Impact of E-government Development on the Level of Corruption: Measuring the Effects of Related Indices in Time and Dimensions

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Abstract: E-government is recognized as a tool to improve transparency and openness in the public sector and to combat corruption. Understanding the relationship between e-government development and the level of corruption would enable leveraging of related projects more effectively in anti-corruption efforts. This paper examined the impact of e-government development on the level of corruption, in the context of economic perspective. In contrast to previous studies, this empirical relationship was measured across sub-indices (dimensions) of related indices between 2002 and 2016. The results showed that higher levels of e-government development are associated with lower levels of corruption. The most important dimensions found are the environment sub-index, which assesses the extent to which a country's market conditions and regulatory framework support entrepreneurship, innovation, and ICT development; the usage sub-index, which assesses the level of ICT adoption by a society's main stakeholders; and the telecommunication infrastructure sub-index measuring a country's ICT infrastructure capacity. Therefore, from the findings of this study, some of the explanations of the possible ways to influence the level of corruption by stimulating concrete e-government development dimensions can be got. This is especially important in the time of a financial crisis and its consequences, which were also discussed in this paper.

Key words: correlation analysis, corruption, dimensions, e-government development, indices, regression models

JEL Classification: C43, D73, H11, L86, O38

Introduction

Technology is continuously changing how governments operate, interact, and serve the public (Bertot et al., 2012; Elbahnasawy, 2014; Kim, 2014; Shim and Eom, 2008; United Nations, 2016). In this regard, countries around the world have utilized Information and Communication Technologies (ICT) to efficiently provide information and services to the public (Bertot et al., 2012; Mistry and Jalal, 2012; Ramaswamy and Selian, 2009). ICT are seen as a cost-effective and convenient way to reduce unnecessary interventions by public officials that may lead to the abuse of power, help to monitor their behaviour and actions, promote openness and transparently providing information and services to the public (Andersen, 2009; Bertot et al., 2010; Kim et al., 2009; Linhartová, 2017; Mistry and Jalal, 2012; Shim and Eom, 2009). However, the effectiveness of using ICT as a means of fighting corruption is affected by various factors that need be explored and their effects measured (Elbahnasawy, 2014; Kim, 2014; Shim and Eom, 2008).

Corruption is cited as one of the most prevalent and persistent challenges in enhancing economic growth and improving the quality of life of citizens across the globe (Bertot et al., 2012; Bussell, 2011; Linhartová, 2017; Mauro, 1997; Mistry and Jalal, 2012). Since corruption is a complex term, it has various connotations and denotations. For example, Jain (2001) defined corruption as "*acts in which the power of public officials is used for personal gains in a manner that contravenes the rules of the game*"; and it has been classified as grand, bureaucratic, and legislative. Most of the efforts in the past decades to address corruption typically began with an analysis of the underlying causes or enabling factors of corruption (Bardhan, 1997; Escresa and Picci, 2017; Kim, 2014; Mistry and Jalal, 2012; Mo, 2001). Negative effects on development of Gross Domestic Product (GDP), unemployment rate or credibility of the country discouraging foreign investors have been shown as a result of corruption (Bardhan, 1997; Jain, 2001; Kněžáčková and Linhartová, 2013; Mistry and Jalal, 2012; Mo, 2001).

The evolution of the Internet has created the underlying infrastructure for e-government, both in information and service delivery (Ojha et al., 2008). E-government can be referred to as (United Nations, 2016): "*the use and application of ICT in public sector to streamline and integrate workflows and processes, to effectively manage data and information, enhance public service delivery, as well as expand communication channels for engagement and empowerment of people.*" The level of e-government development indicates the quality of a country's technological and telecommunication infrastructure and the ability of its citizens, businesses and governments to adopt, use and benefit from modern technologies in the given time period (Máchová and Lněnička, 2015). As governments at different levels and all around the world are increasingly using the Internet to improve their services, it has become important to focus on e-government development and affecting factors (Siau and Long, 2006). As a result, e-government has risen to prominence as one of the tools to fight corruption and to promote economic development (Elbahnasawy, 2014; Kim, 2014; Linhartová, 2017).

