fiscal transfer does not affect disposable income, simply because it is not responsible for contributing to tax revenue. μ is the rate of excessive red tape that is used by public employees to oblige taxpayers to pay part of their after-tax incomes. For Sub-Saharan African economies, public institutions are characterized by poor digital quality, which opens more opportunities for bureaucrats to engage in rent-seeking practices by imposing unnecessary bureaucratic obstacles due to the low probability of detection, and the punishment for those detected is relatively small. Basically, the quality character of public institutions determines the expense associated with excessive bureaucratic procedures (red tape), which constitutes a fraction of the government budget, given as:

$$z = \mu \Longrightarrow z = \mu \pi \tau y \tag{15}$$

where $\mu = \mu(\omega)$, $(0 \leq \mu < 1)$, $\mu'(\omega) < 0$, and ω is the measure of the digital-institutional quality. However, private agents incur costs either by paying bribes to the tax officials or paying bribes to the public officials when seeking the public productive good under the excessive bureaucratic procedures. Assume the dishonest public official is in pursuit of a rental amount that is equivalent to the share of excessive red tape, $\phi z = \phi \mu \pi \tau y$, by admitting bribes. With the authority of discretionary power, corrupt bureaucrats can create greater resources than the excessive red tape costs. This rent reduces the after-tax income of the taxpayer, $\overline{y}_\tau - \phi z$, that leads to the following disposable income:

$$y_d = [1 - \pi\tau(1 + \phi\mu)]y \tag{16}$$

where $\pi(1 + \phi\mu) \lesseqgtr 1$ represents the effective tax rate or effective productivity of public spending, $0 < \pi < 1$ represents the efficiency of tax collection, $\pi\mu \lessgtr$ being the amount by which corruption affects efficiency, and $(1+\phi\mu) \lesseqgtr 1$ stands for the capacity of the corrupt bureaucrats. The stability of the effective tax rate, $\pi(1+\phi\mu) = 1$, is more appealing for the private agent's standard disposable income and optimal growth of an economy. Though, it is rarely to happen than the distortions that may be caused by the private sector workers or government employees, and adding-up the disposable income of the private agents and reducing tax collection, $\pi(1+\phi\mu) < 1$ which reduces the burden on the public sector, and reducing the disposable income and increasing tax collection, $\pi(1+\phi\mu) > 1$ which increases the burden on the public sector. In all three cases, $\pi(1+\phi\mu) \lesseqgtr 1$, corruption exists. The lower the value of μ, which represents small corruption, can raise the productivity of public expenditure, and on the contrary, this is true [Bandeira et al., 2001, Ghosh and Neanidis, 2017].

The profit equation of the firm can be expressed as:

$$\Gamma = y - wl - w_{\mathrm{g}}\mathrm{g} \tag{17}$$

where w_{g} is the (shadow) price of public productive input g, and $w_{\mathrm{g}}\mathrm{g}$ is the cost of public productive inputs. These public inputs are supplied directly by the government to the firms, indirectly through taxation. This shows indirectly the connection between the tax monetary value paid by the firm and the monetary value of the public input (public good) it can get. The level of a firm's economic activities determines the costs and number of public inputs. If the level of the firm's economic activities is high, it means that the costs and number of public inputs are expected to be high, and vice versa hold true. Conversely, taxes collected may affect the productive public input provisions as well. Potentially, if the tax collected is high, it indicates the quantity of public goods will be high, and conversely, this is true.

Assumption: (i) The income of a tax auditor, w_a, increases when the bribed income, $(1-p_b)x$, is higher than the penalty value, $p_b\lambda_b$, i.e., $(1-p_b)x > p_b\lambda_b$, and
(ii) The income of a tax auditor, w_a, does not change when the bribed income, $(1-p_b)x$, is equal to the penalty value, $p_b\lambda_b$, i.e., $(1-p_b)x = p_b\lambda_b$.

Consider an auditor with income w_a who enters a tax evasion agreement for a bribe with the entrepreneur. However, the auditor is aware that an inspector can detect the agreement with a given probability p_b, for which he will have to pay the fine λ_b. The auditor chooses between the three possible strategies: to be honest and not take the bribe, to take the bribe and conceal the evidence of evasion, or to be indifferent to either taking the bribe or not, which will finally affect the auditor's income. In this case, the auditor's corruptible behaviour based on strategies is discussed as a kind of game theory [Allingham and Sandmo, 1972]. The change of income is described by the behaviour of the auditor through the following expression:

$$(1 - p_b)x - p_b\lambda_b \gtreqqless 0 \tag{18}$$

Given the inequality equation (18), the income of an auditor remains unchanged, w_a, if he is honest, $x = 0$. But if the auditor possesses a corrupt character, then he is able to accept the bribe if and only if the following condition holds:

$$(1 - p_b)x - p_b\lambda_b > 0 \Longrightarrow p_b < \frac{x}{x + \lambda_b} \tag{19}$$

Now the income of the corrupted tax auditor becomes $w_a+(1-p_b)x-p_b\lambda_b$. Nevertheless, the auditor's strategy is indifferent between taking the bribe or revealing the evasion if the bribe equals the fines, which implies that:

$$(1 - p_b)x - p_b\lambda_b = 0 \Longrightarrow p_b < \frac{x}{x + \lambda_b} \tag{20}$$

In this instance, the increment of the auditor's income is neutral. Diametrically, equations (18), (19), and (20) can be simultaneously used to examine the corruptibility of public officials under three environments—an honest environment that characterized by zero corruption, dishonest environment that public officials set unnecessary excessive red tape for private monetary gains, and indifferent environment that brings balance equal between either taking a bribe or not taking it due to detections and penalties. However, for economic growth and proper public goods provision, an honest environment is the best environment for business progress and sustainable and inclusive development [Aidt, 2003, Alesina and Angeletos, 2005]. This makes the government furnish the productive public inputs to the private firms (sectors) efficiently [Barreto, 2000].

Proposition 1. *Fiscal transfer and red tape (corruption) reduce the amount of public input provision, which ultimately deteriorates total factor productivity (TFP) and the public good-capital ratio.*

Proof: Suppose the portion of the tax collected is shared for fiscal transfer, and part of it is diverted by corrupt bureaucrats, and the rest is left for the provision of public goods, given as

$$\mathrm{g} = R - z - f \Longrightarrow \mathrm{g} = (1 - \varepsilon - \mu)\pi\tau y \tag{21}$$

This shows that a public good is exogenously directly proportional to tax revenue. In optimal public good provision, $\partial \mathrm{g}/\partial y > 0$ and $\partial \mathrm{g}/\partial(\tau y) > 0$, the private firms benefit more from the consumption of public good when tax evasion is relatively small and incur additional costs in acquiring them when tax evasion is higher. Under these circumstances, the government is running a deficit to finance public goods. Also, red tape and fiscal transfer are negatively related to public goods, indicating the decrease in the most effective delivery of public resources by the government to private firms, which finally leads to inefficient resource allocation and distorts capital accretion [Shleifer and Vishny, 1993, Aidt, 2003].

Inserting the value of $y = Ak^{1-\alpha}\mathrm{g}^{\alpha}$ into equation (21) to compare the consequences that occur before and after fiscal transfer and corruption imposition into the economic system, the following results are yielded: $A = \frac{1}{(1-\varepsilon-\mu)\pi\tau}\left(\frac{\mathrm{g}}{k}\right)^{1-\alpha}$ and $A_0 = \frac{1}{\pi\tau}\left(\frac{\mathrm{g}_0}{k}\right)^{1-\alpha}$, therefore $A < A_0$, given that $\mathrm{g} < \mathrm{g}_0$.

where A is the value of total factor productivity, which is affected by the fiscal transfer and red tape, i.e., corrupt environment, while A_0 is the initial value of total factor productivity without fiscal transfer and red tape, clean environment. However, $A < A_0$ can be presented as $A/A_0 < 1$, which essentially can be written in the following inequality:

$$\frac{A}{A_0} = \frac{1}{(1-\varepsilon-\mu)} < \left(\frac{\mathrm{g}_0}{\mathrm{g}}\right)^{1-\alpha} \tag{22}$$

Empirically, the impact of corruption on Solow residual (TFP) was confirmed to be negative by Kéïta and Laurila [2021] after employing the system GMM for a panel data from 90 countries worldwide over 1996–2014.

Notwithstanding, the public good-capital ratio in clean and unclean environments are expressed in the following equations: $\left(\frac{\mathrm{g}}{k}\right) = (A(1-\varepsilon-\mu)\pi\tau)^{\frac{1}{1-\alpha}}$ and $\left(\frac{\mathrm{g}_0}{k}\right) = (A_0\pi\tau)^{\frac{1}{1-\alpha}}$, hence $\left(\frac{\mathrm{g}}{k}\right) < \left(\frac{\mathrm{g}_0}{k}\right)$, given that $A < A_0$.

where g_0 represents the public factor in the environment without fiscal transfer and corruption. Nevertheless, $\left(\frac{\mathrm{g}}{k}\right) < \left(\frac{\mathrm{g}_0}{k}\right)$ can be expressed as $\left(\frac{\mathrm{g}}{k}\right)/\left(\frac{\mathrm{g}_0}{k}\right) < 1$, which possibly after making simplifications can be presented in the following inequality:

$$\frac{\mathrm{g}}{\mathrm{g}_0} = \left(\frac{(1-\varepsilon-\mu)A}{A_0}\right)^{\frac{1}{1-\alpha}} < 1 \tag{23}$$

The ratio shown in equation (23) shows that the public productive input after transfer and corruption, g, is smaller than the input spent before transfer and corruption, g_0. This illustration aligns with Oh and Reis [2012].

3.3 Optimal tax evasion and growth

The problem of representative households is the efficient allocation of capital and public good inputs across time that maximises their intertemporal desired utility. No-Ponzi

Condition (NPC) is imposed on the quantity of borrowing by households in order to rule out such chain-letter possibilities; the suitable limitation appears to be that the value of assets at present must be asymptotically nonnegative $\lim_{c\to\infty}\left\{a(t)\cdot\left[exp - \int_0^\nu r(\nu)\,d\nu\right]\right\}$, and that in the long-run the level of debt cannot grow as fast as the interest, r(t). Recall that the per capita income was given in equation (16) as $y_d = [1-\pi\tau(1+\phi\mu)]$. Then the maximisation problem for the home is designed as follows.

$$\begin{aligned} \max_{c,b}\ U &= \int_0^\infty \frac{c^{1-\sigma}-1}{1-\sigma}e^{-\rho t}\,dt \\ \text{s.t. } \dot{k} &= [1-\tau(1+\phi\mu)(1-b(1-\eta\overline{m}))]y - c \\ \lim_{c\to\infty} k\cdot\mu &= 0 \end{aligned} \tag{24}$$

where the last constraint is the transversality condition. Optimizing the dynamic value of U subject to the constraint provided in equation (24), by considering the value of $\eta = b\omega$, gives the following present value of Hamiltonian function:

$$H = \frac{c^{1-\sigma}-1}{1-\sigma}e^{-\rho t} + h\{[1-\tau(1+\phi\mu)(1-b(1-\eta\overline{m}))]y - c\} \tag{25}$$

where $\dot{k}$ from equation (24) equals the expression in the braces in equation (25). The variable h represents the costate, which indicates the shadow value price of income, representing the worth of an incremental income received at time t expressed in utils at time 0. However, this shadow price is time-dependent as there exists a distinct value for each constraint, and a household encounters a continuous range of constraints, one for every particular point in time. Pontryagin's initial order requirements for achieving a maximum principle are:

$$\frac{\partial H}{\partial c} = c^{-\sigma}e^{-\rho t} - h \Longrightarrow h - c^{-\sigma}e^{-\rho t} \tag{26}$$

$$\dot{h} = -\frac{\partial H}{\partial k} \Longrightarrow -\dot{h} = h([1-\tau(1+\phi\mu)(1-b(1-b\omega\overline{m})])\frac{\partial y}{\partial k} \tag{27}$$

$$\frac{\partial H}{\partial k} = 0 \Longrightarrow b^* = \frac{1}{2\omega\overline{m}} \tag{28}$$

