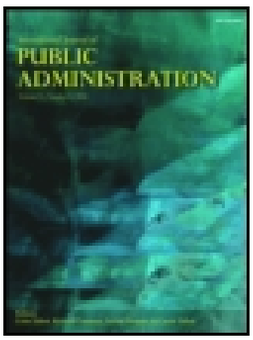

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E-Government as a Tool in Controlling Corruption

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ABSTRACT

Combating corruption is crucial to achieve sustainable development. With the digital revolution, the use of Information and Communications Technology by the government can promote more efficient services, diminishing the discretionary power of officials, and thus reducing corruption and promoting sustainable development. This study empirically investigates the impact of e-Government in reducing corruption on a large panel data of 175 countries, from 2003 to 2019, by estimating regression models. The results suggest that e-Government, accountability, political stability, economic wealth, and internet are significant determinants of corruption. E-Government can be a significant tool to curb corruption, although e-Government Development Index needs to exceed a threshold of 0.39 to reduce corruption. Although e-Government is a recent phenomenon, it can be regarded as an important tool for combating corruption and improving governance, enhancing transparency in public administration, since it reduces discretional power and increases the chance of exposure, eliminating some opportunities for corruption.

KEYWORDS

e-Government; corruption; digitalization; political instability; panel data

Introduction

The United Nations (UN) (2006) set a goal of Peace, Justice, and Strong Institutions in the Sustainable Development Goals to achieve until 2030, with targets as substantially reduce corruption and bribery in all their forms and develop effective, accountable, and transparent institutions at all levels. Fighting corruption is crucial to achieve sustainable development, since it decreases economic growth, increases income inequality and poverty and worsens human development outcomes.

Corruption, defined as the "use of public office for private gain" by the World Bank (Gray & Kaufmann, 1998, p. 7), can have high costs for the society and has been a concern of some international organizations as the World Bank, Transparency International, the International Monetary Fund and the Organisation for Economic Cooperation and Development (OECD). Traditionally corruption was a typical phenomenon of developing countries and economies in transition, but today it is a problem and an important challenge even for the richest countries. Corruption indicators show large divergences between developing and emerging economies, but also among those most economically developed. In the 36 countries classified by the United Nations as developed economies, the 2019 Corruption Perception Index by Transparency International (that ranges from 0 (highly corrupt) to 100 (highly clean)) is below 50 in Bulgaria, Croatia, Greece, Hungary, and Romania and equal to 50 in Slovakia. In 2019, more than two-thirds of countries analysed by Transparency International score below 50, with an average score of 43. Also with globalization, concern about this phenomenon has intensified, since strategic alliances and mergers and acquisitions at the international level depend much more on mutual trust, and different levels of government ethics and regulations changes the game's rules, making the process more difficult (Castro & Nunes, 2013).

Corruption can be understood as a weakness of the administrative system of the public sector and insufficient institutional capacity to perform the fundamental functions of governance: managing human resources; managing the products under the responsibility of the State; observance of the rule of law; formulation and implementation of sound economic policies; revenue collection system; inspection and audit; accountability process; budgetary programming; management of financial control; and public procurement processes (Comissão Interministerial da Reforma do Sector Público [CIRSEP], 2001). Making political institutions more transparent can reduce corruption (Lindstedt & Naurin, 2005).

With the digital revolution, the use of ICTs by the government can provide efficient management of information, promote more efficient services, enhance

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transparency and accountability, citizen participation and awareness, diminishing the discretionary power of officials, and thus reduce corruption.

Recognizing the need to fight corruption, the objective of this paper is to investigate if e-Government development can lower corruption. Some literature shows that e-Government reduces corruption but, in some cases, it persists after the introduction of e-Government. In order to analyse this phenomenon, this paper investigates if e-Government needs to exceed a threshold before having a positive impact in reducing corruption. As corruption is a complex issue, other technological, political, and economic factors are included in the analysis.

The paper is organized as follows: first, the literature is reviewed. Then, the research methodology is defined, followed by the presentation and analysis of the results; and finally conclusions and implications of this study are provided.

Literature review

The dominant theory to explain corruption is the principal-agent-client model, in a context of asymmetric information. The principal (government, representing the state and citizens) employs public officers (agents) to deliver services to citizens and businesses (clients; Klitgaard, 1988). Due to asymmetric information, where the agents know more about the public administration than the other participants, the public officers consider that the State can be a source of income and they have access to a monopoly, discretionary power and without enough accountability for decisions and results, corruption arises (Klitgaard, 1988). This is mathematically formulated by Corruption = monopoly + discretion – accountability (Nuhu & Mpambije, 2017). In order to lessen corrupt levels, the information system of the government should reduce the agent's monopoly, their discretionary power or enhance accountability (DiRienzo et al., 2007).

In the literature, there are several definitions of e-Government. According to the World Bank e-Government refers to "government agencies' use of information technologies (such as Wide Area Networks, the Internet, and mobile computing) that can transform relations with citizens, businesses, and other arms of government" (United Nations, 2018, p. 220). Lau et al. (2008, p. 89) defines e-Government as "the process of connecting citizens digitally to their government in order that they might access information and services offered by government agencies". These technologies allow government to exchange information and services electronically with citizens, business, and government organizations and for the World Bank they can "serve a variety of different ends: better delivery of government services to citizens, improved interactions with business and industry, citizen empowerment through access to information, or more efficient government management." (UN, 2018, p. 220).

