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Examining the global influence of e-governance on corruption: a panel data analysis

Dina Ali Seiam¹ and Doaa Salman^{1*}

Abstract

This study analyzes the impact of e-governance on corruption using a panel dataset comprising 110 countries over the period from 2003 to 2021. The specific focus of the research is on the relationship between the E-government Development Index (EGDI) and its four components, namely the Online Service Index (OSI), Human Capital Index (HCI), Telecommunication Infrastructure Index (TII), and E-Participation Index (EPI), and their effects on the Corruption Perceptions Index (CPI). To examine these relationships, the empirical analysis employs a fixed effect model, which is a suitable statistical approach for panel data analysis. The findings of the study reveal significant negative associations between the EGDI, OSI, HCI, and TII with corruption levels across countries worldwide. This implies that higher levels of e-government development, online service provision, human capital, and telecommunication infrastructure are associated with lower corruption perceptions. However, the EPI does not demonstrate a statistically significant relationship with the CPI. Based on these results, the paper provides recommendations for governments to prioritize two key areas. Firstly, governments should invest in the development of e-government infrastructure to enhance transparency, accountability, and efficiency in public administration, thereby reducing corruption. Secondly, initiatives aimed at enhancing public awareness and understanding of e-governance should be prioritized, as they contribute to increased citizen engagement and participation, which can ultimately lead to improved governance practices and reduced corruption levels.

Keywords E-government, Corruption, Online service index, Human capital index, Telecommunication infrastructure index, E-participation index, Fixed effect model

JEL Classification D73, G3, O11, O14, O38

Introduction

The rapid advancements in technology have transformed our daily lives, making it an invaluable asset in various aspects. With countries engaging in a competitive race to acquire superior technology, the quest for technological supremacy has become a focal point for nations like the USA, China, South Korea, and

many others. In the realm of e-government strategies, the implementation of digital government and the role of emerging technologies in development have long been subjects of debate since the early days of the World Wide Web. Critics have raised concerns about the investment in information technology, particularly considering the economic challenges faced by certain nations and the difficulties in providing high-quality social services to their citizens. On the other hand, academics argue that e-government is a crucial tool that can help reduce social and economic disparities while fostering national-level wealth creation [7].

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E-government is widely acknowledged for its potential to contribute to the reduction or eradication of corruption. In this study, our central focus lies in exploring the concept of corruption and the imperative to combat it. Corruption refers to the misuse of public resources for personal gain, encompassing various forms such as bribery, extortion, influence-peddling, nepotism, fraud, or the illicit use of funds [17].

The objective of this study is to investigate the global influence of e-government on corruption. Several international organizations have already started examining the role of e-government in combating corruption. Using a fixed effect model, our study will explore whether e-government has a direct and indirect positive impact on the Corruption Perception Index (CPI) of countries worldwide, spanning the period from 2003 to 2021.

To structure this paper effectively, we will begin with an introduction, followed by a comprehensive literature review that discusses the key variables affecting the relationship between e-governance and corruption. This review will be supported by both theoretical frameworks and empirical evidence. Additionally, we will present stylized facts illustrating the evolution of these variables over the years. Subsequently, we will outline the data and methodology employed, describing the econometric model and the methods implemented to assess the data. Finally, based on our findings, we will conclude with policy recommendations. By delving into the intricate relationship between e-government and corruption, this study aims to shed light on the potential impact of e-government in curbing corruption and provide valuable insights for policymakers and researchers alike.

Literature review

Governance refers to the process of decision-making and implementation by ruling authorities to address problems and conflicts within a country. Good governance necessitates conditions such as transparency, accountability, effectiveness, and efficiency in governance practices [21]. The emergence of e-governance, facilitated by advancements in Information Technology (IT), has introduced new possibilities. E-governance involves the use of IT by government agencies to enhance their interactions with individuals, industries, and other government entities. It aims to achieve objectives such as faster delivery of citizen services, stronger relationships with industries and businesses, improved access to information for citizens, and more dynamic government administration. Efficient e-governance services have been found to contribute to income growth, increased transparency, reduced corruption, and cost savings [6].

The relationship between e-governance and corruption is significant. Corruption involves the misuse of entrusted

power for personal gain, undermining trust, democracy, economic progress, and social equality. It exacerbates poverty, social divisions, and environmental issues [28–31]. The principal–agent theory provides insights into this relationship, suggesting that information technology can alter the principal–agent relationship and enhance management and control [16]. Corruption can be viewed as an asymmetric information and motivation problem, addressed through the principal–agent–client model. Elected government officials (principals) rely on public workers (agents) to provide public services to residents (clients) on their behalf. However, agents may engage in corrupt practices for personal gain due to their superior knowledge compared to both principals and clients. Corruption thrives in environments with limited accountability, manifesting in forms such as bribery, extortion, fraud, nepotism, and embezzlement [32].

E-government serves as a tool to reshape the principal–agent–client relationship and combat corruption. It facilitates wider access to information, simplifies rules and procedures, provides detailed transaction data for tracking actions and decisions, enhances accountability, and reduces discretionary power through standardization. These features contribute to lower corruption levels [3]. Numerous academic papers provide evidence suggesting a significant negative impact of e-government on corruption [20]. E-government has a positive impact on online services, improved telecommunication infrastructure, and the development of human capital in sub-Saharan Africa, and it also influences how people perceive corruption, [18]. These studies employ various methodologies and measurement approaches to examine the relationship, with findings indicating reduced corruption levels in different countries and regions worldwide, including MENA countries, China, and others.

For instance, a case analysis revealed that e-government can effectively reduce corruption by strengthening reform-oriented actors and promoting good governance. It highlighted how e-government can internally limit corruption by better managing and monitoring employee behavior and externally by improving citizen engagement [24]. Another study using a dynamic panel data model demonstrated that e-government, along with telecommunication infrastructure and online service quality, contributes to reducing corruption. It emphasized the complementary nature of e-government and Internet adoption in anti-corruption efforts [5].