The result from equation (28) indicates that the rate of tax evasion is inversely related to the quality of digital-institution and the expected rate of penalty. This result is particularly intuitive when the digital-institutional quality is sufficiently strong to detect tax evasion and discourage corrupt practices. However, the negative relationship, $\partial b^*/\partial\omega < 0$, exists in advanced economies such as nations in North America and Europe that experience negative correlation between corruption and e-government, while the vise versa of scenario, $\partial b^*/\partial\omega > 0$, has been proven to exist in developing countries such as countries in South Asia and Sub-Saharan Africa that confirm positive association between corruption and e-government [Yamen et al., 2023]. This conjecture is partially theoretically confirmed by Attila [2008] and Djumashev [2006], and empirically verified by the studies, which show that the governments that implement digitalisation policy in their governing systems have strong e-government practices that are characterised by low corruption and tax evasion [Uyar et al., 2021, Nimer et al., 2022]. Substituting $\overline{m} = \lambda p + x(1-p)$ into equation (28), hence the optimal tax evasion is given as:

$$b^* = \frac{1}{2\omega(\lambda p + x(1-p))} \tag{29}$$

Note that b^* is negatively related to ω. The consumption growth rate for the given economic system is derived by substituting equation (26) and its derivative into equation (27); then the equation for the consumption growth rate is

$$\gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}\left([1-\tau(1+\phi\mu)(1-b(1-b\omega\overline{m}))]\frac{\partial y}{\partial k} - \rho\right) \tag{30}$$

$\partial y/\partial k$ is given as the first-order derivative of the output, $y = Ak^{1-\alpha}\mathrm{g}^{\alpha}$ with respect to per capita physical capital. Then $\partial y/\partial k$ yields the following equation:

$$\frac{\partial y}{\partial k} = A\left(\frac{\mathrm{g}}{k}\right)^{\alpha}(1-\alpha) \tag{31}$$

By substituting equation (31) into equation (30), the rate of growth of consumption is represented as:

$$\gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}\left([1-\tau(1+\phi\mu)(1-b(1-b\omega\overline{m}))]A\left(\frac{\mathrm{g}}{k}\right)^{\alpha}(1-\alpha) - \rho\right) \tag{32}$$

The consumption growth rate given by equation (32) resembles the Euler equation, which characterises the time-path of the growth rate of optimal per capita consumption, which is parallel with the result, a balanced growth path without transitional dynamics, given by Del Monte and Papagni [2001], and Mauro [2004]. This consumption growth rate captures the corruption effect on growth with reference to the digital-institutional quality. This expression depicts that the return on private capital investment is relatively smaller in a corrupt environment compared to a clean one. Additionally, this consequential relationship suggests that capital accumulation is less favourable in a corrupt environment than in a pristine one, due to the low attractiveness of investments. However, this growth rate depicts dynamic consumption patterns, $\dot{c}/c = 0$ shows flat consumption if the change in digital-institutional quality equals the change in corruption, which is common in upper-income economies, $\dot{c}/c > 0$ shows that consumption is compensated for by a higher change in digital-institutional quality than the rise in corruption, which is common in high-income economies, and $\dot{c}/c < 0$ represents the loss of consumption due to weak digital-institutional quality against the rise in corruption rate, which is common in low-income countries.

Proposition 2. *Both tax and corruption are negatively related to growth, i.e.,* $\frac{\partial \gamma}{\partial x} < 0$ *and* $\frac{\partial \gamma}{\partial \tau} < 0$.

Proof: Consider the first derivative of growth, equation (32), with respect to tax, τ, and corruption, x. It shows that the coefficient of the first derivative with respect to corruption is zero, $\left(\frac{\partial \gamma}{\partial x} < 0\right)$, indicating that corruption exhibits a negative correlation with economic growth, which is consistent with the empirical findings in De Vaal and Ebben [2011], d'Agostino et al. [2016], and Gründler and Potrafke [2019]. The model also shows that tax reduces growth, $\left(\frac{\partial \gamma}{\partial \tau} < 0\right)$, which is in line with empirical works by Scully [1996], Lee and Gordon [2005], and Canavire-Bacarreza et al. [2013].

3.4 Optimal tax rate and digitalisation

The objective of any benevolent government is to maximise the welfare of households. Throughout this study, the Cobb-Douglas production function has been used, in which utility maximisation coincides with growth maximisation. To maximise growth, the government chooses the optimal tax rate, the optimal penalty rate, and the optimal digital-institutional quality parameters. The optimisation problem related to tax evasion, corruption, and digital-institutional quality can be written in the following setting.

$$\max_{\tau,\lambda,\omega} \gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}\left(([1-\tau(1+\phi\mu)(1-b(1-b\omega\overline{m})])A\left(\frac{\mathrm{g}}{k}\right)^{\alpha}(1-\alpha)-\rho\right) \tag{33}$$

Solving (33) yields the following optimal tax rate:

$$\tau^* = \frac{\alpha}{(1+\phi\mu)\,(1-b[1-b\omega(\lambda p + x(1-p))])} \tag{34}$$

Throughout the model used, the optimal tax rate is not constant and depends on tax evasion, penalty, and digital-institutional quality. Also, it is inconsistent with the constant optimal tax rates in optimal growth models and productive fiscal policies of Barro [1990], Turnovsky and Fisher [1995], Glomm and Ravikumar [1997], and Mauro [2004], which are the shares of productive inputs. In the same meaning, Barro's optimal tax rate is $\tau_B = \alpha$, while in our framework the denominator is $(1+\phi\mu)\,(1-b[1-b\omega(\lambda p + x(1-p))]) \lesseqgtr 1$. Hence, our optimal tax rate can be greater than, equal to, or less than Barro's result, $\tau \lesseqgtr \tau_B$, and this depends on the denominator's value in our answer. This implies that, $\tau < \tau_B$ if $(1+\phi\mu)\,(1-b[1-b\omega(\lambda p + x(1-p))]) > 1$, $\tau = \tau_B$ if $(1+\phi\mu)\,(1-b[1-b\omega(\lambda p + x(1-p))]) =$

1, and $\tau > \tau_B$ if $(1+\phi\mu)\left(1-b[1-b\omega(\lambda p+x(1-p))]\right) < 1$. Still, the values of $\partial\tau^*/\partial b$, $\partial\tau^*/\partial\lambda$, and $\partial\tau^*/\partial\omega$, rely on interplay between the parameters of the denominator's value of our result. However, the optimal tax rate of ours can be shaped by the environment with corruption and the environment without corruption, as explained in Proposition 3. In translational dynamics, Boldrin [1992] confirmed that the equilibrium tax rate is nonconstant, which is quite similar to our optimal tax rate.

Maximising (33) gives the following optimal penalty rate:

$$\lambda^* = \frac{\alpha p\omega B_0 b^2 - (1-\alpha)B_1 B_2}{p\omega B_1 b^2} \tag{35}$$

where $p\omega B_1 b^2 \neq 0$, $B_0 = [1-\tau(1+\phi\mu)(1-b+(1-p)x\omega b^2)]$, $B_1 = \tau(1+\phi\mu)p\omega b^2$, and $B_2 = 1-b+(1-p)x\omega b^2$. The result (35) shows that the computation of the optimal penalty rate by policymakers considers various determinations, including burden to the public sector, digital-institutional quality, tax evasion, and bribery. Since bribes are among the parameters that stand as a domain of optimal penalty rate, as suggested by Basu et al. [1992], the penalty rate or fine should be a function of bribes specified by the country's law. Contrary to Basu's penalty rate calculation, not only bribes but also other factors should be observed when designing the optimal penalty rate function, as presented by result (35). Because $\lambda^* > 1$, then $(\alpha B_0 - B_1)p\omega b^2 > (1-\alpha)B_1 B_2$.

Equation (33) yields the optimal digital-institutional quality as:

$$\omega^* = \frac{\alpha\overline{m}A_0 b^2 - (1-\alpha)(1-b)A_1}{\overline{m}A_1 b^2} \tag{36}$$

where $\overline{m}A_1 b^2 \neq 0$, $\overline{m} = \lambda p + x(1-p)$, $\pi = 1-b+\overline{m}\omega b^2$, $A_0 = 1-\tau(1-b)(1+\phi\mu)$, and $A_1 = \tau(1+\phi\mu)\overline{m}b^2$. Similarly, the computation of optimal digital-institutional quality value requires a combination of multiple parameters. Simply because digital-institutional quality is a multitask policy instrument; for example, it can detect corruption and audit and inspect tax officials and bureaucrats. In one way, e-government can capture illegal transactions done by using ICT devices, and in another way, institutions can conduct auditing and detect illegal transactions operated without ICT devices. The combination of e-government and institutions plays a crucial part in reducing the pervasive effect of corruption. Explanations regarding the strength of optimal digital-institutional quality were discussed in the relationship expressed by equation (5). Since $\omega = d\nu$, we can express e-government as

$$d^* = \frac{\alpha\overline{m}A_0 b^2 - (1-\alpha)(1-b)A_1}{\nu\overline{m}A_1 b^2} \tag{37}$$

The formula (36) implies that e-government is a functional combination of institutional quality and other parameters that express the function of e-government.

Proposition 3. *(i) The tax rate in a corrupt environment is less than the optimal tax rate in an environment free from corruption, $\tau^* < \tau_0$, and (ii) Digital-institutional quality positively influences tax growth, $\frac{\partial \tau^*}{\partial \omega} > 0$.*

Proof (i): Contrast the rate of optimal tax in the corrupt environment and the rate of optimal tax in the environment without corruption; however, the case without corruption holds if $\phi\mu = 0$, then the inequality can be expressed in the following manner:

$$\tau^* < \tau_0 \Longrightarrow \frac{\alpha}{(1+\phi\mu)\left(1 - b[1 - b\omega(\lambda p + x(1-p))]\right)} < \frac{\alpha}{(1 - b[1 - b\omega(\lambda p + x(1-p))])} \tag{38}$$

where τ_0 is the optimal tax rate without corruption. This expression becomes interesting after simplifying and obtaining the inequality condition that holds the meaning $\phi\mu > 0$.

Proof (ii): The positive interdependence relationships between the quality of the digital-institutions and optimal tax are observed from the first derivative of the optimal tax rate equation 34, $\frac{\partial \tau^*}{\partial \omega} > 0$. This indicates that the effectiveness of digital tools strengthens institutions by enhancing accountability and transparency, ultimately facilitating smooth tax collection processes. This key message informs the tax departments of the developing countries to ignore the analog and switch to the digital mechanism of dealing with the tax operations, which enhances the efficiency of the tax systems. The potential interplay of the mechanism can also help finance a strong digital installation and increase the provision of public goods and productive inputs to the private sector, and hence expand growth.

Proposition 4. *The optimal growth rate without corruption is greater than the optimal growth rate with corruption, i.e., $\tau^* < \tau_0$*

Proof: This proposition can be achieved by comparing optimal growth rates with and without corruption. Consider the growth rate with corruption given by $\gamma = \frac{1}{\sigma}\left(([1 - \tau(1+\phi\mu)(1 - b(1 - b\omega\overline{m})])\frac{\partial y}{\partial k} - \rho\right)$, and the growth rate without corruption means that $\phi = 0$ and $\mu = 0$, which is expressed as $\gamma = \frac{1}{\sigma}\left(([1 - \tau(1 - b(1 - b\omega\overline{m})])\frac{\partial y}{\partial k} - \rho\right)$. Comparing the two expressions of optimal growth rates, we find that $\gamma < \gamma_0$ and confirm only if the following ratio relation exists:

$$\frac{1 - \tau\left(1 - b(1 - b\omega(\lambda p + x(1-p)))\right)}{1 - \tau\left(1 - b(1+\phi\mu)(1 - b\omega(\lambda p + x(1-p)))\right)} > \left(\frac{1 - \varepsilon - \mu}{1 - \varepsilon}\right)^{\frac{\alpha}{1-\alpha}} \tag{39}$$

The left-hand side expression is the ratio between the after-tax tax in an environment without corruption and the environment with corruption. Here, the denominator is relatively smaller than the numerator, and the ratio must be greater than one. On the right-hand side, the numerator is relatively smaller than the denominator, and the value of this expression is approximately less than 1. Finally, the left-hand side must be greater than the right-hand side, even when the ratio of the right-hand side approaches one.

Equation (32) indicates a positive correlation between the digital-institutional quality and growth.