E-Government can reduce corruption for several reasons. First, the information systems can promote transparency by extending access to information with higher quality and so citizens and businesses can question arbitrary decisions and unreasonable procedures (Dwivedi et al., 2009; Elbahnasawy, 2014; Gautam et al., 2017; Srivastava et al., 2016). Second, e-Government can limit arbitrariness, by reducing the discretionary power of civil servants and by increasing the capacity of the citizens and businesses to supervise officials' and politicians' decisions (Corojan & Criado, 2012; Elbahnasawy, 2014; Gautam et al., 2017; Klitgaard, 1988). Third, it reduces the monopoly of elements of government by the political class and lowers the interaction between government officials and citizens (Klitgaard, 1988). Fourth, information systems enhance accountability (Corojan & Criado, 2012; Gautam et al., 2017; Klitgaard, 1988).

By promoting independent institutions that attempt to be transparent, e-Government may be an important tool for combating corruption.

Although there are several reports about the impact of e-Government projects on corruption, at the macroeconomic level the literature is still scarce and the results are not consensual. Several studies show empirical evidence that e-Government reduces corruption (Andersen, 2009; Bhatnagar, 2003; Elbahnasawy, 2014; Kim et al., 2009; Lupu & Lazar, 2015; Mistry & Jalal, 2012; Nam, 2018; Shim & Eom, 2008; Srivastava et al., 2016; Starke et al., 2016) but this is not consensual. Bhatnagar (2014) argues that e-Government systems can have weaknesses that allow corrupt behaviours and corrupt officials can learn how to overcome e-Government systems. In recent studies, while Basyal et al. (2018) on a panel data of 176 countries during the period 2003 to 2014, and through a probability reduction approach, did not found statistical evidence that e-government could curb corruption, Nam (2018), considering the political, economic, and cultural condition of countries, suggests that e-Government service maturity could control corruption. More concretely, the study of Nam (2018) highlights that the disparity in cultural, political, and economic between countries influences the impact of e-Government service maturity on corruption.

Corruption is, nevertheless, a complex and multifaceted phenomenon. The literature identifies several causes of corruption as historical and cultural traditions, economic, political, institutional, and individual reasons

(Mauro, 1995, 1998; Rose-Ackerman, 1999; Saha & Gounder, 2013; Sandholtz & Koetzle, 2000; Treisman, 2000).

Better public administration, that is, good governance (greater efficiency, transparency, and integrity) can reduce corruption. Governance consists in "the traditions and institutions by which authority in a country is exercised" (World Bank, 2007, p. 2). This includes the process through which governments are selected, monitored, and replaced – political dimension; the ability of the government to manage its resources and effectively formulate and implement sound policies – economic dimension; and the respect by citizens and the state for the institutions that rule economic and social interactions between them – institutional dimension. In this context, good governance allows responsible management of resources with the aim of economic growth, social development, reduction of inequalities, and the perception of good governance makes a society less corrupt. Kaufmann (2005) empirically demonstrates that improving governance increases income per capita, reduces child mortality, illiteracy, and corruption. Good governance is translated by the perception of representativeness of the "voices" of the different social strata, the capacity of the government to provide acceptable justifications for its decisions and actions taken in the name of the public good (voice and accountability), and political stability that contributes to minimize conflicts, increase economic agents' confidence in governance, leaving less room for corrupt behaviour. Several authors show that political stability (Castro, 2011; Kim, 2014; Park, 2003; Serra, 2006; Weitzel & Berns, 2006; Zhao & Xu, 2015) and accountability (Castro, 2011) can reduce corruption.

In countries where there is greater economic freedom – and that is associated with more flexible regulations – behaviour is more likely to be less corrupt. With excessive regulations, bureaucrats are more likely to engage in rent-seeking behaviours and citizens to circumvent existing barriers enhancing corruption (Dincer & Gunalp, 2020; Holcombe & Boudreaux, 2015). As Dincer and Gunalp (2020, p. 1) refer "A burdensome regulatory environment increases the opportunities for individuals and firms to bypass these regulations through various forms of bribery. As the size of the government increases, potential returns to bypassing regulations increase as well." The quality of regulation is an increasingly relevant dimension for promoting competitiveness, formal sector growth and economic growth and an efficient regulatory climate – without excesses and with transparency and simplicity – reduces corruption (Castro, 2011). At the aggregated level, Holcombe and Boudreaux (2015) analysed for Scandinavian countries how regulatory burden affects corruption and the results suggest that excessive regulation causes more corruption. These results are also supported by Dincer and Gunalp (2020) for the United States.

In the economic literature, it is argued that institutional quality and, consequently, corruption depends on economic factors. The development of public administration is a reflex of the level of income and the degree of prosperity. There is a general consensus that in poor countries corruption is higher than in rich countries (Elbahnasawy, 2014; Jain, 2001; Serra, 2006). This may be due to the fact that rich countries have more resources to fight corruption and, as Seldadyo and de Haan (2006) suggest, corruption behaves as an inferior good: the higher is the income, the lower is the demand. In poor countries, the marginal value of money is higher and so the risk of being caught is lower (Sandholtz & Koetzle, 2000). Several authors found that income has a dampening effect on the level of corruption (Braun & Di Tella, 2004; Brown & Shackman, 2007; Frechette, 2006; Kim, 2014; Saha & Gounder, 2013).

The Internet is "a cost-effective and convenient means to promote openness and transparency and to reduce corruption" (Bertot et al., 2010, p. 264). Internet can act as a tool to control corruption and reduce the costs of fighting corruption. When the internet penetration rate is high the easiness of disclosure of corruption cases is much higher, at a reduced cost and high speed (Jha & Sarangi, 2014). While traditional media (offline) can be more subject to censure and control, the internet and social media can be a source for disclose cases of corruption. Internet can reduce corruption (Bertot et al., 2010) since it provides speedy means of sharing information with low costs and increases the risk of detection for political actors or civil servants. DiRienzo et al. (2007) showed that in countries with greater access to information, corruption is lower. Jha and Sarangi (2014) show that there is a negative impact of internet penetration and social media usage on corruption. In a cross-section study with 170 countries, Garcia-Murillo (2010) found that the internet has a positive effect in reducing corruption.