A panel model analysis conducted on 80 countries found a positive and significant relationship between e-government and reduced corruption. The study also identified additional factors such as government size, government ratio, and gender ratio influencing perceived corruption levels [35]. In a study focusing on 34

European countries, e-government strategies were found to have a positive and significant impact on social indices such as the rule of law, political stability, and health, with observed decreases in mortality rates [7].

While many studies support the association between e-government implementation and reduced corruption, there are a few papers that did not find a significant impact. These studies emphasized other factors such as political stability, economic status, and government effectiveness as influential in reducing corruption [2]. Similarly, another study found significant relationships between e-government development, institutional quality, and ICT development, but did not observe a significant association between ICT development and corruption [15]. Recently research has shown research that financial inclusion plays a significant role in economic growth in European countries as it enhances their development [10]. It is crucial to consider the contextual factors and varying findings of these studies when evaluating the relationship between e-government and corruption.

For the Corruption Perception Index (CPI) for various regions around the globe, comparing the years 2003 and 2022, see Fig. 1. Notably, Europe and Central Asia consistently achieved the highest scores, reaching a range of 58 in both years. These scores surpass the global average of 44, reflecting the concerted efforts made by countries in the region to combat corruption and promote transparency. Several European nations, such as Denmark, Finland, Norway, and Sweden, obtained high scores and ranked prominently in the index [28–31]. Following Europe and Central Asia, East and South Asia exhibited a CPI score of 42 in 2003, which increased to 47 in 2022, also surpassing the global average. However, this region still faces challenges in addressing corruption, as even

countries with high scores experience a decline due to difficulties in defending rights, consulting citizens, and combating pervasive corruption [27].

The Middle East and North Africa region recorded scores of 43 in 2003 and 41 in 2022, which are comparable to the scores of Latin America and the Caribbean (37 in 2003 and 39 in 2022). In contrast, sub-Saharan African countries consistently obtained the lowest scores worldwide, with 29 in 2003 and 34 in 2022. It is worth noting that 90% of the countries in this region scored below 50, indicating a significant struggle in reducing corruption. Additionally, the African population faces numerous challenges, including food shortages, rising living expenses, an ongoing epidemic, and persistent conflicts [28–31].

According to Fig. 2, Europe has the highest e-government Development Index with a score of 0.8305 because European countries are actively exploring creative ways to deliver public services to residents. Despite their terrible circumstances, the majority of the region’s countries agreed not to cut resources for e-government investments. Denmark, Finland, Sweden, Iceland, Estonia, and the Netherlands lead Europe in EDGI and are classified as having a very high EDGI. Then there are Asia (0.6493) and the Americas (0.6438), which are both close to each other. Finally, Africa (0.6102) and Oceania (0.5081) are both below the global average [33].

According to Fig. 3, Europe and Central Asia exhibit significant political stability in comparison to other regions. Conversely, the Middle East has experienced a decrease in political stability, reaching a level close to -0.4. This decline can be attributed to the failure of the Arab Spring movement to dismantle power structures that enable those in authority to maintain control. Consequently, widespread governmental corruption

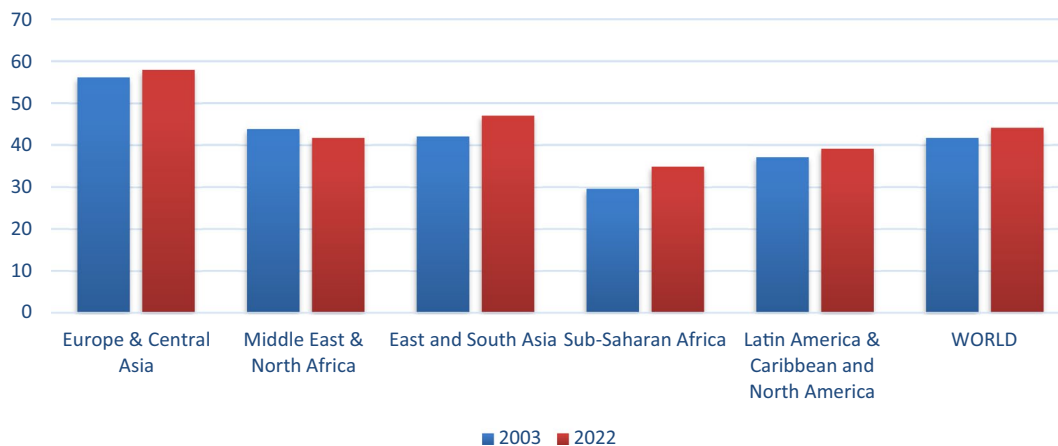


Fig. 1 CPI of the regions of the world in 2003 and 2022. [26–31] Source:

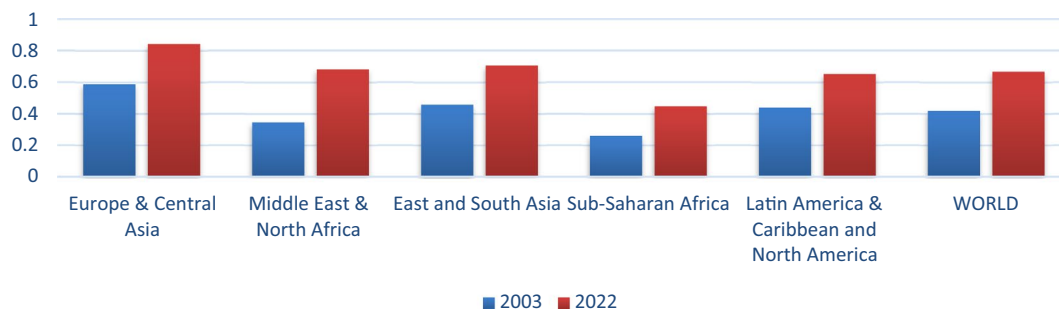


Fig. 2 EDGI in regions in 2003 and 2022. Source: [33]