Proposition 5. *Digital-institutional quality improves growth,* $\frac{\partial \gamma}{\partial \omega} > 0$.

Proof: Again, this can be done by taking the first derivative of growth, γ, with respect to the digital-institutional quality, ω. The result shows a positive correlation between the digital-institutional quality and growth, $\frac{\partial \gamma}{\partial \omega} > 0$. The stronger the institution (ν), the higher the economic growth, and the higher the digital development (d), the more growth is achieved. But our model combines both into one term, known as the digital-institutional quality, that concurrently considers the role of both instruments in detecting corruption and finally increases growth. This study is marked to employ the role of the digital-institutional quality index in raising growth detection and combating corruption.

In summary, we have modelled the corruption-growth nexus by incorporating digital-institutional quality and have successfully demonstrated a few outcomes: The detrimental effects of corruption reduce the provision of public goods, distort investment incentives, and lower the productivity of the private sector. The negative consequences of corruption result in diminished growth potential, reduced sustainable and inclusive development, and exacerbated income inequality between the affluent and the impoverished. Nevertheless, proper use of digital-institutional tools could lead to less corruption and make the economy transition from low quality to high quality. Furthermore, the next section of the paper empirically tests the relationship between digital-institutional quality and corruption by employing econometric techniques. The section will help to verify the theoretical strength of the model and conclude the empirical implications of the nexus for the developing countries.

4 The empirical strategy

4.1 The data and sources

This research considers corruption as the dependent variable. [India] characterizes corruption as "the abuse of entrusted authority for personal gains through extortion, bribery, nepotism, fraud, power brokering, money laundering, or embezzlement." Transparency International (2023) formulates and disseminates the Corruption Perceptions Index (CPI), which assesses the perceptions of corruption as observed by business people and evaluates countries on a scale of 0 (extremely corrupt) to 100 (completely clean) across 180 nations. The CPI refers to the perceived degrees of corruption within public institutions in various countries and territories around the world, as assessed by 13 autonomous opinion polls and expert evaluations (Transparency International, 2023). The data show that more than two-thirds of the countries scored below 50 percent, which strongly proves that these countries have insignificant serious issues with corruption. The world average is about 43 percent, while many countries have not shown any progress and have grown worse in the previous decades.[3] However, before the year 2012, Transparency International reported the CPI scores ranging on a scale from 0 (extremely corrupt) to 10 (purely clean). Therefore, this paper converted the reported scores to 100 scales to adapt the data from 2012 onward.

The primary explanatory variable used in this research is the e-government development index (EGDI), which was first released in 2003. E-government refers to the usage of information technology and communication systems, particularly online Internet applications, by public offices to efficiently provide public services at different levels, increasing efficiency and facilitating the accessibility and provision of public services and information to individuals, employees, commercial associates, additional organizations, and state authorities [Abramson and Morin, 2003]. The economic and social affairs department of the United Nations (UNDESA), public administration and development management division (DPADM) (2022) establishes and disseminates the index of E-Government development (EGDI) that relies on a thorough analysis of the digital response of all 193 United Nations Member States, evaluating national websites, and the implementation of e-government policies and strategies in both general usage and specific sectors for the provision of key services. The assessment ranks the country's e-government performance relative to others, but it is not a perfect measurement.[4] The EGDI varies from 0 (least developed) to 1 (most developed). Additionally, this paper examines three key composite attributes of e-government: the human capital index, the telecommunication infrastructure index, and the provision of online services index, in conjunction with the E-participation index, which is derived as a subsidiary index to the EGDI, capturing citizens' participation in government-related processes and services. This study covers 44 Sub-Saharan African economies, and the list is given in the appendix.

Along with the explanatory variables, there are considerable control variables: gov-

[3] see https://www.transparency.org/en/cpi/2023

[4] see https://publicadministration.un.org/egovkb/en-us/About/Overview/-E-Government-Development-Index

ernment effectiveness, rule of law, political stability, and the log of real GDP per capita that present key anti-corruption variables. The real GDP per capita is the gross domestic product per person modified for variations in currency purchasing power [Kravis et al., 1978]. The World Justice Project defines the rule of law as an enduring framework of laws, standards, institutions, and citizen dedication that expresses four common principles: open government, just law, accountability, and accessible and unprejudiced justice. [5] Kaufmann et al. [2009] considered the quality of property rights, the police, contract enforcement, and the courts to observe the strength of the law and impartiality of the legal system, and the confidence that the agents possess when implementing legal procedures. With reference to the World Governance Indicators (WGI), the government effectiveness measures the views on the quality of public services, the standard of civil services and the varying degrees of their freedom from political imperativeness, formulation of policy, strength of implementation, and the credible commitment of the government to adhere to such frameworks [Kaufmann et al., 2009][6] The absence of violence or terrorism and political stability is defined by the World Governance Indicators (WGI) as an indicator of the likelihood of perceptions of political unrest or politically prompted violence, including terroristic violence that shows the political climate of the state where the government is being stabilized or destabilized or overthrown by unconstitutional actions Kaufmann et al. [2009].[7] The WGI and Kaufmann et al. [2009] annually publish the indices of rule of law, political stability, and government effectiveness, whose values vary from -2.5 (extremely undetected, insignificant, ineffective, inappropriate or unstable) to 2.5 (highly detected, significant, effective, appropriate, or stable). Lastly, Table 12 shows the institutions that have been constructed from the rule of law, political instability, government effectiveness, and voice & accountability using the principal component analysis (PCA).

4.2 Summary statistics

Table 2 presents the summary statistics for the dependent variable and explanatory variables utilised in this study. The table indicates that the mean score of the Corruption Perception Index (CPI) in Sub-Saharan African countries is around 31, with the highest score value of 40 and the lowest score value of 4. Similarly, the average score value of the EGDI is around 30%, with the highest score value of 74% and the lowest score value

[5] see https://worldjusticeproject.org/about-us/overview/what-rule-law

[6] see https://databank.worldbank.org/metadataglossary/worldwide-governance-indicators/series/GE.EST

[7] see https://databank.worldbank.org/metadataglossary/worldwide-governance-indicators/series/PV.EST

of 0%. The standard deviation indicates that the volatility of the corruption perception index is 11.83, while for the EGDI it is 13.6%. The mean value of digitalization serves as a composite of e-government for the telecommunication infrastructure index, the online service index, and the human capital index, which are 14.1%, 25%, and 50.2%, with a maximum score value of 82%, 83.3%, and 90.4%, and a minimum score value of 0.2%, 0%, and 0%, respectively. The index of government development is published solely for the years 2003, 2004, 2005, and 2008, and then every 2 years thereafter (UNDESA, 2022). According to Transparency International (2023), the low-corruption Sub-Saharan African countries are: Seychelles (71%), Cabo Verde (64%), and Botswana (59%), while the high-corruption countries are Equatorial Guinea (17%), South Sudan (13%), and Somalia (11%). Hence, the data points totalled 432, as noted in Table 2, which capture the e-government data available for 11 years from 44 Sub-Saharan African economies.

Table 3 presents a pairwise correlation matrix, indicating a positive correlation between the dependent variable and the explanatory variables for the entire sample. For example, positive correlations were revealed in the following key regressors: EGDI, the telecommunication infrastructure index, the e-participation index, the online service index, the human capital index, subscribers, government effectiveness, political stability, rule of law, and real GDP per capita. With a value of about 0.532, the corruption perception index has a positive correlation with digitalisation. This association is parallel with the literature done by Pathak et al. [2007] and Mistry and Jalal [2012], where both reveal a positive relationship between corruption perception index and the EGDI. Obviously, in the analysis, we can be genuinely sure that these findings will yield the most precise estimated results. Obviously, based on the characteristics of the data set, showing both quick and slow changes between EGDI and corruption scores is beyond the reach of this research. Through GMM, we compute the dynamics, and it is indispensable to investigate them thoroughly to fully grasp how EGDI and corruption interact over time.

5 The empirical model

This study utilises panel data from 44 Sub-Saharan African countries to examine whether the digital government service reduces corruption levels. We structure the econometric model as follows:

$$corruption_{it} = \beta_0 + \beta_1 digitalisation_{it} + \beta_2 X_{it} + \gamma_i + \varepsilon_{it} \tag{40}$$

where i and t denote nations and years, correspondingly; Corruption denotes the illicit economic actions that are neither taxed nor disclosed to the government officials; β_0 is the constant, β_1 and β_2 are the coefficients of the main predictor variables. Digitalization is defined as the adaptation of ICT (EGDI, online service index, telecommunication infrastructure index, human capital index, and electronic participation index) for digitizing government services, deliveries, and administration. X_{it} captures control variables that include political instability, rule of law, government effectiveness, real GDP per capita, and extended robustness regressors such as interaction between EGDI and government effectiveness, and interaction between the log of real GDP per capita and government effectiveness; γ_i is a constant characteristic of a country i; and ε_{it} is the error term. Equation (40) explains both the pooled OLS and the fixed effects estimates. The pooled OLS model assumes that there are no unseen effects specific to entities, regressors are uncorrelated with error terms if the model is correctly specified and γ_i is constant between countries, while the assumptions of the fixed effects model are zero conditional mean that is mathematically expressed as $E(\varepsilon_{it}|\gamma_{it}, digitalisation_{i1}, ..., digitalisation_{iT}) = 0$ and γ_i are random variables that capture unobserved heterogeneity Chamberlain [1980], observations between entities are independent and identically distributed from their joint distribution. More importantly, the fixed effects (FE) model is one variant of Equation (40), which treats γ_i as an unobserved random variable that is potentially correlated with the observed regressors $digitalisation_{it}$ [Cameron and Trivedi, 2005].

$$corruption_{it} = \alpha + \rho corruption_{i,t-1} + \beta digitalisation_{it} + \theta control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (41)$$

The additional variables from the former model are $corruption_{i,t-1}$ is a one-year lag of $corruption_{it}$, and γ_t is the time-specific effect. However, this follows a two-step system GMM standard by Arellano and Bover [1995] and Blundell and Bond [1998] instead of Arellano and Bond [1991], both employ instruments in terms of lagged values. However, the system GMM estimator can achieve greater estimation efficiency compared to the difference GMM because it uses more instruments [Lio et al., 2011]. The dynamic panel data model specified in Equation (41) has numerous advantages over the model outlined in Equation (40) for the following reasons. To begin with, corruption seems to persist, as noted in the literature. For example, Tirole [1996] illustrated the tradeoff transfer of corruption practice from corrupted old members to noncorrupt new members of the organization by asserting that the new organization members may suffer from the corruptible behaviour left by the old members, and this translation concludes the necessary and sufficient principles that rebuild the group's reputation and titles. Mauro [2004] argues that individuals and organizations do not have incentives to combat widespread corruption in countries, even if citizens would benefit if corruption were eliminated. Likewise, Mishra [2006] argues that corruption experiences a strong inclination to prevail as individual norms become immune to interventions regardless of the quality of anti-corruption measures, initiatives, and incentives. In order to analyse the corruption persistence, we really need to work on a dynamic econometric model with lagged dependent variables as shown in Equation (41). Secondly, the possibility of using the corruption-digitalization nexus adopted in Equation (40) that carries the endogeneity problem and inconsistent coefficients arises due to the inability to rectify this problem.