Research methodology

The empirical investigation on the impact of e-Government on corruption is examined for 175 countries in the period 2003–2019. The list of the countries included is reported in the Appendix (Table A1). The sample includes 17% of countries that are low-income economies, 26% of lower middle-income economies, 25% of upper middle-income economies and 32% of high-income economies, which is not very different from the percentages observed in the world (15.5%, 21.6%, 25.7%,

nd 37.2%, respectively). The countries analysed are divided across the regions in the following manner: 18% of the countries in the sample are from Americas (AME), 16% are from the Asia Pacific region (AP), 11% are from the Eastern Europe and Central Asia (ECA), 10% are from the Middle East & Northern Africa (MENA), 18% are from the Western Europe/European Union (WE/EU), and finally the largest portion (27%) of countries in the sample are from the sub-Saharan Africa region (SSA). The statistical computations for the exploratory analysis and the estimation of the panel models were performed with the software GRETL 2019d, RStudio version 1.2.1335 and R version 3.6.0.

The analysis will be performed in two steps: first, it will be analysed if e-Government influences the perceived corruption in the public sector when controlling with other variables that potentially influence corruption. Next, it will be analysed if e-Government needs to exceed a threshold before having a positive impact in reducing corruption.

The hypotheses under investigation are:

H1. e-Government development lowers corruption;

H2. e-Government needs to exceed a threshold before having a positive impact in reducing corruption.

Random effects models have been used to study corruption and e-government (e.g., Elbahnasawy, 2014; Zhao et al., 2021). Both random and fixed effects models can partially remove the country-specific time-invariant effects and focus on the impact of the regressors on the dependent variable. While a fixed effects model estimates a coefficient for each individual, it is very intolerant to measurement inaccuracy and cannot allow time-invariant variables (Zhao et al., 2021). A random effects model is more flexible because it uses a random variable, with zero mean and an estimated variance, to express the individual effects. Also, when the number of countries is large and the number of years is small (Judge et al., 1985), the random effects estimators are more efficient than the fixed effects.

For testing the first hypothesis, a random effects model is estimated.

Random Effects Linear Model:

$$COR_{i,t} = \beta_0 + \beta_1 eGov_{i,t} + \beta_2 PS_{i,t} + \beta_3 VA_{i,t} + \beta_4 Regulation + \beta_5 GDPpc_{i,t} + \beta_6 Internet_{i,t} + \alpha_i + \varepsilon_{i,t} \quad (1)$$

In model (1), the country-specific effects are represented by a random variable α_i with normal distribution with zero mean and constant variance, uncorrelated with the explanatory variables, and $\varepsilon_{i,t}$ is a normally distributed random variable with zero mean and constant variance that represents the error term. The dependent variable, *COR*, is the corruption in country i ($i = 1, \ldots, N$, where $N = 175$ denotes the total number of countries) in the year t ($t = 1, \ldots, T$, where $T = 17$ denotes the total number of years). Corruption is measured by the *Corruption Perception Index* (CPI) published by Transparency International. This index measures the perceived level of corruption in the public sector, according to experts and business people, and ranges from 0 (highly corrupt) to 100 (very clean), and high scores mean less corruption.

In the absence of a theoretical framework for corruption (Elbahnasawy, 2014; Seldadyo & de Haan, 2006), the choice of independent variables was guided by previous empirical studies on the determinants of corruption, discussed in the literature review.

E-Government is measured by the *e-Government Development Index* (*eGov*) from the United Nations and it is the weighted average of normalized scores on the three most important dimensions of e-Government: 1) the Online Service Index, that is the scope and quality of online services quantified; 2) the Telecommunication Infrastructure Index, which measures the status of the development of telecommunication infrastructure; and (3) the Human Capital Index (United Nations, 2018). It ranges from zero to one, where higher scores denote better e-Government development.

Political Stability and Absence of Violence/Terrorism (*PS*) together with *Voice and Accountability* (*VA*) are two dimensions of the Worldwide Governance Indicators of the World Bank, which range from approximately −2.5 (weak) to 2.5 (strong) governance performance. The first indicator measures the perceptions of enterprises, citizens, and experts of the likelihood of political instability and/or politically motivated violence, including terrorism and the second reflects "the perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media" (Kaufmann et al., 2006, p. 4). *Regulation* is measured by a component of the Economic Freedom of the World Index, Regulation (area 5), developed by the Fraser Institute, which focus on regulatory restraints that limit freedom of exchange in credit markets, labour markets, and business regulations. This indicator allows to analyse the extent that governments restrict competition in business, in arrangements between employees and employers and freedom of exchange in credit markets. It ranges from 1 to 10, where 10 denotes more freedom.

Economic Wealth is measured by the Gross Domestic Product per capita (*GDPpc*) based on purchasing power parity (PPP), in constant 2017 international dollars, collected from the World Bank's database. *Internet* represents the percentage of individuals using the internet, and data was collected from the International Telecommunication Union. Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV, among others.

Since low scores of CPI represent high levels of corruption it is expected that β_1, β_2, β_3, β_4, β_5 and β_6 will be positive, meaning that higher levels of e-Government, political stability, voice and accountability, regulation, GDP per capita or the use of internet increase transparency, that is, reduce corruption.