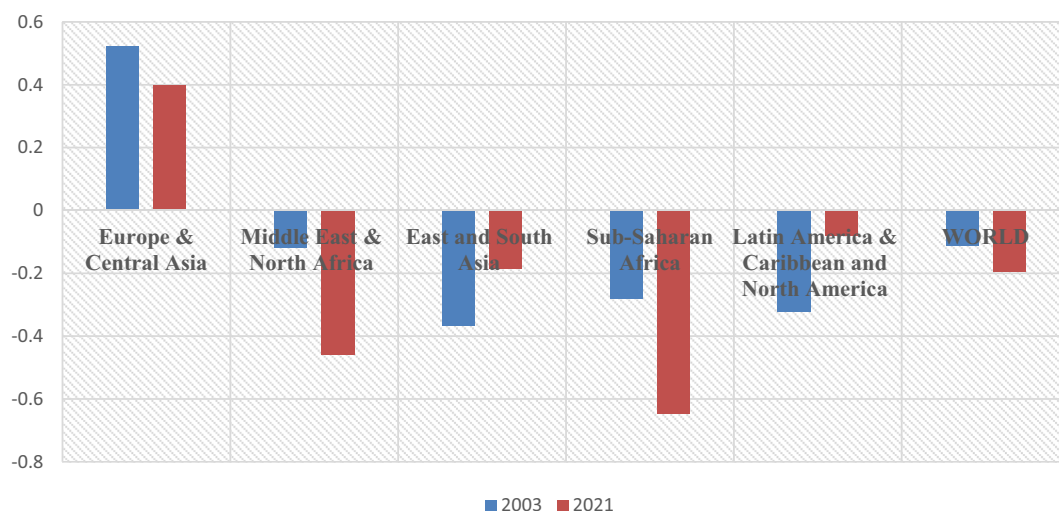


Fig. 3 Political stability and absence of violence/terrorism estimate in regions in 2003 and 2021. Source: Worldwide Governance Indicators, 2023

contributes to civil unrest and violence, exacerbating the already existing conflicts in the region [28–31]. Furthermore, Sub-Saharan countries face notable political instability due to various structural pressures. These pressures stem from factors such as demographics, lack of development, cross-group discrimination, and horizontal inequalities [22].

The graph presented in Fig. 4 demonstrates a significant rise in global Internet usage from 2003 to 2021 across all regions. North America has the highest number of individuals with Internet access, followed by Europe and Central Asia. However, it is important to note that Internet connectivity remains limited or nonexistent in many low-income and rural areas of developing nations. While nearly 60% of the global population has Internet access, over 4 billion people still lack access due to physical constraints, resource limitations, and government regulations. In certain cases, governments restrict Internet access as a means to control information and maintain power, resulting in an unequal distribution of Internet

access on a global scale. China and India have the largest number of Internet users, with an estimated 1.1 billion users in China and 711 million users in India [19].

Furthermore, the data reveal a positive correlation between variables such as the E-government Development Index (EGDI), E-participation Index (EPI), Online Service Index (OSI), Human Capital Index (HCI), Telecommunication Infrastructure Index (TII), and the Corruption Perception Index (CPI), as shown in Figs. 5, 6, 7, 8, and 9. This indicates that the implementation of e-governance and its associated components can contribute to the reduction or control of corruption. In other words, E-government appears to be a valuable tool in enhancing efficiency, effectiveness, and transparency, thereby aiding in the fight against corruption [2].

Methods

In this research paper, the authors employed panel data analysis as their chosen methodology, considering it to be more effective than time series and cross-sectional

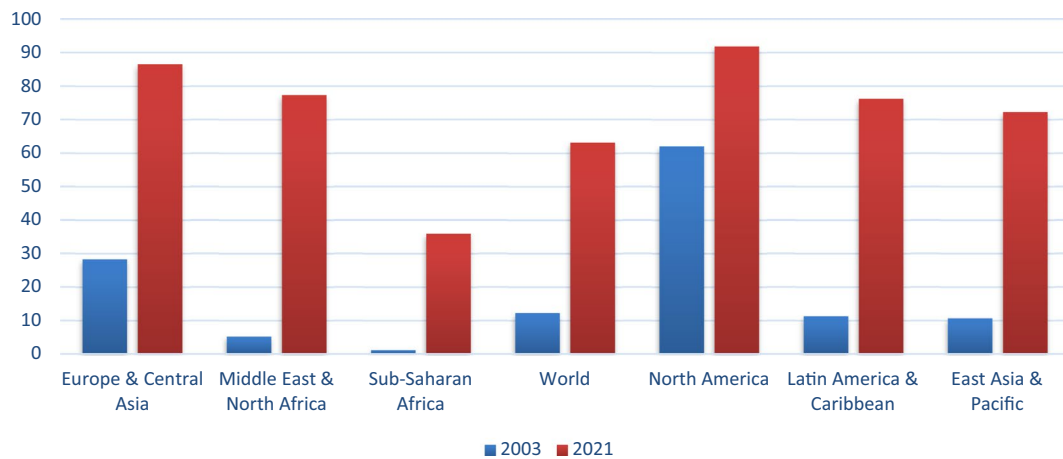


Fig. 4 Individuals using the Internet (% of the population) 2003 and 2021. *Source:* World Bank, 2023