To determine the problem of endogeneity, an instrumental variable is adapted in the dynamic panel data model, which is termed the GMM estimator that employs the dynamic characteristics of the data to produce appropriate instrumental variables [Lio et al., 2011]. Estimating Equation (41) may produce several econometric problems, such as first, the digitalization of explanatory variables is assumed endogenously; second, the correlation between the fixed effect of the country and the explanatory variables may exist; and third, autocorrelation may persist due to the presence of the dependent variable lagged $corruption_{it-1}$ in the regressors. Furthermore, the panel of this study contains a short time dimension (T) and a large nation dimension (N). Equation (41) is not suitable for a pooled OLS because it has the potential to produce inconsistent and biased elasticities. The GMM estimator established by Arellano and Bond [1991] and suggested by Holtz-Eakin et al. [1988] solves the above problems, possesses multiple traits. To tackle the endogeneity issue, the method removes the lagged endogenous variables and uses them as tools instead. Next, taking first differences helps wipe out fixed effects from the model. Then again, to handle autocorrelation, past values of the dependent variable act as proxies. Lastly, the Arellano-Bond method works well when the problem has many individuals associated but few time frames. This study utilizes the system GMM method as an augmented version of the Arellano-Bond method to help figure out Equation (41). This approach uses the actual values to build a setup with two sections—one using raw data (levels), the other using changes (differenced) between points, given below:

$$corruption_{it} = \alpha + \rho corruption_{i,t-1} + \beta digitalisation_{it} + \theta control_{it} + \mu_i + \lambda_{it} + \varepsilon_{it} \quad (42)$$

$$\Delta corruption_{it} = \rho \Delta corruption_{i,t-1} + \beta \Delta digitalisation_{it} + \theta \Delta control_{it} + \Delta \lambda_{it} + \Delta \varepsilon_{it} \quad (43)$$

where Δ is the first difference operator. Provided that connection between the lagged dependent variables ($\Delta corruption_{i,t-1} = corruption_{i,t-1} - corruption_{i,t-2}$) and the residual ($\Delta \varepsilon_{i,t} = \varepsilon_{i,t} - \varepsilon_{i,t-1}$), as well, by combining the equations, additional instruments are obtained which yield more efficient parameter estimates as in Arellano and Bover [1995], Blundell and Bond [1998] and significantly improve efficiency [Roodman, 2009]. The autocorrelation test (AR(2)) and the Hansen over-identification test restrictions are applied to test the consistency of the system. Most importantly, the system GMM is robust to unbalanced panels and gaps in the datasets Roodman [2009], which is the case for this study.

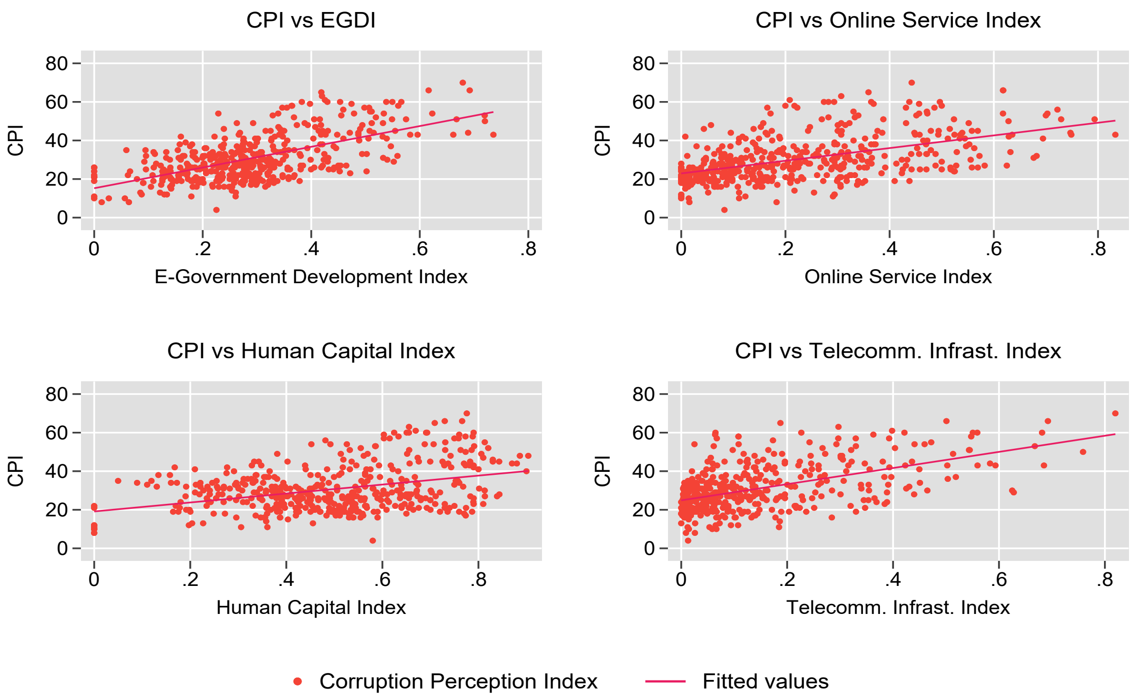
6 Results

In this part, we show the results of our model estimates. Tables 8 to 11 present the findings of the study for the complete sample, considering various baseline regressors such as the e-government index, the telecommunication infrastructure index, the human capital index, the online service index, and the e-participation index. For a robustness check, the study extends to include numerous regressors such as government effectiveness, rule of law, political stability, log of real GDP per capita, intersection of development index and government effectiveness, and interaction of log of real GDP per capita and government effectiveness. Conveniently, I show that significant reductions of corruption are connected to better access and usage of e-government services, which are typical variables used in this study. Figure 4 represents scatter plots with fitted value lines of different positive slopes, which display distributional effects and the correlation between the y-label variable and the x-label variable differently. For example, figure 4a (CPI vs EGDI) shows a steep slope that depicts the strong positive correlation between the e-government development index and corruption perception index, followed by figure 4d (CPI vs Telecom. Infrastructure Index), figure 4c (CPI vs Online Service Index), and figure 4b (CPI vs Human Capital Index). These relationships portray the same correlation represented in Table 6, which coincides with the same positive correlational statistics as 0.615, 0.543, 0.509, and 0.370, for figures 4a, 4d, 4c, and 4b, respectively.

6.1 Results for the whole sample

The indicators and measures for the dependent and independent variables utilised in this examination, together with their secondary, are presented in Table 1. Multiple regression analysis on dependent and explanatory variables was conducted by using the least square methods (Pooled OLS), instrumental variable (IV–2SLS), fixed effects model (FE), and Arellano-Bond system generalized method of moments (GMM) based on the data from the year 2003 to 2022 over 44 Sub-Saharan African countries. Since not all variables were reported equally from all countries, this affected the degree of freedom. Each table from Table 8 to Table 11 contains columns representing robust results that move from the left side (column 1) to the right side (column 8). The effective sample sizes for OLS and FE, IV–2SLS, and Arellano-Bond system GMM are 432, 419, and 388, respectively. Tables 8 to 11 display the Arellano-Bond AR(2) test, which shows that the null hypothesis, which posits the absence of autocorrelation, can not be rejected. This suggests that there is no significant problem of second-order serial correlation present in the models [Roodman, 2009]. Also, a considerable degree of cross-country variation in corruption can be explained by the explanatory variables through the adjusted R-squared, R^2. Finally, the value of the Hansen test p-value presented from these tables is great enough to fail to reject the (constructed) orthogonality conditions at standard levels of confidence, declaring that the overidentification restrictions are acceptable.

Figure 4: Corruption Perception Index (CPI) and E-Government



Source: Transparency International (2022) and the United Nations (2022)

Table 8 concludes the possible results produced from different methods for the whole sample, and one of the methods can effectively figure out the endogeneity issue (IV and system-GMM). In column (1), we applied the simple least squares regression (pooled OLS), which consists of the e-government development index (EGDI) and the corruption perception index (CPI) (log). The regression provides a positive and significant coefficient of EGDI (1.646) even at the 99% confidence level, indicating that a one standard deviation rise in EGDI leads to an increase in the corruption perception index (CPI by 1.646, which is consistent with the theoretical forecasts and relationship identified in Table 7 located in the appendix. Taking control for government effectiveness, rule of law, political stability, and log of real GDP per capita in Table 8, column (2), the estimated point of the effect of e-government development index falls but keeps a positive and significant sign (0.394). Also, in column (2), rule of law (0.340) is statistically significant at the 1% level, and government effectiveness (0.103) and log of per capita real GDP are statistically significant at the 5% level, which is in line with Castro and Lopes [2023] hypothesis, who insist that widespread corruption can be combated by using digital means.

In column (3), we employ the instrumental variable (IV–2SLS) technique to coefficients of the corruption perception index (CPI) with respect to EGDI; IV–2SLS is among the proper methods used to remove endogeneity. Comparable to the obtained coefficient in column (1) (2.077), the estimation yields a statistically significant positive coefficient that proves the impact of e-government strategies on the degree of corruption. This scenario is consistent with Kim et al. [2009], who proposed that these economies should be clearly appraised when designing the effective e-government anti-corruption plan. This effect still holds after adding the control variables in column (4), and the coefficient has the same sign as the one obtained with Pooled OLS (2.084). Moreover, the control variables do not enter with the anticipated sign, but with significant coefficients, for instance, the log of real GDP per capita. Still, column (4), rule of law, political stability, and log of per capita real GDP are all statistically significant at the 1% level.

However, in column (6), the log of real GDP per capita has a positive sign (0.330), but it remains statistically significant, as in column (2). The elasticity of CPI with e-government (EGDI) is shown in column (7) with the expected positive at the 99% confidence level and coincides with the results of the previous estimation techniques. Also, Column (8) shows the statistically significant impact of government effectiveness and the rule of law in reducing corruption. In summary' immune systems and causes Dutch diseases.[8] In a nutshell, Table 8 displays the positive coefficients of all the techniques employed (Pooled OLS, IV–2SLS, FE, and System GMM), which means that a one-standard-deviation increase in each regressor increases perceived corruption by the amount of coefficients presented in the table, except the log of real GDP per capita in columns (2) (-0.0368) and (4) (-0.140), which implies that an additional unit in income leads to a decrease in the corruption perception index (CPI) by 0.0368 and 0.140, respectively.

[8]see https://www.brookings.edu/articles/dutch-disease-an-economic-illness-easy-to-catch-difficult-to-cure/

6.2 Results for extended regressors for the whole sample

In Table 9, variables such as the telecommunication infrastructure index, the e-participation index, the human capital index, and the online service index are added to construct a robustness scenario. Findings based on Pooled OLS are displayed in columns (1) and (2). The e-government coefficient in column (1) is 1.704, which means that a 1-unit increase in EGDI is connected with a 1.704 unit increase in the CPI score with a confidence level of 99%, keeping other factors constant. There is no significance for this factor for column (2) when adding some new variables, which are contrary to the results shown in Table 8, column (2). Brown and Brudney [2003] concludes that knowledge-worker models - based on an investigation of US police departments that sought to adopt them to improve productivity, performance, and effectiveness - enable police departments to deter crime more effectively and pinpoint issues and opportunities more precisely, reducing uncertainty and encouraging organizational decision-making. Shim and Eom [2008] analysed national data on how EGDI affects corruption and concluded that e-government can mitigate corruption by expanding good governance, empowering reform-oriented agents, and promoting internal monitoring and management of employee behaviour. Similarly, the findings revealed that government effectiveness policies are significant in curbing corruption, column (2) (0.137) with Pooled OLS and (8) (0.110) with a system GMM at levels 5% and 1%, which is consistent with Kim [2007] who explored data from 163 different countries using multivariate statistical analysis and found that when it comes to determining the efficiency of e-government at global-level, the effectiveness of government is far more significant than any other driver.

Countries that show strong digital performance are probably the affluent, developed ones and with less corrupt behaviour, like countries in the North America region, Europe & Central Asia, and East Asia & the Pacific, presented in Figure 3. In contrast to Sub-Saharan Africa, a significant composite factor like the telecommunication infrastructure index in column (2) (0.512) and the rule of law in columns (2) (0.304), measured by Pooled OLS, and (4) (0.343) measured by IV–2SLS are the best performing drivers in enhancing EGDI, working smoothly towards increasing corruption. The preparedness in favour of ICT infrastructure remains significant as it possibly leads individuals to increased familiarity with the e-government system. Consequently, infrastructure is acknowledged as a catalyst for successful e-government systems, which, in line with an anecdote-based analysis by Choi [2014] found that ICT infrastructure exerts a statistically significant impact on reducing corruption. However, positive coefficients and statistical significance in the rule of law indicator are potentially confirmed in the study conducted by Kim

[2014]. Finally, the results of online participation are statistically significant at the 5% and 1% in columns (3) (-0.625) based on IV–2SLS, and (4) (0.283) based on IV–2SLS and (5) (0.153) based on FE, respectively, which is consistent with Choi [2014]. In short summary, Table 9 shows three regressors that reduce perceived corruption: the log of the real GDP per capita (-0.0368) displayed in column (2) presented by OLS, which is exactly the same as the coefficient presented in column (2) of Table 8 (-0.0368); the online participation (-0.625) found in column (3) presented by IV–2SLS; and human capital (-0.290) from column (6) presented by FE, which signify that a rise in one standard deviation resulted in a decrease in the CPI presented by the coefficients. Here, the system GMM produced a positive and statistically significant result, which contributed to the reduction of corruption. The adjusted R-squared, R^2, for the Pooled OLS of column (2) is 0.735, which is higher than the rest and confirms that the model is strong enough to explain the variation in the variables.