It is known that corruption is caused by income levels and corruption also affects the income levels. To tackle this possible endogeneity problem and serial autocorrelation of the residuals, we confirmed if our results are robust using dynamic panel models with the System GMM estimator. This estimator for dynamic regression models, proposed by Arellano and Bover (1995) and Blundell and Bond (1998), uses lagged differences of the dependent variable as instruments for equations in levels, in addition to lagged levels of the dependent variable as instruments for equations in first differences. It provides a consistent estimator under homoskedasticity for panel data where the autoregressive parameter is moderately large and the number of time series observations is moderately small (Blundell & Bond, 1998). GMM system models have been used in papers that study corruption, to avoid all the problems of country-specific effects, serial correlation, and endogeneity (Dincer & Gunalp, 2020). A GMM estimator can be applied in either a one-step or two-step process. In this paper, we used a two-step estimator, which uses residuals obtained from the first-step estimation to construct a weighted consistent variance-covariance matrix when the assumptions of independence and homoscedasticity to the estimated parameters do not hold (Bahrini & Qaffas, 2019).

GMM Dynamic Linear Model:

$$\begin{aligned} COR_{i,t} = {} & \beta_0 + \beta_1 eGov_{i,t} + \beta_2 PS_{i,t} + \beta_3 VA_{i,t} \\ & + \beta_4 Regulation + \beta_5 GDPpc_{i,t} + \beta_6 Internet_{i,t} \\ & + \beta_7 COR_{i,t-1} + \alpha_i + \varepsilon_{i,t} \end{aligned} \tag{2}$$

The dynamic panel model in equation (2) includes the coefficient β_7 to represent the effect of the lagged corruption perception index on its current level, random variables α_i to represent the country-specific effects, and $\varepsilon_{i,t}$ to represent the error term.

Table 1 shows the summary of indicators and measurements for the dependent and the independent variables used, their data sources and expected sign.

The second hypothesis (H2), which intends to find if countries need to achieve a certain threshold for e-Government development before it has a positive impact in reducing corruption, will be analysed based on the following regression equations, where $eGov^2$ is the square of the e-Government Development Index:

Random Effects Non-linear Model:

$$\begin{aligned} COR_{i,t} = {} & \beta_0 + \beta_1 eGov_{i,t} + \beta_2 eGov^2{}_{i,t} + \beta_3 PS_{i,t} \\ & + \beta_4 VA_{i,t} + \beta_5 Regulation + \beta_6 GDPpc_{i,t} \\ & + \beta_7 Internet_{i,t} + \alpha_i + \varepsilon_{i,t} \end{aligned} \tag{3}$$

GMM Dynamic Non-linear Model:

$$\begin{aligned} COR_{i,t} = {} & \beta_0 + \beta_1 eGov_{i,t} + \beta_2 eGov^2{}_{i,t} + \beta_3 PS_{i,t} \\ & + \beta_4 VA_{i,t} + \beta_5 Regulation + \beta_6 GDPpc_{i,t} \\ & + \beta_7 Internet_{i,t} + \beta_8 COR_{i,t-1} + \alpha_i + \varepsilon_{i,t} \end{aligned} \tag{4}$$

Table 1. Summary of measurements.

Variables	Measurement	Data source	Expected sign
Dependent variable			
Perception of Corruption (COR)	Corruption Perception Index (CPI): from 0 (highly corrupt) to 100 (highly clean)	Transparency International	
Independent variables			
e-Government (EGOV)	e-Government Development Index: from 0 (least developed) to 1 (most developed)	UN Department of Economic and Social Affairs (UNDESA)	+
Political Stability (PS)	Political Stability and Absence of Violence/Terrorism: from approximately −2.5 (highly instable) to 2.5 (highly stable)	World Bank – Worldwide Governance Indicators (www.govindicators.org)	+
Voice and Accountability (VA)	Voice and Accountability: from approximately −2.5 (weak) to 2.5 (strong) governance performance		+
Regulation	Regulation is a component of Economic Freedom: 0 to 10 (more freedom)	Fraser Institute	+
Economic wealth (GDPpc)	Gross Domestic Product per capita (GDPpc) based on purchasing power parity (PPP), in constant 2011 international dollars	World Bank	+
Use of Internet (Internet)	Percentage of individuals using the Internet	International Telecommunication Union	+

If the threshold exists, it will be given by the minimum of the curve between COR and eGov. To find that minimum point, one must compute the partial derivatives of COR in order of eGov from equation (3) or (4) and find the point where the first derivative is null, and the second derivative is positive:

$$\begin{cases} \frac{\partial COR_{i,t}}{\partial eGov_{i,t}} = \beta_1 + 2\beta_2 eGov = 0 \\ \frac{\partial^2 COR_{i,t}}{\partial eGov^2_{i,t}} = 2\beta_2 > 0 \end{cases} \Leftrightarrow \begin{cases} eGov = -\frac{\beta_1}{2\beta_2} \\ \beta_2 > 0 \end{cases} \quad (5)$$

Therefore, if the model has a positive coefficient β_2 of the term $eGov^2$, the threshold is obtained when $eGov = -\frac{\beta_1}{2\beta_2}$.

Results and discussion

Table 2 reports the descriptive statistics of the variables. During the period under analysis the highest value for the CPI is observed in Finland and Iceland (97), and Afghanistan reports a deep-rooted, systemic corruption problem (8). In the sample, the average score is 41.83, and in 2019 about 68% of the countries score below 50, denoting that corruption is a serious problem. E-Government ranges from 0.95, observed in South Korea and Denmark, to the lowest level of development (0.0) in Central African Republic. The average scores for Political Stability and Voice and Accountability are negative, expressing political instability and/or politically motivated violence, including terrorism, and lack of freedom of expression and accountability. Denmark is among the leading states in terms of the progress achieved in the dimension of Voice and Accountability, and Finland in Political Stability. Bahamas, Belize, and New Zealand have the regulatory restraints that limit less the freedom of exchange in credit, labour, and product markets and Venezuela the highest regulatory burden. Kuwait reported the highest percentage of individuals using internet (100%) and Timor the lowest.