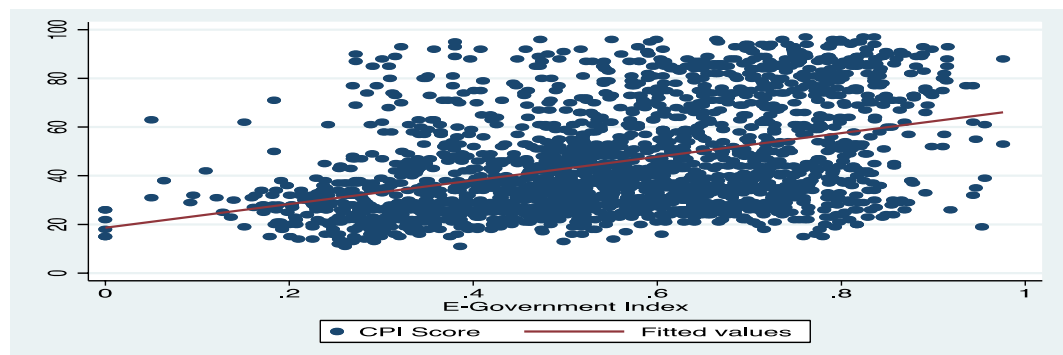


Fig. 5 Correlation between EGDI and CPI. *Source:* Author’s Calculations—using STATA

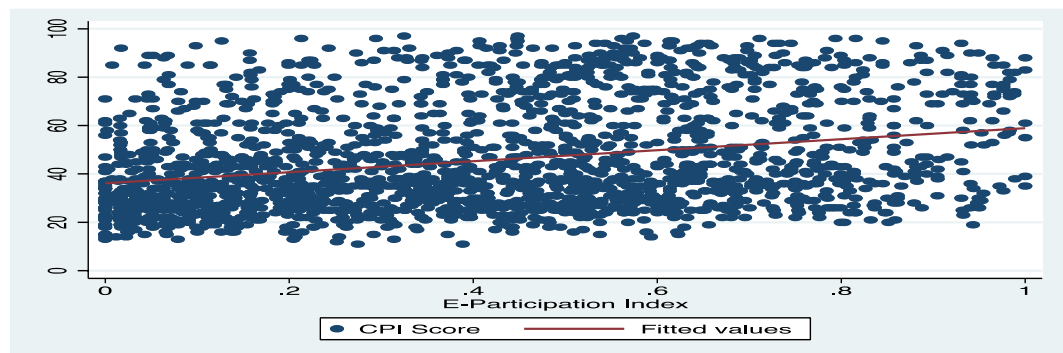


Fig. 6 Correlation between EPI and CPI. *Source:* Author’s Calculations—using STATA

analysis. The panel analysis was deemed stronger and superior because it can better capture variations, allowing for the description and analysis of complex relationships between dependent and independent variables. The primary purpose of using panel analysis was to increase the number of observations within the study to obtain

accurate results, particularly when data were absent or lacking for certain years. Additionally, panel data analysis is suitable for testing more intricate models compared to other types of analysis. It also offers several advantages, such as increased data variability, enhanced ability to address endogenous regulations that may be causal, and

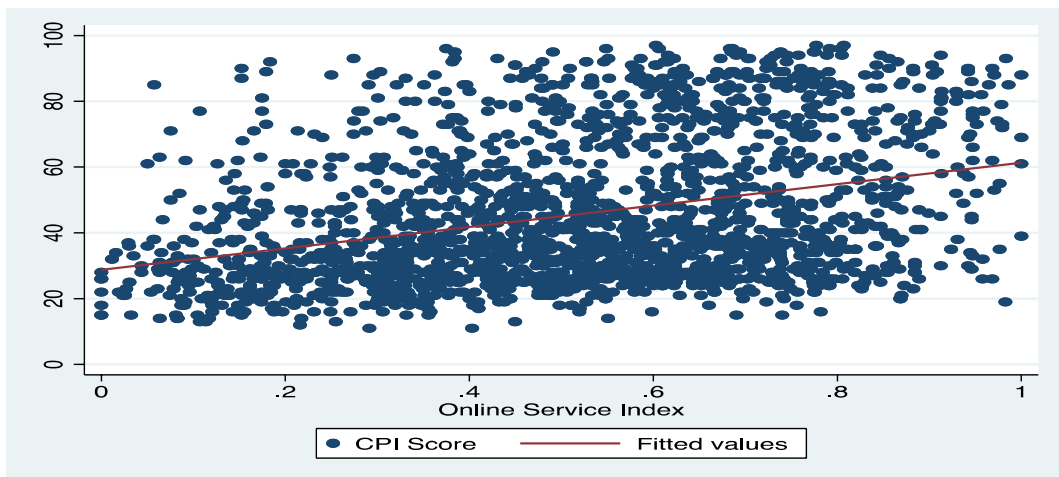


Fig. 7 Correlation between OSI and CPI. *Source:* Author's Calculations—using STATA

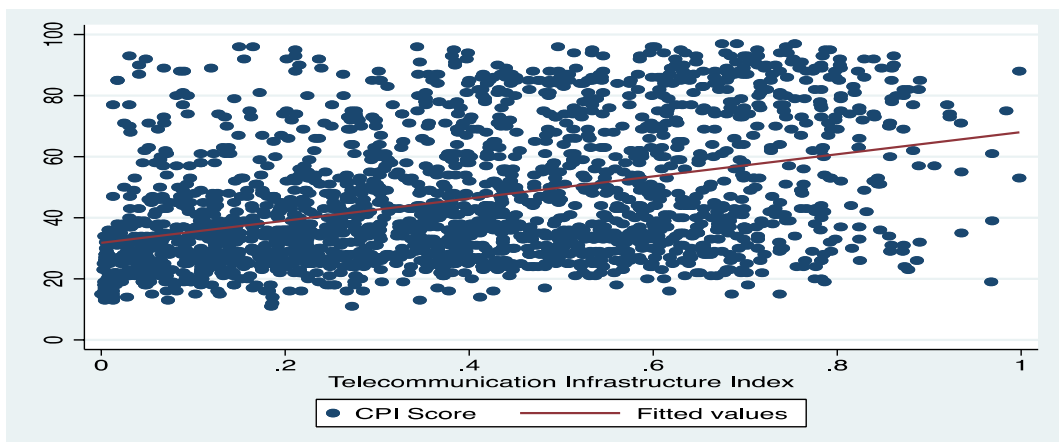


Fig. 8 Correlation between TII and CPI. *Source:* Author's Calculations—using STATA