6.3 Results for extended regressors for the whole sample with partial and full interactions

Table 10 adds two interaction regressors to the models, which impacted other coefficients. This causes the statistical significance to vary between elasticities. The interaction of income and government effectiveness is the best positive combination for reducing corruption at the level of 1%, and human capital in column (1) (-0.0297) is statistically significant at the level of 5%. The interaction between the EGDI and government effectiveness in column (1) (-0.212) is statistically significant at the level of 10%, which is partially in line with the statistical evaluations performed by Kim [2014] on combined data from more than 200 different nations and confirms that the interaction of income and government effectiveness is the best. Also, Columns (2) for Pooled OLS, (4) for IV–2SLS, (6) for FE and (8) for system GMM consider interactions between log of per capita real GDP and government effectiveness as additional control variable, combining both columns, the best predictors of anti-corruption presented in each of these columns are the log of per capita real GDP in column (2) (-0.0402), which is in line with Elbahnasawy [2014] who used a dynamic model of panel data that addresses the endogeneity problem; online participation in column (6) (-0.224); and human capital in column (6) (-0.267), which are statistically significant at the 5%, 10%, and 10%, respectively. Many desirable results are presented in this table, in addition to the rest. Finally, the adjusted R-squared, R^2, of this table from column (1) (0.737) is greater than that of Table 8 column (2) (0.714) and Table 9 column (2) (0.735).

Table 11 displays regressions using both interactions presented in columns (2) of the pooled OLS, (4) from IV–2SLS, (6) from FE, and (8) from the GMM system, which change the magnitudes and improve the values of the elasticities. The interaction between the real GDP per capita (log) and the effectiveness of the government in column (6) (0.0820) is statistically significant at the level of 10% %, which is consistent with Kim [2014] at the level of 1%. In column (2), the elasticities of the interaction between the EGDI and government and between the per capita real GDP (log) and government effectiveness are statistically significant at the 1% and 5% levels, respectively. However, the first three most positive, powerful predictors of anti-corruption are telecommunication infrastructure, rule of law, and political stability. No statistically significant results were displayed for column (4). Also, the powerful negative controllers of corruption are EGDI (-0.868), the interaction of EGDI and government effectiveness (-0.489) and (-0.321), online participation (-0.224), which is exactly the same value found in Table 9 column (6), human capital (-0.276), and government effectiveness (-0.501). All coefficients that perceived corruption lagged are positive and statistically significant at the level of 1%, meaning that higher corruption in the past significantly increases current corruption. Finally, the adjusted R-squared, R^2, of this table from column (2) (0.739) is greater than that of column 8 (2) (0.714), column 9 (2) (0.735), and column 10 (1) (0.737). The addition of more explanatory variables improves the quality of the goodness-of-fit. Lastly, digital institutions do not reduce the amount of corruption, and the informal economy does not increase the degree of corruption, except in column 7 as presented in Table 12.

Overall, this paper pictures the corruption-digitalisation nexus by using both theoretical and empirical models that hold a dual balance of the theme and draw actionable insights and a clear conclusion for policy design and stakeholders in low-income and emerging market economies, which are ineffective in adapting to technological information. Some of the previous works are based on one-sided version of the coin; for instance, the empirical work by Ouedraogo and Sy [2020], who used a multilevel ordered probit model on the individual-level data from Afrobarometer surveys and several indices of digitalisation, and confirmed that an increase in e-government use is connected with the decline in the corruption perception and tenably an increase of tax officials trusts. Also, the reported results by Paul and Adams [2024], who employed a panel data analysis from 48 Sub-Saharan African countries to investigate the effect of e-government development indices on the corruption perception index (CPI) employing cross-sectional data from the year 2012 to 2020, demonstrated that e-government had a positive impact on how people perceive corruption. Furthermore, to these institutions in Sub-Saharan Africa, Kanyam et al. [2017] embraced the use of ICT (the internet and mobile phone) and revealed that cell phones serve as effective instruments for reducing corruption.

On the other side of the coin, few papers admitted digital parameters in their theoretical models. For example, Leite and Weidmann [1999] added a societal-technological parameter as an anti-corruption detector instrument in a growth model with an infinite horizon in an open economy. They asserted that the use of technology in society can help to increase corruption detection in investment flows and minimise the deleterious impact of corruption on growth. Surprisingly, the empirical part of Leite and Weidmann [1999] did not consider the power of e-government to deter corruption, which brought disequilibrium in designing and implementing policies without empirical verification, although it certainly works. In a different manner, Ruhashyankiko and Yehoue [2006] introduced an induced-technology parameter in the extended version of the principal–agent–client model to emphasize augmented labour with innate ability to increase productivity and growth of the private sectors. The enactment of this technology in the theoretical model does not add to bribery detection, but rather increases efficiency in the labour with an innate ability, and speeds up production of private firms. However, the empirical part of Ruhashyankiko and Yehoue [2006] concluded that a technology-induced expansion of the private industry results in a decrease in aggregate corruption and proposed that publicly issued corruption dominates privately issued corruption. Considerably, some studies, for example, Del Monte and Papagni [2001], Mauro [2004], Djumashev [2007], Bai et al. [2013], etc., discuss the distortions brought about by corruption in growth and recommend legal and mechanical remedies without advocating the contribution embedded in the digital revolution in curbing corruption.

Leite and Weidmann [1999] considers bribery as a fraction of physical investment, Mauro [2004] treats tax on factor income as a bribe, Bai et al. [2013] contends that a bribe is just an additional payment to the government, analogous to a tax, and thinks of a bribe payment as a type of tax on output. In contrast, this paper treats bribes and taxes differently, meaning that bribes affect tax collection asymmetrically, depending on the detection method used by the authority and whether the civil servant is honest or dishonest. This paper not only uses theoretical approaches to show the corruption-digital nexus but also extends the use of real-world data to clearly confirm the unmatched power of information technology in reducing corruption and conditionally validate the conclusion drawn in the theory. Following a similar pattern of illustrating distortions brought about by corruption in growth as Del Monte and Papagni [2001], Mauro [2004], Djumashev [2007], Bai et al. [2013], etc. However, this paper emboldens the use of digital-institutional quality in securing tax revenue loss against bribery and tax evasion, which finally encourages equal access to public goods, promotes efficiency of the private sector, cuts income inequality, increases growth, and sustainable development. Furthermore, this paper is based on Sub-Saharan Africa, highlights obstacles, and suggests solutions for adapting digital technology.

7 Concluding Remarks

This paper has contributed both theoretically and empirically to show how digital-institutional quality can contribute to the growth of a typical Sub-Saharan economy. Theoretically, the paper developed a unique model that illustrates connections between digital-institutional quality and the level of corruption in Sub-Saharan Africa in an environment of tax evasion and the informal sector. Intuitively, theoretical results show that the digital-institutional quality is capable of reducing corruption in both the tax department and in the provision of public goods. Mere digitalisation cannot be effective unless the rule of law and governance are effective. It indicates that the quality of digital institutions and tax collection is positively related. Moreover, the paper has empirically measured the intensity of the connection between the e-government development index and the corruption perception index for a sample of 44 Sub-Saharan African countries over the period 2003–2022, using four different estimation methods (Pooled OLS, IV–2SLS, FE, and a two-step system GMM). We extended the models with additional control variables to assess robustness and discovered that the results improved the elasticities of the models. The strong positive correlation and statistically significant results displayed in this study do not mean that Sub-Saharan Africa has defeated corruption, and their governments are clean, but show that the governments in the region are still lagging behind in the principles for curbing corruption and that the effective use of e-government can result in low corruption. E-government is cited as a partial tool for curbing corruption because it cannot eliminate all the structural drivers that foster corruption in the region. The e-government (EGDI) score of Sub-Saharan Africa is below the world average score because its implementation is hindered by various obstacles and difficulties, despite its numerous benefits.

The challenges mentioned by the previous paragraph are classified as follows: technical obstacles (e.g., shortcomings of ICT infrastructure, lack of privacy of protecting individual information, weak security of protecting all information and system in opposition to any revelation to unauthorized access, for instance cyberattacks); organizational barriers (e.g., lack of support from top management, opposition to transitioning to digital methods, poor collaboration between partners and stakeholders, and shortage of skilled workers); societal obstacles (e.g., presence of digital gap or digital accessibility divide is large, and resistance due cultural beliefs and values); monetary challenges (e.g., absence of financial support); and institutional and political barriers (e.g., absence of support from top management, opposition to transitioning to digital methods, poor collaboration between partners and stakeholders, and shortage of skilled workers); societal obstacles (e.g., presence (e.g., unwillingness of government agencies to embrace new technologies and invention due to weak flexibility, fear of government workers and politicians of failing to maintain their control over authority that make them unwilling to adopt ICT innovation because the innovation would bring transparency and accountability in governance and, finally, will eliminate the current gap that encourages corruption) [Drew, 2011, Misuraca et al., 2010, Onuigbo and Eme, 2015].

The doubted ICT legal framework is enacted, and the infrastructure of the government is bolstered, enhancing the stability of revenue authorities without political intervention, enhancing transparency and accountability, bringing equal promotion opportunities for government officials, empowering competition to minimise the existence of monopoly, and creating sounder government-citizen relationships that can enhance the achievements of the low-corruption mission.

The multifaceted approach of this study also adds to a more profound discernment of the links between perceived corruption and e-government, but also greatly enhances the current reservoir of knowledge worldwide; our observations have shown that predictors like e-government and telecommunication infrastructure are the most powerful indicators in increasing corruption in the region. But prediction improves after introducing full interaction between the effective government and e-government, and interaction between the effective government and economic prosperity. Through this interaction, the results show that e-government is negative (-0.868) and statistically significant in the 5% of Table 8 column (2), suggesting that e-government can cure perceived corruption if there are cohesive functions between effectiveness and e-government, and a clear combination between the income of the region and effectiveness of the governments. Additionally, the interaction of government effectiveness and e-government is expected to curb corruption more effectively than the interaction of government effectiveness and income. The percentage of corruption is established if key ICT-enabled environments of low-corruption missions are established, for example: first, creating a culture of transparency and openness by empowering citizens using ICT-enabled transparency and participating in openness initiatives; second, adopting equal technology literacy to bridge the digital gap by enabling users to access and interact with the information integrated into the technology; third, supported ICT policies such as training public officials and making them flexible in technological adaptation; etc., other factors for stable, strong, and sustainable e-government on combating corruption are discussed in in the previous paragraph.

Moreover, for decision-makers, the results of the study underscore the critical role of e-governance in mitigating corruption, particularly in low and lower-middle-income nations in Sub-Saharan Africa. Especially for those economies, strategies focused on broadening access to and utilisation of digital services, enhancing digital infrastructure, and promoting inclusive digital ecosystems may significantly reduce the extent of corruption. Policymakers should focus on dynamic, long-term initiatives to promote digital inclusivity and efforts to sustain substantial reductions in corruption. Ultimately, upcoming studies on the effects of e-government on corruption may focus on examining the impact of electronic corruption (e-corruption) tools in settings with limited conventional digital access. Research may investigate the impact of mobile accessibility blockchain on corruption, while evaluating the long-term effects of specific digital inclusion policies. In addition, regional and sector-focused evaluations could provide deeper insight into the unique challenges and successes of digital inclusion approaches in various economic settings.

The limitation of the study is based on the index of the digital-institutional quality. The United Nations, UNDESA, only offers data on the e-government development index (EGDI) and its composite (provision of online services, telecommunication connectivity, and human capacity). The World Bank Development Indicator (WDI) displays the institutions' data (rule of law, government effectiveness, political stability, etc.). In modern societies where activities are shifting from analogue to digital platforms, securing and storing information is becoming essential for ensuring principles of good governance (i.e., transparency, rule of law, inclusiveness, accountability, etc.). And to capture the efficiency of modern government, one indicator is required, which is digital-institutional quality that will take into action the informational bahaviour of the governing system and the citizens. Due to the lack of this indicator, the paper employs the combination of factors from the UNDESA and EGDI to represent the digital-institutional quality.