The results of the bivariate Pearson correlation coefficients among the variables are presented in Table 3. According to the results, it appears to be a very strong and positive correlation between e-Government development and the use of internet. The perception of corruption has a strong and positive correlation with all the independent variables, meaning that less corruption is associated to higher e-Government Development, diffusion of internet, good governance, and higher income. Political Stability has a strong and positive correlation with Voice and Accountability and e-Government with Gross Domestic Product per capita and Voice and Accountability, all statistically significant at 1%.

Table 4 reports the results of the estimation of the random effects linear model (1) and the system GMM linear model (2).

The linear model (column I), as measured by the adjusted R-squared, shows that 32% of the variance in the CPI is explained by the variables included in the analysis. The joint χ^2 test shows that, globally, these regressors are significant at the 0.01 level. All

Table 2. Descriptive statistics.

Variable	N	Minimum	Maximum	Mean	SD
Corruption Perception	2,804	8	97	41.83	20.38
E-Government	2,967	0.0	0.95	0.47	0.21
Political Stability	2,964	−3.18	1.69	−0.13	0.95
Voice and Accountability	2,967	−2.26	1.80	−0.08	0.97
Regulation	2,334	2.46	9.24	6.97	1.04
Economic Wealth	2,896	718,3	115,415.40	18,733.50	19,907.40
Use of Internet	2,963	0.0	100.00	35.23	29.69

N – Number of observations, which varies across the variables due to missing values; SD – Standard Deviation
Source: Own elaboration.

Table 3. Correlation matrix.

Variable	Corruption Perception Index	E-Government	Political Stability	Voice and Accountability	Regulation	Economic wealth
E-Government	0.7834					
Political Stability	0.7476	0.6034				
Voice and Accountability	0.7470	0.6599	0.6780			
Regulation	0.6298	0.5765	0.5595	0.5227		
Economic wealth	0.7988	0.7704	0.6288	0.5376	0.5479	
Use of Internet	0.7631	0.8800	0.5915	0.5791	0.5719	0.7707

All correlations are statistically significant at level 1%
Source: Own elaboration.

Table 4. Estimation results of the panel data linear models (1) and (2) Dependent variable: Corruption perception index.

	RE (I)		GMM (II)
Variables	Estimate	VIF	Estimate
Constant	24.7580***		15.0781***
	(14.0460)		(22.87)
COR (−1)			0.0441***
			(9.325)
E-Government	9.4961***	2.2084	5.0431***
	(5.0298)		(4.703)
Political Stability	2.1441***	1.1785	4.1335***
	(6.8366)		(29.91)
Voice and Accountability	6.3408***	1.1899	6.08147***
	(13.5395)		(34.45)
Regulation	1.1598***	1.1972	2.0066***
	(5.1648)		(21.13)
Economic Wealth	0.00021***	1.3311	0.0003***
	(8.2673)		(35.73)
Use of Internet	0.0442***	2.2339	0.0877
	(5.2793)		(9.772)
Adjusted R-square	0.3206		
Test for AR(1) errors (*p*-value)			−9.7538 (0.0000)
Test for AR(2) errors (*p*-value)			−4.2662 (0.0000)
Sargan overidentification test χ^2 (*p*-value)			130.475 (0.5700)
Wald test χ^2 (*p*-value)	1073.53 (0.0000)		73,979.4 (0.0000)
Number of instruments			142
Number of observations	2263		2042

The t-values and z-values are in parentheses below the coefficients; *** Denotes statistical significance at level 1%
Source: Own elaboration.

Variance Inflation Factors (VIF) are below three, so there is not a problem of multicollinearity. Since the random effects model suffers from non-constant variance of the residuals (Breusch-Pagan homoskedasticity test reports a test statistic of 178.71 with p-value<$2.2*10^{-16}$), we chose to report the coefficients computed by the robust variance-covariance matrix using the method of White. As expected, there is cross-sectional dependence (Pesaran CD test reports z = 20.312 and p-value <$2.2*10^{-16}$) and serial autocorrelation (Breusch-Godfrey/Wooldridge test reports χ^2 = 1041.1 and p-value<$2.2*10^{-16}$), which supports the use of dynamic models (column II). The AR tests of orders 1 and 2 confirm the presence of serial autocorrelation, justifying the need to include the Corruption Perception Index of the previous year (lagged variable COR(−1)) in model (2). The Sargan overidentification test resulted in a p-value of 0.57, and therefore the null hypothesis that the instruments are valid is not rejected, validating the model. The results of the Wald test also rejects that the slope coefficients are jointly zero, confirming the significance of the variables in the model.

The independent variables included in the model have the expected sign and the estimates are statistically significant at the level of 0.01. Considering the estimates of the GMM model (2) in column II, an increase by 0.1 in the e-Government Development Index improves the Corruption Perception Index score by 0.504 points (all else being equal), which suggests that e-Government development reduces the perceived corruption in the public sector. This validates the first hypothesis, confirming that the expanded interaction between government and civil society by the means of Information and Communication Technologies usage could curb corruption.

The results also suggest that an increase in score of Political Stability or Voice and Accountability by one point decreases corruption by 4.13 or 6.08, respectively, ceteris paribus. An efficient regulatory climate, without excesses and with more freedom, is also a significant determinant to reduce corruption: an increase by one point in regulation decreases corruption by 2.01 points.

GDP *per capita* is statistically significant at the 0.01 level. The positive sign of the estimate means that rich countries have lower perceived corruption than poor countries. A rise in one international constant dollar in GDP per capita decline corruption by 0.0003 points, ceteris paribus. Holding everything else constant, an increase by one percentage point in the percentage of individuals using Internet lowers the perceived corruption by 0.088 points.

So, the use of digital technologies and innovations by the government can potentially reduce the perceived corruption in the public sector. E-Government allows to deliver services more efficiently and increases transparency, reducing the scope for corruption.