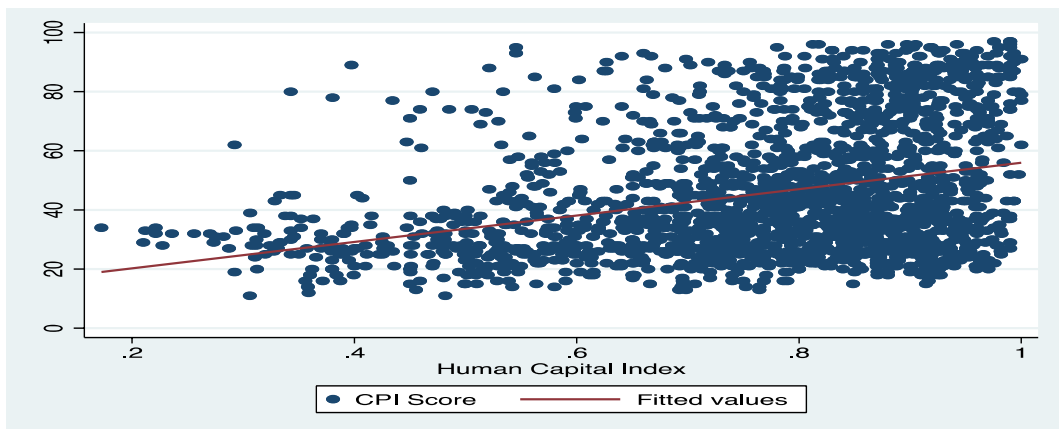


Fig. 9 Correlation between HCI and CPI. *Source:* Author's Calculations—using STATA

better control over potential collinearity among independent variables [11].

The researchers relied on secondary data for their analysis, which was collected from reputable sources including the World Bank, World Governance Indicators, Transparency International, and the United Nations E-government Surveys. These sources are widely recognized for their reliability and accountability. To estimate and test the econometric model, the researchers utilized the Stata program.

Data and variables

This research aims to examine the influence of e-governance on corruption. The significance of e-governance lies in the rapidly evolving technological landscape and its increasing importance in our daily lives. E-governance components have made accessing information and various services easier for people. This paper seeks to investigate whether e-government has a direct and indirect positive effect on corruption across 110 countries worldwide from 2003 to 2021.

The dependent variable of focus is the Corruption Perception Index (CPI), while the main variable of interest is the E-government Development Index (EDGI). The EDGI comprises four components: the Online Service Index (OSI), Human Capital Index (HCI), Telecommunication Infrastructure Index (TII), and E-Participation Index (EPI). Additionally, this paper controls for factors such as inflation, the number of individuals using the Internet, gross domestic product (GDP), and political stability and absence of violence/terrorism. The data for these variables are sourced from the World Bank indicators, World Governance indicators, Transparency International, and United Nations E-government Surveys.

The EDGI evaluates the performance of countries worldwide by assessing their national websites and the implementation of e-government strategies and policies in delivering necessary services. Political stability and absence of violence/terrorism gauge public perceptions concerning the likelihood of political instability or politically motivated violence, including terrorism. The indicator score ranges from weak (around -2.5) to strong (2.5) on a standard normal distribution scale. Gross domestic product (GDP) represents the total value added by all resident producers in an economy, including product taxes and minus subsidies, without accounting for depreciation of assets or depletion and degradation of natural resources. GDP data are presented in constant local currency. Inflation, measured by the consumer price index, reflects the annual percentage change in the cost to the average consumer of acquiring a specified basket of goods and services, which may be fixed or subject to periodic changes, such as on a yearly basis. The Laspeyres

formula is commonly used for calculating inflation. The term “Internet users” refers to individuals who have utilized the Internet within the last three months, regardless of the device used (e.g., computer, mobile phone, personal digital assistant, gaming console, digital TV, etc.).

Proposed form of the model

The proposed model for estimating variables in this study goes as follows:

$$CPI_{it} = \alpha + \beta_1 EDGI_{it} + \beta_2 EPI_{it} + \beta_3 OSI_{it} + \beta_4 HCI_{it} + \beta_5 TII_{it} + \beta_6 RGDP_{it} + \beta_7 POLS_{it} + \beta_8 INF_{it} + \beta_9 IUI_{it} + \epsilon_{it}$$

The dependent variable CPI_{it} represents the Corruption Perception Index, while the dependent variables EDGI represent the E-government Development Index, EPI represents the E-Participation Index, OSI represents the Online Service Index, HCI represents Human Capital Index, TII represents Telecommunication Infrastructure Index, RGDP represents gross domestic product (GDP), POLS represents political stability and absence of violence/terrorism, INF represents inflation, and IUI represents individuals using the Internet.

Data analysis

Table 1 provides basic statistical results. The CPI score, which is the dependent variable, has an average value of 45.678 across all countries, indicating that corruption is a prevailing issue globally. Moreover, the CPI variable has the highest mean compared to the other variables. In contrast, the inflation variable (INF) has the highest maximum value of 557.202 and the lowest minimum value of -10.067.

Table 2 shows that there is a statistically significant but moderate negative correlation between the dependent variable, Corruption Perception Index (CPI), and two independent variables, inflation (INFcpi), and RGDP, at a 10% significance level. However, the remaining

Table 1 Descriptive analysis. *Source:* Author’s Calculations

Variable	Obs	Mean	Std. Dev	Min	Max
CPI Score	2090	45.678	21.243	11	97
EGDI	2090	0.556	0.182	0	0.976
EPI	2090	0.418	0.262	0	1
OSI	2090	0.52	0.222	0	1
HCI	2090	0.77	0.158	0.172	1
TII	2090	0.383	0.238	0	0.998
PolS	2090	-0.055	0.919	-3.18	1.687
INFcpi	2034	5.992	17.566	-10.067	557.202
LRGDP	2089	27.918	3.003	22.589	37.263
IUI	2065	44.872	31.303	0.024	100