References

Richard A Aborisade and Nurudeen B Aliyyu. Corruption and africa. In *The development of Africa: Issues, diagnoses and prognoses*, pages 227–254. Springer, 2017.

Mark A Abramson and Therese L Morin. *E-government 2003*. Rowman & Littlefield, 2003.

Alberto Ades and Rafael Di Tella. Rents, competition, and corruption. *American economic review*, 89(4):982–993, 1999.

Victor Adewopo, Sylvia Worlali Azumah, Mustapha Awinsongya Yakubu, Emmanuel Kojo Gyamfi, Murat Ozer, and Nelly Elsayed. A comprehensive analytical review on cybercrime in west africa. *arXiv preprint arXiv:2402.01649*, 2024.

Anubha Agarwal and Dibyendu Maiti. Icts and effectiveness of governance: A cross-country study. In *Digitalisation and Development: Issues for India and Beyond*, pages 321–343. Springer, 2019.

Toke S Aidt. Economic analysis of corruption: a survey. *The Economic Journal*, 113(491): F632–F652, 2003.

Alberto Alesina and George-Marios Angeletos. Corruption, inequality, and fairness. *Journal of Monetary Economics*, 52(7):1227–1244, 2005.

Floortje Alkemade and Roald AA Suurs. Patterns of expectations for emerging sustainable technologies. *Technological Forecasting and Social Change*, 79(3):448–456, 2012.

Michael G Allingham and Agnar Sandmo. Income tax evasion: A theoretical analysis. *Journal of public economics*, 1(3-4):323–338, 1972.

Thomas Barnebeck Andersen. E-government as an anti-corruption strategy. *Information Economics and policy*, 21(3):201–210, 2009.

Sergey Anokhin and William S Schulze. Entrepreneurship, innovation, and corruption. *Journal of business venturing*, 24(5):465–476, 2009.

Manuel Arellano and Stephen Bond. Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *The review of economic studies*, 58(2):277–297, 1991.

Manuel Arellano and Olympia Bover. Another look at the instrumental variable estimation of error-components models. *Journal of econometrics*, 68(1):29–51, 1995.

David Alan Aschauer. Is public expenditure productive? *Journal of monetary economics*, 23(2):177–200, 1989.

Joseph Attila. Corruption, taxation and economic growth: theory and evidence. 2008.

Costas Azariadis and Amartya Lahiri. Do rich countries choose better governments? *Contributions to Macroeconomics*, 2(1):1051, 2002.

Jie Bai, Seema Jayachandran, Edmund J Malesky, and Benjamin A Olken. Does economic growth reduce corruption? theory and evidence from vietnam. Technical report, National Bureau of Economic Research, 2013.

Andrea Camara Bandeira, Fernando Garcia, and Marcos Fernandes Gonçalves da Silva. How does corruption hurt growth? evidences about the effects of corruption on factors productivity and per capita income. 2001.

Egidijus Barcevičius, Guoda Cibaitė, Cristiano Codagnone, Vaida Gineikytė, Luka Klimavičiūtė, Giovanni Liva, Loreta Matulevič, Gianluca Misuraca, Irene Vanini, et al. Exploring digital government transformation in the eu. *Publications Office of the European Union, Luxembourg*, 2019.

Pranab Bardhan. Corruption and development: a review of issues. *Political corruption*, pages 321–338, 2017.

Raul A Barreto. Endogenous corruption in a neoclassical growth model. *European economic review*, 44(1):35–60, 2000.

Robert Barro and Xavier Sala i Martin. convergence. *Journal of Political Economy*, 100 (223):51, 1992.

Robert J Barro. Government spending in a simple model of endogeneous growth. *Journal of political economy*, 98(5, Part 2):S103–S125, 1990.

Kaushik Basu, Sudipto Bhattacharya, and Ajit Mishra. Notes on bribery and the control of corruption. *Journal of public Economics*, 48(3):349–359, 1992.

Sarfraz Batool, Shahzad Ali Gill, Saba Javaid, and Ali Junaid Khan. Good governance via e-governance: moving towards digitalization for a digital economy. *Review of applied management and social sciences*, 4(4):823–836, 2021.

John Carlo Bertot, Paul T Jaeger, and Justin M Grimes. Promoting transparency and accountability through icts, social media, and collaborative e-government. *Transforming government: people, process and policy*, 6(1):78–91, 2012.

Vinay Kumar Bhargava and Emil P Bolongaita. *Challenging corruption in Asia: Case studies and a framework for action.* World Bank Publications, 2004.

Shahjahan H Bhuiyan. Modernizing bangladesh public administration through e-governance: Benefits and challenges. *Government Information Quarterly*, 28(1):54–65, 2011.

Richard Blundell and Stephen Bond. Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics*, 87(1):115–143, 1998.

Michele Boldrin. Public education and capital accumulation. Technical report, Discussion Paper, 1992.

Mary Maureen Brown and Jeffrey L Brudney. Learning organizations in the public sector? a study of police agencies employing information and technology to advance knowledge. *Public administration review*, 63(1):30–43, 2003.

A Colin Cameron and Pravin K Trivedi. *Microeconometrics: methods and applications*. Cambridge university press, 2005.

Gustavo Canavire-Bacarreza, Jorge Martinez-Vazquez, and Violeta Vulovic. Taxation and economic growth in latin america. 2013.

Conceição Castro and Isabel Cristina Lopes. E-government as a tool in controlling corruption. *International Journal of Public Administration*, 46(16):1137–1150, 2023.

Gary Chamberlain. Analysis of covariance with qualitative data. *The review of economic studies*, 47(1):225–238, 1980.

Peerayuth Charoensukmongkol and Murad Moqbel. Does investment in ict curb or create more corruption? a cross-country analysis. *Public Organization Review*, 14:51–63, 2014.

Jin-Wook Choi. E-government and corruption: A cross-country survey. *World Political Science*, 10(2):217–236, 2014.

Giorgio d'Agostino, J Paul Dunne, and Luca Pieroni. Corruption and growth in africa. *European Journal of Political Economy*, 43:71–88, 2016.

Richard Damania, Per G Fredriksson, and Muthukumara Mani. The persistence of corruption and regulatory compliance failures: theory and evidence. *Public choice*, 121 (3):363–390, 2004.

James Danowski, Aaron van Klyton, Tai-Quan Winson Peng, Siyuan Ma, Raphaël Nkakleu, and Altante Désirée Biboum. Information and communications technology development, interorganizational networks, and public sector corruption in africa. *Quality & Quantity*, 57(4):3285–3304, 2023.

Albert De Vaal and Wouter Ebben. Institutions and the relation between corruption and economic growth. *Review of Development Economics*, 15(1):108–123, 2011.

Alfredo Del Monte and Erasmo Papagni. Public expenditure, corruption, and economic growth: the case of italy. *European journal of political economy*, 17(1):1–16, 2001.

Clara Delavallade. What drives corruption? evidence from north african firms. *Journal of African Economies*, 21(4):499–547, 2012.

Ratbek Djumashev. Public goods, corruption and growth. 2006.

Ratbek Djumashev. Corruption, uncertainty and growth. 2007.

Mohammed Alshehri; Steve J Drew. E-government principles: implementation, advantages and challenges. *International Journal of Electronic Business*, 9(3):255–270, 2011.

Nasr G Elbahnasawy. E-government, internet adoption, and corruption: an empirical investigation. *World Development*, 57:114–126, 2014.

Kimberly Ann Elliott. *Corruption and the global economy*. Peterson Institute, 1997.

Martha Garcia-Murillo. Does a government web presence reduce perceptions of corruption? *Information Technology for Development*, 19(2):151–175, 2013.

Sugata Ghosh and Kyriakos C Neanidis. Corruption, fiscal policy, and growth: a unified approach. *The BE Journal of Macroeconomics*, 17(2), 2017.

Gerhard Glomm and Balasubramanian Ravikumar. Productive government expenditures and long-run growth. *Journal of Economic Dynamics and control*, 21(1):183–204, 1997.

Cheryl W Grey and Daniel Kaufmann. Corruptionand development. *Finance & Development*, 35(1):8, 1998.

Klaus Gründler and Niklas Potrafke. Corruption and economic growth: New empirical evidence. *European Journal of Political Economy*, 60:101810, 2019.

Mr Sanjeev Gupta, Mr Michael Keen, Ms Alpa Shah, and Ms Genevieve Verdier. *Digital revolutions in public finance*. International Monetary Fund, 2017.

Sanjeev Gupta, Hamid Davoodi, and Rosa Alonso-Terme. Does corruption affect income inequality and poverty? *Economics of governance*, 3:23–45, 2002.

Douglas Holtz-Eakin, Whitney Newey, and Harvey S Rosen. Estimating vector autoregressions with panel data. *Econometrica: Journal of the econometric society*, pages 1371–1395, 1988.

Patrick Amir Imam and Davina Jacobs. Effect of corruption on tax revenues in the middle east. *Review of Middle East Economics and Finance*, 10(1):1–24, 2014.

United Nations Development Programme (India) and Macmillan India Limited. *Tackling corruption, transforming lives: Accelerating human development in Asia and the Pacific*. UNDP, 2008.

Arvind K Jain. Corruption: A review. *Journal of economic surveys*, 15(1):71–121, 2001.

Daniel A Kanyam, Genti Kostandini, and Susana Ferreira. The mobile phone revolution: have mobile phones and the internet reduced corruption in sub-saharan africa? *World Development*, 99:271–284, 2017.

Daniel Kaufmann, Aart Kraay, and Pablo Zoido. Governance matters. *Available at SSRN 188568*, 1999.

Daniel Kaufmann, Aart Kraay, and Massimo Mastruzzi. Governance matters viii. *Policy research working paper*, 4978:2–6, 2009.

Kouramoudou Kéïta and Hannu Laurila. Corruption and tax burden: What is the joint effect on total factor productivity? *Economies*, 9(1):26, 2021.

Chon-Kyun Kim. A cross-national analysis of global e-government. *Public Organization Review*, 7:317–329, 2007.

Chon-Kyun Kim. Anti-corruption initiatives and e-government: a cross-national study. *Public Organization Review*, 14:385–396, 2014.

Seongcheol Kim, Hyun Jeong Kim, and Heejin Lee. An institutional analysis of an e-government system for anti-corruption: The case of open. *Government information quarterly*, 26(1):42–50, 2009.

Robert Klitgaard. *Controlling corruption*. Univ of California Press, 1988.

Stephen Knack and Philip Keefer. Institutions and economic performance: cross-country tests using alternative institutional measures. *Economics & politics*, 7(3):207–227, 1995.

Irving B Kravis, Alan W Heston, and Robert Summers. Real gdp per capita for more than one hundred countries. *The Economic Journal*, 88(350):215–242, 1978.

Young Lee and Roger H Gordon. Tax structure and economic growth. *Journal of public economics*, 89(5-6):1027–1043, 2005.

Mr Carlos Leite and Jens Weidmann. *Does mother nature corrupt? Natural resources, corruption, and economic growth.* International Monetary Fund, 1999.

Mon-Chi Lio, Meng-Chun Liu, and Yi-Pey Ou. Can the internet reduce corruption? a cross-country study based on dynamic panel data models. *Government information quarterly*, 28(1):47–53, 2011.

Giovanni Liva, Cristiano Codagnone, Gianluca Misuraca, Vaida Gineikyte, and Egidijus Barcevicius. Exploring digital government transformation: a literature review. In *Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance*, pages 502–509, 2020.

Dibyendu Maiti and Akshara Awasthi. Ict exposure and the level of wellbeing and progress: a cross country analysis. *Social Indicators Research*, 147(1):311–343, 2020.

Dibyendu Maiti and Bhavna Khari. Digitalisation, e-governance and the informal sector. *Structural Change and Economic Dynamics*, 2025.

Sunny Marche and James D McNiven. E-government and e-governance: the future isn't what it used to be. *Canadian Journal of Administrative Sciences/Revue Canadienne des Sciences de l'Administration*, 20(1):74–86, 2003.

Paolo Mauro. Corruption and growth. *The quarterly journal of economics*, 110(3):681–712, 1995.

Paolo Mauro. The persistence of corruption and slow economic growth. *IMF staff papers*, 51(1):1–18, 2004.