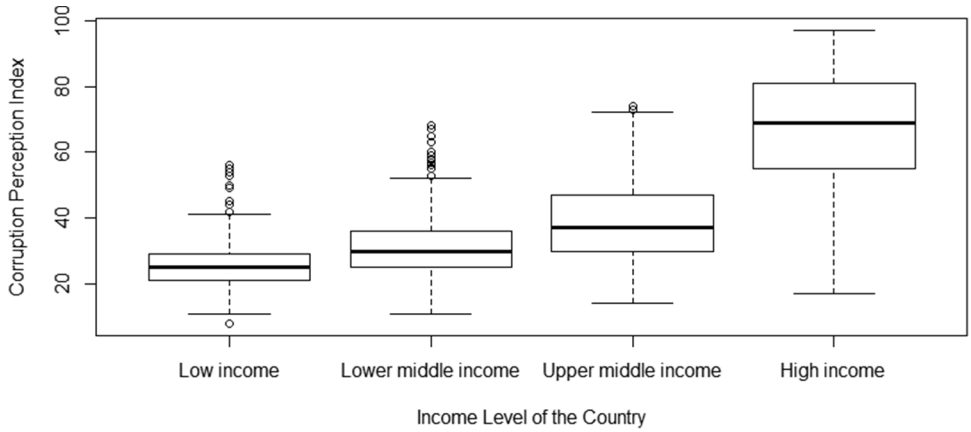

Figure 1. Corruption perception index by level of income, 2003–2019. Notes: The line in bold represents the median, framed between the 1st quartile (lower end of the box) and the 3rd quartile (upper end of the box). The lower and upper bars represent, respectively, the minimum and maximum of the distributions, and the circles are the outliers. Source: own elaboration.

Figure 1 depicts the distribution of the Corruption Perception Index by levels of income, according to the classification of the World Bank, for the included countries in the panel regression. As the income level increases, the perceived corruption decreases. Although corruption is higher in poor countries, it is also a problem in rich countries, since 25% of the countries with upper middle income have scores under 30 and 25% of the countries with high income have scores below 55. Furthermore, for all levels of income, the minimum score of the Corruption Perception Index is not very different between countries.

Figure 2 reports the Corruption Perception Index by region. Western Europe/European Union's countries present higher scores for the Corruption Perception Index, although 25% of the countries have scores under 50. On the contrary, the median value is lower in the Eastern Europe and Central Asia and sub-Saharan Africa, where 75% of the countries score below 36. It is in the sub-Saharan Africa and Asia Pacific that the minimum values are registered although in this area 75% of the countries have average scores lower than 51. In Asia Pacific the outliers are New Zealand and Singapore with scores over 90, in

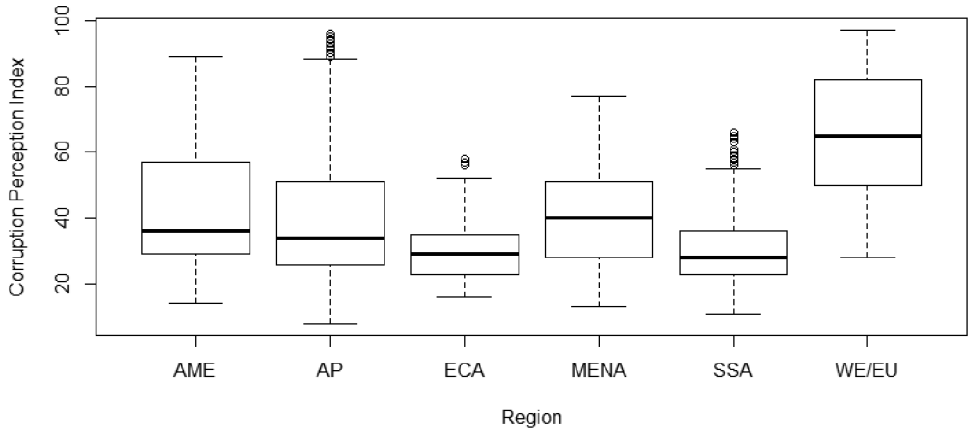

Figure 2. Corruption perception index by region, 2003–2019. Legend: AME – Americas; AP- Asia Pacific; ECA – Eastern Europe and Central Asia; MENA – Middle East & Northern Africa; SSA-Sub-Saharan Africa; WE/EU – Western Europe/European UnionThe line in bold represents the median, framed between the 1st quartile (lower end of the box) and the 3rd quartile (upper end of the box). The lower and upper bars represent, respectively, the minimum and maximum distributions.Source: own elaboration.

Table 5. Estimation results of non-linear regression models (3) and (4) Dependent variable: Corruption perception index.

Variables	RE (I)		GMM (II)
	Estimates	VIF	Estimates
Constant	27.5290***		23.3592***
	(20.63)		(38.61)
COR(−1)			0.0556***
			(12.15)
E-Government	−45.5243***	22.1922	−43.2678***
	(−13.73)		(−23.87)
E-Government squared	63.2901***	24.9593	55.7362***
	(16.09)		(29.32)
Regulation	1.9181***	1.7355	2.2128***
	(9.95)		(32.08)
Political Stability	4.8262***	2.4206	4.9474***
	(17.90)		(38.02)
Voice and Accountability	5.1746***	2.4544	4.9809***
	(18.28)		(30.70)
Economic Wealth	0.0003***	3.2248	0.0003***
	(19.57)		(35.40)
Use of Internet	0.0408**	5.1792	0.0584***
	(2.88)		(6.726)
Adjusted R-square	0.3562		
Test for AR(1) (*p*-value)			−9.8803 (0.0000)
Test for AR(2) (*p*-value)			−2.9719 (0.0030)
Sargan overidentification test χ^2 (*p*-value)			129.184 (0.6014)
Wald test χ^2 (*p*-value)	9104.73 (0.0000)		52,060.7 (0.0000)
Number of instruments			143
Number of observations	2263		2042

The t-values and z-values are in parentheses below the coefficients; *** Denotes statistical significance at level 1%
Source: Own elaboration.