Table 2 Correlation analysis. *Source:* Author’s Calculations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) CPI score	1.000									
(2) EGDI	0.417*	1.000								
(3) EPI	0.281*	0.796*	1.000							
(4) OSI	0.339*	0.910*	0.887*	1.000						
(5) HCI	0.333*	0.721*	0.317*	0.481*	1.000					
(6) TII	0.407*	0.926*	0.768*	0.805*	0.531*	1.000				
(7) PoS	0.774*	0.328*	0.185*	0.235*	0.326*	0.304*	1.000			
(8) INFcpi	-0.193*	-0.111*	-0.099*	-0.100*	-0.074*	-0.105*	-0.196*	1.000		
(9) LRGDP	-0.145*	-0.001	0.034	0.038	-0.037	-0.020	-0.287*	-0.002	1.000	
(10) IUI	0.723*	0.481*	0.415*	0.425*	0.285*	0.507*	0.565*	-0.181*	-0.075*	1.000

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

Table 3 Hausman [8] specification test. *Source:* Author’s Calculations

	Coef
Chi-square test value	341.654
p value	0

independent variables exhibit a significant and positive correlation with the dependent variable at a 10% significance level. Among them, political stability (PoS) has the strongest and highest positive correlation coefficient of 0.774 (Tables 3, 4, and 5).

Furthermore, there is a statistically significant but moderate negative correlation between the E-government Development Index (EDGI) and the independent variable INF at a 10% significance level. In contrast, the remaining independent variables demonstrate a significant and positive correlation with EDGI, except RGDP, which has a 10% significance level. The strongest correlation coefficient was between EDGI and TII, which is 0.926. The four components of EDGI, namely EPI, OSI, HCI, and TII, exhibit a significant but negative correlation with INF at a 10% significance level.

At a 10% significance level, there is a statistically significant and moderate negative correlation between the independent variable political stability (PoS) and two other independent variables inflation (INF) and RGDP, but there is a significant and positive correlation between PoS and IUI (individuals using the Internet) with 10% significance level. The inflation (INF) variable shows a significant and negative correlation with other independent variables individuals using the Internet (IUI) at a 10% significance level. The RGDP dependent variable shows a significant and negative correlation with other independent variables individuals using the Internet (IUI) at a 10% significance level. However, as perfect multicollinearity

Table 4 Pooled OLS model. *Source:* Author’s Calculations

	CPI score	CPI score	CPI score	CPI score	CPI score
EGDI	5.101 (3.20)**				
PoS	12.765 (35.55)**	12.864 (35.79)**	12.857 (35.90)**	12.625 (34.53)**	12.836 (35.82)**
INFcpi	-0.027 (1.64)	-0.029 (1.72)	-0.027 (1.64)	-0.028 (1.69)	-0.028 (1.69)
LRGDP	0.268 (3.01)**	0.283 (3.18)**	0.268 (3.01)**	0.270 (3.04)**	0.279 (3.14)**
IUI	0.266 (24.75)**	0.278 (25.77)**	0.268 (25.14)**	0.274 (27.35)**	0.267 (24.27)**
EPI		0.199 (0.19)			
OSI			3.403 (2.68)**		
HCI				5.360 (3.14)**	
TII					3.113 (2.52)*
_cons	24.412 (9.56)**	26.215 (10.49)**	25.356 (10.09)**	22.668 (8.28)**	25.688 (10.27)**
R^2	0.72	0.72	0.72	0.72	0.72
N	2008	2008	2008	2008	2008

* $p < 0.05$; ** $p < 0.01$

(1) does not exist between any of the variables we precede our analysis using all the selected variables.

The Hausman test will be used where one of the models compared produces coherent and effective findings under the null hypothesis, and one of the models—is reliable yet ineffective, while the other—is inaccurate and consistent with the alternative hypothesis [23].

Based on the results that are demonstrated in the table above, where the Chi-square is equal to 341.654 with a

Table 5 Fixed effect model. *Source:* Author's Calculations

	CPI score	CPI score	CPI score	CPI score	CPI score
EGDI	1.954 (2.94)**				
PolS	3.803 (11.26)**	3.796 (11.23)**	3.793 (11.23)**	3.907 (11.53)**	3.796 (11.24)**
INFcpi	-0.005 (0.71)	-0.005 (0.70)	-0.005 (0.73)	-0.005 (0.74)	-0.005 (0.72)
LRGDP	0.056 (0.20)	0.071 (0.25)	0.056 (0.20)	0.044 (0.16)	0.072 (0.25)
IUI	0.083 (14.16)**	0.083 (13.69)**	0.083 (14.00)**	0.089 (15.25)**	0.082 (13.61)**
EPI		0.766 (1.75)			
OSI			1.303 (2.46)*		
HCI				1.737 (2.20)*	
TII					1.357 (2.73)**
_cons	39.663 (4.99)**	40.025 (5.01)**	40.084 (5.02)**	39.490 (5.08)**	39.869 (5.00)**
R ²	0.7202	0.7183	0.7198	0.7201	0.7197
N	2008	2008	2008	2008	2008

* $p < 0.05$; ** $p < 0.01$

probability of 0 which is less than 0.5, then we reject the Ho. Therefore, the results have concluded that the fixed effect is of better use in this study as a fixed effect model.

Results

The pooled OLS model, also known as integrated ordinary least squares (OLS), assumes that the data matrices of the cross-sectional dimensions are comparable to each other [34]. In the table above, five models are presented with five different main independent variables: E-government Development Index, E-participation Index, Online Service Index, Human Capital Index, and Telecommunication Infrastructure Index. All of these variables have a significant and positive effect on the dependent variable, the Corruption Perception Index (CPI), except for the E-participation Index, which has an insignificant effect.