Christopher S Mayanja and James L Nkata. Pursuing sustainable development goals in uganda: Do anti-corruption strategies of management development institutes matter? *Journal of Public Administration and Policy Research*, 11(4):38–47, 2019.

Ajit Mishra. Persistence of corruption: some theoretical perspectives. *World Development*, 34(2):349–358, 2006.

Vishal Mishra and Shailendra Singh Bisht. Mobile banking in a developing economy: A customer-centric model for policy formulation. *Telecommunications Policy*, 37(6-7): 503–514, 2013.

Jamshed J Mistry and Abu Jalal. An empirical analysis of the relationship between e-government and corruption. *International Journal of Digital Accounting Research*, 12, 2012.

Gianluca Misuraca, Enrico Ferro, and Brunella Caroleo. Assessing emerging ict-enabled governance models in european cities: Results from a mapping survey. In *International Conference on Electronic Government*, pages 168–179. Springer, 2010.

Pak Hung Mo. Corruption and economic growth. *Journal of comparative economics*, 29 (1):66–79, 2001.

Fiscal Monitor. Curbing corruption. *Washington, DC: IMF*, 2019.

IMF Fiscal Monitor. Capitalizing on good times. april 2018.

Antonio Muñoz-Cañavate and Pedro Hípola. Electronic administration in spain: From its beginnings to the present. *Government Information Quarterly*, 28(1):74–90, 2011.

Fredrick Mutungi, Rehema Baguma, Tomasz Janowski, and Danube University Krems, Austria. Towards digital anti-corruption typology for public service delivery. In *Proceedings of the 20th Annual International Conference on Digital Government Research*, pages 484–494, 2019.

U Myint. Corruption: Causes, consequences and cures. *Asia pacific development journal*, 7(2):33–58, 2000.

Oleksii Mykhalchenko. E-governance in the management decision-making process. *Ekonomichnyy analiz*, 32(1):81–94, 2022.

Valentina Ndou et al. E-government for developing countries: Opportunities and challenges. *Electron. J. Inf. Syst. Dev. Ctries.*, 18(1):1–24, 2004.

Khalil Nimer, Ali Uyar, Cemil Kuzey, and Friedrich Schneider. E-government, education quality, internet access in schools, and tax evasion. *Cogent Economics & Finance*, 10 (1):2044587, 2022.

Hyunseung Oh and Ricardo Reis. Targeted transfers and the fiscal response to the great recession. *Journal of Monetary Economics*, 59:S50–S64, 2012.

Adegboyega Ojo, Tomasz Janowski, and Johanna Awotwi. Enabling development through governance and mobile technology. *Government Information Quarterly*, 30:S32–S45, 2013.

Richard Amaechi Onuigbo and Okechukwu Innocent Eme. Electronic governance & administration in nigeria: Prospects &challenges. *Arabian Journal of Business and Management Review (OMAN Chapter)*, 5(3):18, 2015.

Rasmané Ouedraogo and Mr Amadou N Sy. *Can digitalization help deter corruption in Africa?* International Monetary Fund, 2020.

Raghuvar Dutt Pathak, Gurmeet Singh, Rakesh Belwal, and RFI Smith. E-governance and corruption-developments and issues in ethiopia. *Public Organization Review*, 7: 195–208, 2007.

Chima Paul and Samuel Olorunfemi Adams. The effect of e-government development indices (egdi) on corruption perception index in sub-sahara africa: A panel data analysis. *African Journal of Science, Technology, Innovation and Development*, 16(1):17–25, 2024.

Lorenzo Pellegrini and Reyer Gerlagh. Corruption's effect on growth and its transmission channels. *Kyklos*, 57(3):429–456, 2004.

David Roodman. How to do xtabond2: An introduction to difference and system gmm in stata. *The stata journal*, 9(1):86–136, 2009.

Susan Rose-Ackerman. *Corruption: A study in political economy*. Academic press, 2013.

Susan Rose-Ackerman and Bonnie J Palifka. *Corruption and government: Causes, consequences, and reform*. Cambridge university press, 2016.

Jean-François Ruhashyankiko and Etienne B Yehoue. Corruption and technology-induced private sector development. 2006.

Gerald W Scully. Taxation and economic growth in new zealand. *Pacific Economic Review*, 1(2):169–177, 1996.

Harry Seldadyo and Jakob De Haan. The determinants of corruption: a reinvestigation. In *A paper presented for the EPCS–2005 conference, Durham, UK*, 2005.

Ghulam Shabbir and Mumtaz Anwar. Determinants of corruption in developing countries. *The Pakistan development review*, pages 751–764, 2007.

Swapnil Sharma, Arpan Kumar Kar, and MP Gupta. Unpacking digital accountability: Ensuring efficient and answerable e-governance service delivery. In *Proceedings of the 14th International Conference on Theory and Practice of Electronic Governance*, pages 260–269, 2021.

Dong Chul Shim and Tae Ho Eom. E-government and anti-corruption: Empirical analysis of international data. *Intl Journal of Public Administration*, 31(3):298–316, 2008.

Andrei Shleifer and Robert W Vishny. Corruption. *The quarterly journal of economics*, 108(3):599–617, 1993.

Sizwe Snail ka Mtuze and Melody Musoni. An overview of cybercrime law in south africa. *International Cybersecurity Law Review*, 4(3):299–323, 2023.

Jakob Svensson. Eight questions about corruption. *Journal of economic perspectives*, 19 (3):19–42, 2005.

Vito Tanzi. Corruption around the world: Causes, consequences, scope, and cures. *Staff papers*, 45(4):559–594, 1998.

Vito Tanzi and Partho Shome. Tax evasion: Causes, estimation, methods, and penalties. *A Focus on Latin America. Commission for Latin America and the Caribbean. Serie Politica Fiscal*, 38, 1993.

Jean Tirole. A theory of collective reputations (with applications to the persistence of corruption and to firm quality). *The Review of Economic Studies*, 63(1):1–22, 1996.

UN ANTI-CORRUPTION TOOLKIT. The global programme against corruption un anti-corruption toolkit. *UNODC. Disponível em: https://www. un. org/ruleoflaw/blog/document/the-global-programme-against-corruption-un-anti-corruption-toolkit*, 2004.

Stephen J Turnovsky and Walter H Fisher. The composition of government expenditure and its consequences for macroeconomic performance. *Journal of Economic Dynamics and Control*, 19(4):747–786, 1995.

Ali Uyar, Khalil Nimer, Cemil Kuzey, Muhammad Shahbaz, and Friedrich Schneider. Can e-government initiatives alleviate tax evasion? the moderation effect of ict. *Technological Forecasting and Social Change*, 166:120597, 2021.

JC Jansen van Vuuren, L Leenen, and P Pieterse. Development and implementation of cybercrime strategies in africa with specific reference to south africa. *Journal of Information Warfare*, 19(3):83–101, 2020.

Nagarajan Vittal. *Corruption in India: The roadblock to national prosperity*. Academic Foundation, 2003.

Shang-Jin Wei. Why is corruption so much more taxing than tax? arbitrariness kills, 1997.

Shang-Jin Wei. How taxing is corruption on international investors? *Review of economics and statistics*, 82(1):1–11, 2000.

Ahmed Yamen, Ali Coskun, and Hounaida Mersni. Digitalization and tax evasion: the moderation effect of corruption. *Economic research-Ekonomska istraživanja*, 36(2), 2023.

8 Appendix

Table 1: Summary of variables used in the empirical analysis

Variable	Measurements	Sources
CPI	Corruption Perception Index, bounded between 0 and 100, with 0 being the highest corruption rating and 100 being the lowest corruption	Transparency International (2003-2022)
EGDI	UN E-Government Development Index, indexed on a scale from 0 to 1, with 0 showing the least developed while 1 shows the most developed	UNDESA (2022)
E-Participation Index	E-Participation Index, indexed on a scale from 0 to 1, with higher values signifying more online tools to enable citizen involvement	UNDESA (2022)
Online Service Index	Online Service Index, indexed on a scale from 0 to 1, with higher values indicating a wider range and higher quality of online services	UNDESA (2022)
Telecom. Infrastructure Index	Telecommunications Infrastructure Index, indexed on a scale from 0 to 1, with higher values signifying more development of telecommunications infrastructure	UNDESA (2022)
Human Capital Index	Human Capital Index, the index ranges between 0 and 1, with 1 meaning maximum potential is reached and 0 representing minimum productivity	UNDESA (2022)
Law	Rule of law is represented by the Kaufmann Index: from -2.5 (highly unobserved) to 2.5 (highly observed)	WDI (2022)
Effectiveness	Government effectiveness is represented by the Kaufmann Index: from -2.5 (highly ineffective) to 2.5 (highly effective)	WDI (2022)
Stability	Political stability is represented by the Kaufmann Index: from -2.5 (highly unstable) to 2.5	WDI (2022)
Real GDP per capita	Annual real GDP per capita at constant 2015 United States dollars	WDI (2022)
Subscribers	Mobile cellular subscribers per 100 inhabitants, measures the number of both active prepaid and post-paid subscriptions that offer voice communication in the last 3 months	WDI (2022)

Table 2: Summary statistics of variables

Variable	N	Mean	Skewness	Kurtosis	SD	Min	Max
CPI	463	30.719	.845	3.396	11.764	4	70
E-government index	463	.288	.525	3.551	.136	0	.736
E-participation index	463	.174	1.165	3.629	.178	0	.848
Online service index	463	.237	.764	2.960	.18	0	.833
Human capital index	463	.498	-.281	2.714	.191	0	.904
Telecom. Infrastructure	463	.139	1.647	5.570	.153	0	.82
Rule of law	463	-.717	.136	2.932	.669	-2.591	1.024
Gov effectiveness	463	-.799	.439	3.287	.658	-2.439	1.15
Political stability	463	-.596	-.355	2.521	.922	-3.281	1.201
Control of corruption	463	-.657	.741	3.191	.661	-1.937	1.699
Regulatory quality	463	-.722	.132	3.484	.657	-2.548	1.197
Voice & Accountability	463	-.557	-.0280	2.282	.752	-2.209	.975
Real GDP per capita	453	63.528	4.602	22.761	276.805	-20.805	1602.902

Table 3: Countries used to construct Figure 2 Corruption Control by Region

Region	Countries
North America	Bermuda, Canada, and the United States of America.
South Asia	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.
Middle East & North Africa	Algeria, Bahrain, Djibouti, Egypt, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates, West Bank and Gaza, and Yemen.
East Asia & Pacific	Australia, Brunei Darussalam, Cambodia, China, Democratic People's Republic of Korea, Fiji, Guam, Hong Kong, Indonesia, Japan, Kiribati, Lao People's Democratic Republic, Macao SAR, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Myanmar, Nauru, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Singapore, Solomon Islands, Thailand, Timor-Leste, Tonga, Tuvalu, Vanuatu, Viet Nam.
Latin America & Caribbean	Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bolivia, Brazil, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela, and Virgin Islands (U.S.).
Europe & Central Asia	Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Greenland, Hungary, Iceland, Ireland, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Türkiye, Turkmenistan, Ukraine, United Kingdom, Uzbekistan.
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Republic of Congo, Cote d'Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

Table 4: Countries used to construct Figure 3 CPI by Region

Region	Countries
North America	Canada, and the United States of America.
South Asia	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.
Middle East& North Africa	Algeria, Bahrain, Egypt, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates, and Yemen.
East Asia& Pacific	Australia, Cambodia, China, Democratic People's Republic of Korea, Fiji, Hong Kong, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Papua New Guinea, Philippines, Republic of Korea, Singapore, Solomon Islands, Thailand, Timor-Leste, Vanuatu, Viet Nam.
Latin America & Caribbean	Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.
Europe & Central Asia	Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Türkiye, Turkmenistan, Ukraine, United Kingdom, and Uzbekistan.
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Republic of Congo, Cote d'Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

Table 5: Countries used to construct Figure 4 EGDI by Region

Region	Countries
North America	Bermuda, Canada, and the United States of America.
South Asia	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.
Middle East & North Africa	Algeria, Egypt, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates, and Yemen.
East Asia & Pacific	Australia, Brunei Darussalam, Cambodia, China, Fiji, Indonesia, Japan, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Myanmar, Nauru, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Singapore, Solomon Islands, Thailand, Timor-Leste, Tonga, Tuvalu, Vanuatu, Viet Nam.
Latin America & Caribbean	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.
Europe & Central Asia	Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Türkiye, Ukraine, United Kingdom, and Uzbekistan.
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Republic of Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

Table 6: SSA countries used to run regressions and used to construct Figure 5

Income Group	Sample of Countries
Low income	Burkina Faso, Burundi, Central African Republic, Chad, Democratic Republic of Congo, Ethiopia, Gambia, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Somalia, Sudan, Togo, Uganda.
Lower-middle income	Angola, Benin, Cabo Verde, Cameroon, Comoros, Republic of Congo, Cote d'Ivoire, Eswatini, Ghana, Guinea, Kenya, Lesotho, Mauritius, Nigeria, Senegal, Tanzania, Zambia, Zimbabwe.
Upper-middle income	Botswana, Equatorial Guinea, Gabon, Namibia, South Africa.
High income	Seychelles.