Eastern Europe and Central Asia the outlier is Georgia with scores near 58, and in sub-Saharan Africa there are three countries (Botswana, Cape Verde and Seychelles) with Corruption Perception Index between 60 and 70.

In the next step it will be analysed if e-Government needs to exceed a threshold before having a positive impact in reducing corruption through the estimation of models (3) and (4). The results are reported in Table 5.

The percentage of variation in the Corruption Perception Index is 36% explained by the independent variables included (column I). The Variance Inflation Factors (VIF) have increased a lot, which is natural to happen because the model has two terms using the same variable: the E-Government and its square, so although there are large VIFs, there is not an actual problem of multicollinearity.

All the independent variables included in the model have estimates which are statistically significant at the level of 0.01. Apart from the terms regarding E-Government, all the variables have the same sign as in the previous model.

The signs of the coefficients of variables E-Government and its square have to be read together and analysed according to equations (3)-(5). From this, and because e-Government Development Index is a positive value that ranges from 0 (least developed) to 1 (most developed), having a positive coefficient β_2 of the term eGov^2, means that the coefficient of the term eGov must be negative (β_1). Therefore, the obtained estimates for these two coefficients presented in Table 5 have the expected sign. The threshold that needs to be achieved in e-Government development before having a positive impact in reducing corruption is obtained when $eGov = -\frac{\beta_1}{2\beta_2}$. With the estimates obtained for the models, the computed threshold according to equation (3) is 0.3597 in the RE model (column I) and 0.3881 in the GMM model (column II). This validates the second hypothesis that was formulated.

Considering the GMM estimates for the coefficient of the variable Political Stability, it suggests that an increase by one point in this score decreases corruption by 4.95 points, and an increase by one point in the Voice and Accountability score will result in a decline of 4.98 points in corruption, ceteris paribus. When the score of Regulation increases one point, corruption decreases 2.21 points. GDP *per capita* is statistically significant at the 0.01 level. As in the previous model, the positive sign of this estimate means that rich countries have lower perceived corruption than poor countries. A rise in one international constant dollar in GDP per capita lowers corruption by 0.0003 points, ceteris paribus. This model also states that, holding

everything else constant, an increase by one percentage point in the percentage of individuals using Internet can lower the perceived corruption by 0.06 points.

The results achieved are statistically significant and suggest that there is a level of e-Government development from which the increase in this level reduces corruption. Considering the results from the GMM model, this threshold is 0.3881, which positions 41 countries under the threshold in 2019 (listed in Table A2. of the Appendix), which means that until they develop e-Government over this threshold, this tool alone is not enough to curb corruption. These countries belong to Americas (Haiti), Eastern Europe and Central Asia (Turkmenistan), Middle East & Northern Africa (Iraq, Libya and Yemen Republic), Asia Pacific (Afghanistan, Laos, Myanmar, Pakistan, Papua New Guinea, and Solomon Islands) and the remaining 30 countries belong to sub-Saharan Africa. It is worthwhile to highlight that in this list there is not any country from Western Europe/European Union. From the list of the countries below the threshold of 0.3881, the majority (54%) are low-income countries, followed by 36% of lower middle-income economies and 10% of upper middle-income economies. In these countries in 2019, the average percentage of the use of internet was only 18.6%, and the two analysed dimensions of the Worldwide Governance Indicators of the World Bank (*Political Stability and Absence of Violence/Terrorism* (*PS*) together with *Voice and Accountability* (*VA*)) have negative means (−0.95 and −0.81, respectively) denoting lack of good governance. The GDP per capita based on Purchasing Power Parity in constant 2017 international dollars has an average of 3,977 in 2019 which is very low comparing to the global average presented in Table 2. The Corruption Perception Index has a mean score of 27.2 indicating a high level of corruption and the mean of e-Government Development Index is 0.29 and so most of the countries need to substantially increase this indicator before noticing a positive impact in tackling corruption.

In the other 134 countries, corruption can be lower if e-Government increases. In Figure 3 it is observed the convex shape of the curve from the boundary of 0.3881.

Conclusions

Corruption is one of the major challenges in the 21st century and it is a problem, not only in developing countries, but also in the most developed economies. These countries, given their economic activity with the rest of the world, have an increased responsibility for controlling corruption, maintaining high ethical standards in both the private and public sectors.

With the digital revolution, the use of ICTs can increase the efficiency, speediness, and transparency of governments and, on the other hand, can promote dissemination of information and knowledge. The use of these technologies by the government can promote transparency in their services, leaving less space to corrupt behaviours, through monitoring the