In the first model, there is a positive and significant relationship between the E-government Development Index and the Corruption Perception Index. A one-unit increase in the EDGI leads to a 5.101 increase in the CPI score with a 99% confidence level, holding the other variables constant. Similarly, when political stability increases by one unit, the CPI score increases by 12.765 with a 99% confidence level, while inflation (INF) has an insignificant effect on the CPI. Additionally, a 1% increase in real

gross domestic product (RGDP) leads to a 26.8% increase in the CPI score with a 99% confidence level, and a 1% increase in Internet users results in a 26.6% increase in the CPI score with a 99% confidence level.

In the second model, there is a positive but insignificant relationship between the E-participation Index (EPI) and CPI. However, there is a positive and significant relationship between political stability (PolS) and EPI. A one-unit increase in PolS leads to a 12.864 increase in the CPI score with a 99% confidence level. Inflation remains insignificant in its relation to the CPI. Similarly, a 1% increase in RGDP results in a 28.3% increase in the CPI score with a 99% confidence level. Furthermore, Internet users have a significant and positive effect on the CPI, with a 1% increase in users leading to a 26.8% increase in the CPI score with a 99% confidence level.

In the third model, there is a significant and positive relationship between the Online Service Index and the Corruption Perception Index. When the OSI increases by one unit, the CPI score increases by 3.403 units with a 99% confidence level. Political stability also has a positive and significant effect on the CPI, with a one-unit increase in PolS resulting in a 12.857 increase in the CPI score. Inflation remains insignificant, but RGDP and Internet users have significant and positive effects on the CPI. A 1% increase in RGDP leads to a 26.8% increase in the CPI score, while a 1% increase in Internet users results in a 26.8% increase in the CPI score.

In the fourth model, there is a 99% confidence level between the Human Capital Index (HCI) and CPI, as they have a positive and significant relationship. A one-unit increase in HCI leads to a 5.360 increase in the CPI score. Similarly, political stability has a positive and significant effect on the CPI, with a one-unit increase in PolS resulting in a 12.625 increase in the CPI score. Inflation remains insignificant. Additionally, a 1% increase in RGDP leads to a 27% increase in the CPI score, and a 1% increase in Internet users results in a 27.4% increase in the CPI score, both with a 99% confidence level.

In the fifth model, there is a 95% confidence level between the Telecommunication Infrastructure Index (TII) and the CPI, with a positive and significant effect. A one-unit increase in TII leads to a 3.113 increase in the CPI score. Political stability also has a positive and significant effect on the CPI, with a one-unit increase in PolS resulting in a 12.836% increase in the CPI score with a 99% confidence level. Conversely, inflation remains insignificant in its relationship with the CPI. However, both RGDP and Internet users have positive and significant effects on the CPI with a 99% confidence level. A 1% increase in RGDP leads to a 27.9% increase in the CPI score, while a 1% increase in Internet users results in a 26.7% increase in the CPI score. All of the models have

an R2 value of 72%, indicating that 72% of the variations in the CPI score can be explained by the independent variables.

Discussion

The fixed effects model is employed in this study to assess the relationship between the estimator and the outcome variables for each group. Each group possesses unique qualities that may influence the estimated variables in an undetermined manner [26]. The table presented in the discussion section includes five models with five different main independent variables: the E-government Development Index (EDGI), E-participation Index (EPI), Online Service Index (OSI), Human Capital Index (HCI), and Telecommunication Infrastructure Index (TII). All of these variables exhibit a significant and positive effect on the dependent variable, the Corruption Perception Index (CPI), except for the E-participation Index, which has an insignificant effect.

In the first model, the EDGI demonstrates a positive and significant relationship with the CPI score at a 99% confidence level. This implies that a 1-unit increase in EDGI results in a 1.954 increase in the CPI score. The study highlights the potential of e-government as an essential instrument for preventing corruption and improving governance. E-government can increase transparency in public administration, reduce discretionary power, and enhance the possibility of exposure, thereby limiting opportunities for corruption [4]. Furthermore, political stability exhibits a positive and significant relationship with the CPI score at a 99% confidence level. A 1-unit increase in political stability leads to a 3.803 increase in the CPI score. However, both the inflation (INF) and real gross domestic product (RGDP) variables have an insignificant relationship with the CPI score. On the other hand, the number of individuals using the Internet (IUI) demonstrates a positive and significant relationship at a 99% confidence level, with an 8.3% increase in the CPI score for a 1% increase in Internet users.

In the second model, there is an insignificant relationship between the dependent variable CPI and three independent variables: EPI, inflation (INF), and RGDP. However, a positive and significant relationship is observed between political stability (PolS) and the CPI score at a 99% confidence level. A 1-unit increase in political stability results in a 3.796 increase in the CPI score. Similarly, the number of individuals using the Internet (IUI) exhibits a positive and significant relationship with the CPI score at a 99% confidence level, with an 8.3% increase in the CPI score for a 1% increase in Internet users.

In the third model, there is a significant and positive relationship between the Online Service Index (OSI) and

the Corruption Perception Index. A 1-unit increase in OSI leads to a 1.303-unit increase in the CPI score at a 95% confidence level. This finding emphasizes the role of online platforms in facilitating communication between the public and government institutions. The use of mobile applications, data analysis, artificial intelligence, and websites contributes to the fight against corruption by increasing access to public information, digitizing government services, monitoring officials' operations, and facilitating corruption reporting [25]. Additionally, political stability exhibits a positive and significant effect on the CPI score at a 99% confidence level. A 1-unit increase in political stability leads to a 3.793 increase in the CPI score. The variables inflation (INF) and RGDP have an insignificant relationship with the CPI score. Furthermore, Internet users (IUI) have a significant and positive effect on the CPI score at a 99% confidence level, with an 8.3% increase in the CPI score for a 1% increase in Internet users.

In the fourth model, there is a 95% confidence level relationship between the Human Capital Index (HCI) and the CPI, with both variables exhibiting a positive and significant relationship. A 1-unit increase in HCI leads to a 1.737 increase in the CPI score. Similarly, political stability shows a positive and significant effect on the CPI score at a 99% confidence level. A 1-unit increase in political stability results in a 12.625 increase in the CPI score. However, inflation (INF) and gross domestic product (GDP) have an insignificant effect on the CPI score. Additionally, a 1% increase in Internet users (IUI) leads to an 8.9% increase in the CPI score at a 99% confidence level.