Table 7: Correlation Coefficient

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) CPI	1.000										
(2) E-government	0.615	1.000									
(3) E-participation	0.353	0.618	1.000								
(4) Online service	0.509	0.809	0.820	1.000							
(5) Human capital	0.370	0.646	0.011	0.219	1.000						
(6) Telec. Infrastr	0.543	0.785	0.611	0.628	0.249	1.000					
(7) Rule of law	0.837	0.603	0.279	0.475	0.480	0.420	1.000				
(8) Gov effect	0.828	0.669	0.300	0.538	0.537	0.448	0.916	1.000			
(9) Polit. stability	0.674	0.473	0.105	0.241	0.519	0.319	0.790	0.714	1.000		
(10) Subscribers	0.545	0.663	0.576	0.555	0.165	0.845	0.388	0.395	0.312	1.000	
(11) GDP/capita	0.483	0.566	0.154	0.273	0.548	0.525	0.457	0.547	0.477	0.482	1.000

Table 8: E-government and Corruption: regressors for the whole sample: 2003–2022.

	Pooled OLS		IV-2SLS		Fixed Effect		System GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.log of CPI							0.780***	0.594***
							(0.000)	(0.000)
E-government	1.646***	0.394***	2.077***	2.084***	0.743***	0.327***	0.364***	0.0704
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.004)	(0.432)
Rule of law		0.340***		0.279***		0.241		0.0952*
		(0.000)		(0.000)		(0.106)		(0.055)
Gov effectiveness		0.103**		-0.0268		0.0684		0.107***
		(0.039)		(0.687)		(0.490)		(0.001)
Political stability		0.0273		0.0673***		-0.0318		0.0144
		(0.177)		(0.009)		(0.518)		(0.465)
Log of GDP per capita		-0.0368**		-0.140***		0.330***		-0.0194
		(0.018)		(0.000)		(0.001)		(0.236)
Constant	2.877***	3.835***	2.748***	3.952***	3.143***	1.120*	0.644***	1.656***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.098)	(0.001)	(0.000)
Observations	432	432	419	419	432	432	388	388
Adjusted R-squared	0.334	0.714	0.319	0.563	0.103	0.250		
AR2							1.161	1.007
No. of Instruments							56	60
Hansen-J (P-value)							0.846	0.882
RMSE	0.316	0.207	0.322	0.257	0.168	0.154		
F Statistic	229.7	166.3			28.06	19.60	49065.1	32241.7

p-values in parentheses

* $p<0.10$, ** $p<0.05$, *** $p<0.010$

Table 9: E-government and Corruption: extended regressors for the whole sample: 2003–2022.

	Pooled OLS		IV-2SLS		Fixed Effect		System GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.log of CPI							0.785***	0.601***
							(0.000)	(0.000)
E-government	1.704***	-0.203	2.884***	20.27	0.514***	-0.116	0.401***	0.0511
	(0.000)	(0.462)	(0.000)	(0.125)	(0.009)	(0.511)	(0.005)	(0.629)
E-participation	-0.0706	-0.0516	-0.625**	0.283*	0.153*	-0.203	-0.0941	0.0163
	(0.490)	(0.702)	(0.019)	(0.079)	(0.085)	(0.135)	(0.109)	(0.790)
Online service		0.190		-7.441		0.294**		
		(0.333)		(0.112)		(0.028)		
Human capital		-0.0900		-6.617		-0.290**		
		(0.390)		(0.127)		(0.044)		
Telecom. infrastructure		0.512***		-6.461		0.241**		
		(0.000)		(0.140)		(0.035)		
Rule of law		0.304***		0.343***		0.219		0.0926*
		(0.000)		(0.000)		(0.152)		(0.059)
Gov effectiveness		0.137**		0.0973		0.104		0.110***
		(0.010)		(0.282)		(0.340)		(0.001)
Political stability		0.0479**		0.0135		-0.0242		0.0125
		(0.024)		(0.773)		(0.613)		(0.546)
Log of GDP per capita		-0.0368**		0.00734		0.296***		-0.0187
		(0.024)		(0.908)		(0.006)		(0.287)
Constant	2.873***	3.958***	2.623***	3.695***	3.182***	1.579**	0.634***	1.631***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.045)	(0.001)	(0.000)
Observations	432	432	419	419	432	432	388	388
Adjusted R-squared	0.333	0.735	0.239	.	0.111	0.279		
AR2							1.234	0.989
No. of Instruments							57	61
Hansen-J (P-value)							0.877	0.894
RMSE	0.316	0.199	0.340	0.529	0.168	0.151		
F Statistic	119.1	100.6			15.63	14.47	30949.3	27835.6

p-values in parentheses

* $p<0.10$, ** $p<0.05$, *** $p<0.010$

Table 10: E-government and Corruption: extended regressors for the whole sample: 2003–2022.

	Pooled OLS		IV-2SLS		Fixed Effect		System GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.log of CPI							0.590***	0.601***
							(0.000)	(0.000)
E-government	-0.475	-0.199	35.83	20.51	0.112	-0.115	-0.0455	0.0486
	(0.140)	(0.479)	(0.260)	(0.122)	(0.662)	(0.509)	(0.718)	(0.657)
E-participation	-0.0607	-0.0537	0.628	0.275*	-0.210	-0.224*	0.0276	0.00846
	(0.648)	(0.686)	(0.169)	(0.084)	(0.127)	(0.097)	(0.662)	(0.897)
Online service	0.219	0.184	-12.42	-7.551	0.271**	0.309**		
	(0.264)	(0.364)	(0.256)	(0.108)	(0.035)	(0.024)		
Human capital	-0.0793	-0.0923	-10.68	-6.698	-0.317**	-0.267*		
	(0.476)	(0.379)	(0.269)	(0.124)	(0.034)	(0.059)		
Telecom. infrastructure	0.603***	0.521***	-11.79	-6.491	0.184	0.228**		
	(0.000)	(0.000)	(0.269)	(0.141)	(0.160)	(0.037)		
Rule of law	0.292***	0.303***	0.506***	0.337***	0.232	0.245	0.0933*	0.0905*
	(0.000)	(0.000)	(0.008)	(0.000)	(0.140)	(0.112)	(0.088)	(0.064)
Gov effectiveness	0.222***	0.180	-0.915	0.303	0.0421	-0.526*	0.152***	0.164
	(0.004)	(0.248)	(0.271)	(0.379)	(0.757)	(0.054)	(0.007)	(0.296)
Political stability	0.0438**	0.0470**	0.0413	0.00824	-0.0250	-0.0246	0.0112	0.0140
	(0.042)	(0.030)	(0.507)	(0.857)	(0.603)	(0.608)	(0.572)	(0.497)
Log of GDP per capita	-0.0297*	-0.0402**	-0.0451	-0.00836	0.291***	0.367***	-0.0135	-0.0205
	(0.074)	(0.041)	(0.686)	(0.858)	(0.006)	(0.001)	(0.460)	(0.310)
E-government x Gov effectiveness	-0.212*		2.442		0.177		-0.117	
	(0.075)		(0.223)		(0.271)		(0.343)	
Log of GDP per capita x Gov effectiveness		-0.00537		-0.0256		0.0881**		-0.00674
		(0.757)		(0.537)		(0.018)		(0.734)
Constant	3.984***	3.987***	3.220***	3.832***	1.568**	1.050	1.670***	1.650***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.045)	(0.162)	(0.000)	(0.000)
Observations	432	432	419	419	432	432	388	388
Adjusted R-squared	0.737	0.734	.	.	0.279	0.284		
AR2							0.997	1.005
No. of Instruments							62	62
Hansen-J (P-value)							0.882	0.916
RMSE	0.198	0.200	0.851	0.534	0.151	0.150		
F Statistic	99.49	92.51			15.38	21.68	19929.3	22326.8

p-values in parentheses

* p<0.10, ** p<0.05, *** p<0.010

Table 11: E-government and Corruption: extended regressors for the whole sample: 2003–2022.

	Pooled OLS		IV-2SLS		Fixed Effect		System GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.log CPI							0.780***	0.611***
							(0.000)	(0.000)
E-government	1.646***	-0.868**	2.077***	-59.93	0.743***	-0.0468	0.364***	-0.0576
	(0.000)	(0.023)	(0.000)	(0.293)	(0.000)	(0.866)	(0.004)	(0.648)
E-participation		-0.0529		-0.836		-0.224*		0.0280
		(0.688)		(0.339)		(0.098)		(0.644)
Online service		0.312		19.92		0.302**		
		(0.133)		(0.293)		(0.019)		
Human capital		-0.0441		15.29		-0.276*		
		(0.703)		(0.301)		(0.055)		
Telecom. infrastructure		0.644***		18.58		0.212		
		(0.000)		(0.283)		(0.109)		
Rule of law		0.289***		-0.0861		0.247		0.0852
		(0.000)		(0.853)		(0.115)		(0.127)
Gov effectiveness		-0.0648		-5.427		-0.501*		0.0887
		(0.691)		(0.322)		(0.069)		(0.597)
Political stability		0.0468**		0.146		-0.0248		0.0142
		(0.031)		(0.232)		(0.607)		(0.461)
Log of GDP per capita		0.0107		1.001		0.360***		-0.00841
		(0.651)		(0.323)		(0.001)		(0.639)
E-government x Gov effectiveness		-0.489***		-10.79		0.0529		-0.153
		(0.002)		(0.301)		(0.768)		(0.318)
Log of GDP per capita x Gov effectiveness		0.0496**		1.242		0.0820*		0.00954
		(0.032)		(0.308)		(0.058)		(0.702)
Constant	2.877***	3.750***	2.748***	-0.821	3.143***	1.084	0.644***	1.557***
	(0.000)	(0.000)	(0.000)	(0.860)	(0.000)	(0.145)	(0.001)	(0.000)
Observations	432	432	419	419	432	432	388	388
Adjusted R-squared	0.334	0.739	0.319	.	0.103	0.282		
AR2							1.161	0.994
No. of Instruments							56	63
Hansen-J (P-value)							0.846	0.916
RMSE	0.316	0.198	0.322	1.249	0.168	0.151		
F Statistic	229.7	93.89			28.06	20.70	49065.1	26054.1

p-values in parentheses

* p<0.10, ** p<0.05, *** p<0.010

Table 12: Digital-institutions and corruption: 2003–2022.

	Pooled OLS		IV-2SLS		Fixed Effect		System GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.Log of CPI							0.841***	0.711***
							(0.000)	(0.000)
Informal economy	-0.241*		-4.147***		-0.272***		0.0404	
	(0.069)		(0.000)		(0.001)		(0.613)	
EGDI x Institutions		0.700***		1.431***		0.442***		0.203***
		(0.000)		(0.000)		(0.000)		(0.000)
[1em] Constant	3.427***	3.288***	4.657***	3.212***	3.436***	3.312***	0.542***	0.969***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)
Observations	463	463	448	448	463	463	413	413
Adjusted R-squared	0.00824	0.477			0.0279	0.0704		
AR2							1.129	1.005
No. of Instruments							56	56
Hansen-J (P-value)							0.724	0.750
RMSE	0.387	0.281	0.735	0.399	0.173	0.169		
F Statistic	3.311	305.5			13.17	23.69	55707.6	50888.0

p-values in parentheses

* p<0.10, ** p<0.05, *** p<0.010