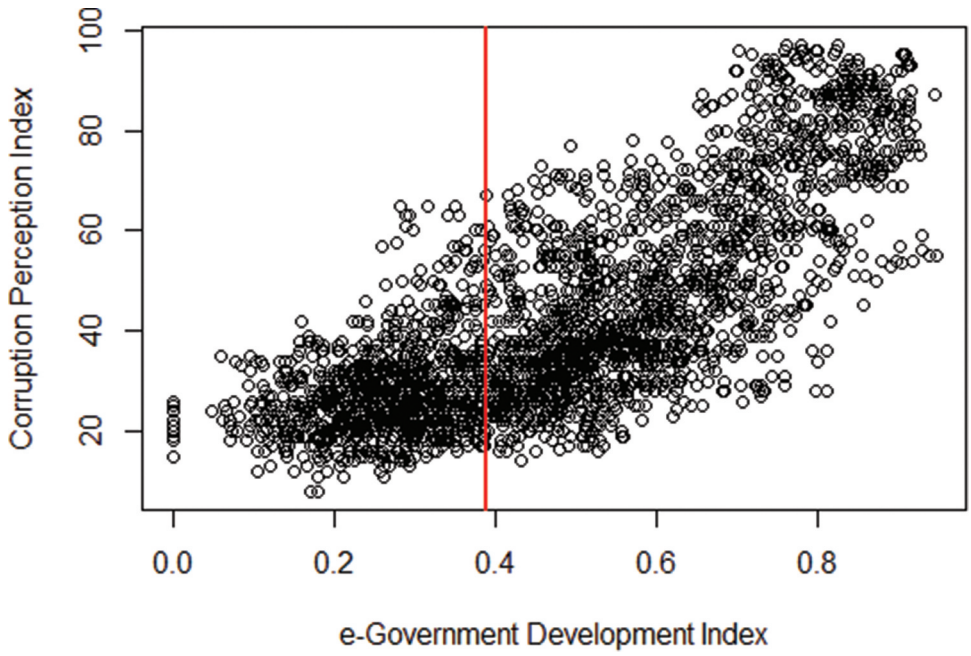

Figure 3. Scatter plot of corruption perception index vs. e-Government development index. Source: own elaboration.

activity of civil servants and reducing the need for interactions between civil society and government employees.

The results of this study suggest that e-Government is an effective tool to curb corruption, nevertheless that occurs after a threshold of 0.39 for e-Government Development Index. In the sample, there are still 41 countries that have not reached that limit, so they need to implement a considerable amount of development in their electronic services to reduce corruption. The results also suggest that the political stability, accountability, sound regulation, income and the use of internet have dampening effects on corruption.

However, the importance of e-Government in reducing corruption needs to be recognized by policymakers and although the positive global trends towards higher level of e-Government, some countries need to reinforce it by investing in online services, telecommunication infrastructures, but also in developing human capital in the public sector. This paper shows that the use of the available technologies could be transformative with regard to reduce corruption, but it is important to point out that they are only one of the instruments at the disposal of the public authorities, and governments need to reinforce institutional systems as well. Promoting good governance towards the strengthening of political stability, voice and accountability and sound regulation creates a sound environment leaving less space to corruption.

E-Government can improve public services quality, transparency, and accountability, and so reduce corruption, but it needs the involvement of citizens. To attain sustainable development, citizens and businesses should collaborate alongside with governments in producing public value and addressing societal challenges.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Table A1. List of countries included in the study.

Afghanistan	Burundi	Equatorial Guinea	Israel	Mauritania	Portugal	Sweden
Albania	Cambodia	Eritrea	Italy	Mauritius	Qatar	Switzerland
Algeria	Cameroon	Estonia	Jamaica	Mexico	Romania	Tajikistan
Angola	Canada	Ethiopia	Japan	Moldova	Russian Federation	Tanzania
Argentina	Cape Verde	Finland	Jordan	Mongolia	Rwanda	Thailand
Armenia	Central African Republic	France	Kazakhstan	Montenegro	Samoa	Timor-Leste
Australia	Chad	Gabon	Kenya	Morocco	São Tomé and Principe	Togo
Austria	Chile	Gambia	Korea, South	Mozambique	Saudi Arabia	Tonga
Azerbaijan	China	Georgia	Kuwait	Myanmar	Senegal	Trinidad and Tobago
Bahamas	Colombia	Germany	Kyrgyzstan	Namibia	Serbia	Tunisia
Bahrain	Comoros	Ghana	Laos	Nepal	Seychelles	Turkey
Bangladesh	Congo Democratic Republic	Greece	Latvia	Netherlands	Sierra Leone	Turkmenistan
Barbados	Congo Republic Brazzaville	Guatemala	Lebanon	New Zealand	Singapore	Uganda
Belarus	Costa Rica	Guinea	Lesotho	Nicaragua	Slovak Republic	Ukraine
Belgium	Côte d'Ivoire	Guinea Bissau	Liberia	Niger	Slovenia	United Arab Emirates
Belize	Croatia	Guyana	Libya	Nigeria	Solomon Islands	United Kingdom
Benin	Cyprus	Haiti	Lithuania	Norway	South Africa	United States
Bhutan	Czech Republic	Honduras	Luxembourg	Oman	South Sudan	Uruguay
Bolivia	Denmark	Hungary	Macedonia, FYR	Pakistan	Spain	Uzbekistan
Bosnia and Herzegovina	Djibouti	Iceland	Madagascar	Panama	Sri Lanka	Vanuatu
Botswana	Dominica	India	Malawi	Papua New Guinea	St. Lucia	Venezuela, RB
Brazil	Dominican Republic	Indonesia	Malaysia	Paraguay	St. Vincent and the Grenadines	Vietnam
Brunei Darussalam	Ecuador	Iran	Maldives	Peru	Sudan	Yemen, Rep.
Bulgaria	Egypt	Iraq	Mali	Philippines	Suriname	Zambia
Burkina Faso	El Salvador	Ireland	Malta	Poland	Swaziland	Zimbabwe

Table A2. List of countries which e-Government is under the threshold-level of 0.3881.

Afghanistan	Chad	Equatorial Guinea	Haiti	Madagascar	Niger	Solomon Islands
Angola	Comoros	Eritrea	Iraq	Malawi	Pakistan	South Sudan
Benin	Congo Democratic Rep.	Ethiopia	Laos	Mali	Papua New Guinea	Sudan
Burkina Faso	Congo Rep. Brazzaville	Gambia	Lesotho	Mauritania	São Tomé and Principe	Turkmenistan
Burundi	Côte d'Ivoire	Guinea	Liberia	Mozambique	Senegal	Yemen, Rep,
Central African Rep.	Djibouti	Guinea Bissau	Libya	Myanmar	Sierra Leone	