In the fifth model, there is a 99% confidence level relationship between the Telecommunication Infrastructure Index (TII) and the CPI, with a positive and significant effect. A 1-unit increase in TII results in a 1.357 increase in the CPI score. Political stability also exhibits a positive and significant effect on the CPI score at a 99% confidence level. A 1-unit increase in political stability leads to a 3.796 increase in the CPI score. Conversely, inflation (INF) and RGDP have an insignificant relationship with the CPI score. Moreover, Internet users (IUI) have a positive and significant relationship with the CPI score. I'm sorry, but I don't have access to the specific table or study you are referring to. However, based on the information you provided, it seems that the study used a fixed effects model to analyze the relationship between various independent variables (such as E-government Development Index, E-participation Index, Online Service Index, Human Capital Index, and Telecommunication Infrastructure Index) and the dependent variable, Corruption Perception Index (CPI).

The results of the analysis indicate the significance and direction of the relationship between each independent

variable and the CPI. For example, the E-government Development Index, political stability, and the number of Internet users show a significant and positive relationship with the CPI. This suggests that higher levels of e-government development, political stability, and Internet usage are associated with lower levels of perceived corruption.

On the other hand, variables such as the E-participation Index, inflation, and gross domestic product (GDP) show an insignificant relationship with the CPI, indicating that these factors may not have a significant impact on perceived corruption.

It is important to note that these findings are specific to the study you mentioned and may not necessarily apply universally. The results of any statistical analysis can vary depending on the specific dataset and methodology used.

Conclusions

The study emphasizes the importance of e-government in combating corruption and promoting transparency. Specifically, the study examines the impact of the E-Government Development Index (EDGI) on the Corruption Perception Index (CPI) and explores the relationships between EDGI, Online Service Index (OCI), Telecommunication Infrastructure Index (TII), and Human Capital Index (HCI) using a fixed effect model and data from 2003 to 2021.

The findings of the study reveal a positive and significant association between EDGI, OCI, TII, and HCI, indicating that the development of e-government plays a crucial role in combating corruption and enhancing transparency. However, variables such as Economic Performance Index (EPI), inflation, and gross domestic product (GDP) show an insignificant relationship with CPI.

Although the research provides valuable insights, it is important to acknowledge certain limitations. One limitation pertains to data collection, as some variables had missing years due to the biennial reports conducted by the United Nations E-government Surveys. To address this issue, the interpolation method was employed.

Based on the comprehensive analysis of e-governance and corruption, the study offers several recommendations for effectively utilizing e-government for corruption control. These recommendations include prioritizing investments in human capacity and skills, implementing agendas and programs to foster ICT skill development, emphasizing public awareness and education about e-governance, and considering various factors such as electronic service prioritization, infrastructure quality, and resource requirements in e-government implementation.

In summary, this research highlights the significance of e-government in controlling corruption and promoting transparency. The theoretical implications contribute

to our understanding of the relationship between e-government development and corruption perception, while the practical implications provide valuable recommendations for governments and policymakers to effectively utilize e-governance for corruption control and societal development.

Appendix A

List of countries in the sample

Albania	Greece	Oman
Algeria	Guatemala	Pakistan
Angola	Haiti	Panama
Argentina	Honduras	Papua New Guinea
Armenia	Hungary	Paraguay
Australia	Iceland	
Austria	India	Peru
Azerbaijan	Indonesia	Philippines
Bahrain	Iran, Islamic Rep	Poland
Bangladesh	Iraq	Portugal
Belarus	Ireland	Qatar
Belgium	Italy	Romania
Bolivia	Jamaica	Russian Federation
Botswana	Japan	Saudi Arabia
Brazil	Jordan	Senegal
Bulgaria	Kazakhstan	Singapore
Cameroon	Kenya	Slovak Republic
Canada	Korea, Rep	Slovenia
Chile	Kuwait	South Africa
China	Kyrgyz Republic	Spain
Colombia	Lithuania	Sri Lanka
Costa Rica	Luxembourg	Sudan
Croatia	Madagascar	Sweden
Cuba	Malawi	Switzerland
Cyprus	Malaysia	Thailand
Denmark	Mali	Trinidad and Tobago
Dominican Republic	Mauritius	Tunisia
Ecuador	Mexico	Turkiye
Egypt, Arab Rep		Uganda
El Salvador	Morocco	Ukraine
Estonia	Mozambique	United Arab Emirates
Ethiopia	Myanmar	UK
Finland	Namibia	Uruguay
France	Netherlands	Vietnam
Gambia, The	New Zealand	Zambia
Georgia	Nicaragua	Zimbabwe
Germany	Nigeria	
Ghana	Norway	

Abbreviations

CPI	Corruption perception index
EDGI	E-government development index
EPI	E-participation index
FGLS	Feasible generalized least squares
GDP	Gross domestic product
GMM	Generalized method of moments
INF	Inflation
IUI	Individuals using the Internet
MENA	Middle East and North Africa
POLS	Political stability and absence of violence/terrorism
PTR	Panel threshold regression

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Author contributions

All authors contributed to the completion of this article from conceptualization to the concluding remark. Hence, we have read and approved the manuscript. DS designed and drafted the work and substantively revised it. MS was responsible for the analysis and interpretation of data. All authors have read and approved the manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. The data used for this research sourced from the a primary research and the results are available.

Declarations

Ethics approval and consent to participate

All authors declare that there are no potential risks or burdens associated with this study and we took the approval of the participant prior to do the study. All the comments and views are related to the authors, not to the institution they are working.

Consent for publication

All authors declare that there are no potential risks or burdens associated with this study and we took the approval of the participant prior to do the study.

Competing interests

The authors declare that they have no competing interests.

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