In 2008, Ojha et al. published a paper in which they argued that neutral impact assessment reports continue to expose cases where corruption persists even after the introduction of e-government. Some of the new studies indicate that e-government has a positive impact on the reduction of corruption in government (Kim, 2014; Kněžáčková and Linhartová, 2013; Lupu and Lazar, 2015; Mistry and Jalal, 2012; Prasad and Shivarajan, 2015; Srivastava et al., 2016). However, approaches of this kind carry with them some shortcomings. For example, as stated by Grönlund and Flygare (2011), different indices should be tested to ensure that the effects of e-government are robust across different indices and their rankings. Most of related empirical studies ignore these different indices, although they are commonly used and sometimes are also more suitable because they consist of various ICT dimensions. Furthermore, for changes to be discernible there is a need of a long time-span in order to observe large changes in corruption levels within countries (within-country variation) (Andersen, 2009; Bussell, 2011; Grönlund and Flygare, 2011; Lupu and Lazar, 2015; Mistry and Jalal, 2012; Shim and Eom, 2009). More precisely, as stated by Kim (2014), a cross-time study would also give a better picture of whether or

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not e-government is an efficient tool of reducing corruption in government. Finally, an adequate data sample is required to detect the difference between developed and developing countries (Andersen, 2009; Escresa and Picci, 2017; Grönlund and Flygare, 2011; Mistry and Jalal, 2012; Shim and Eom, 2009).

To overcome these shortcomings, established indices were used in order to measure the relationship between e-government development and the level of corruption. Furthermore, all these indices were examined since the year they were firstly introduced. Finally, the dimensions of these indices were examined to get deeper insights about this relationship. The use of decomposed sub-indices (dimensions) rather than one aggregate index of e-government development enables a more accurate evaluation as it shows the effects of the different e-government dimensions on the level of corruption. The following research questions were designed to guide the attainment of this study objectives:

1. Is there any relationship between corruption and e-government development on the national level?
2. Is there any progress in the trend of this relationship between examined years?
3. Do e-government development indices consistently explain the level of corruption, i.e., does good score on an e-government development index consistently over time predict good score on a corruption index?
4. What e-government development indices or dimensions have the strongest relationship with the level of corruption, i.e. are the best predictors of reduction in corruption?

The rest of the paper is organized as follows. In the theoretical background section, the theoretical relationship between the research topics is investigated. In the methodology and methods section, the research methodology is described together with data sources, measures and related indices. The empirical findings are reported and discussed in the following section. Then, limitations of the study are outlined. The last section concludes this paper.

Literature Review and Background

Corruption and Economic Development

The question whether corruption can affect the economic level of countries and their economic growth is still generating controversy among researchers. On the other hand, if there is adequate legislation and enforcement, the argument about corruption as the "*grease*" or "*speed money*" of economy is unacceptable (Bardhan, 1997; Jain, 2001; Mauro, 1997). The economic transition from poor to rich strongly reduces corruption, while periods of high inflation increase corruption. In this way, the more economically developed countries are exposed to the temptation to abuse of state power less than the poor economies. However, while the citizens of rich countries are mostly more educated, their transactions are faster and more transparent than in traditional societies where the boundaries between public and private are less obvious.

Empirical studies dealing with this issue provided quantified consequences of corrupt activities on the economy. These studies explored the correlation between corruption and indicators of economic performance or growth and the overall economic level of the country, i.e. especially the changes in the dynamics of GDP growth and changes in the level of GDP per capita. According to findings of Leite and Weidmann (1999), Mauro (1995), Mauro (1997) or Tanzi and Davoodi (2001), the corruption has a quantifiable negative impact on the economic performance and growth, where a decrease of corruption by 1% on a scale of 0-10 leads to a decrease of GDP per capita by 2%. Mauro (1995) analysed a set of data consisting of subjective indices of corruption and various factors for a cross section of countries. The results showed that corruption decreases economic growth. In 1997, Mauro expanded this analysis and presented new evidence on the relationship between corruption and the composition of government expenditure (Mauro, 1997). These findings were confirmed and further expanded by studies of Brunetti et al. (1998), Gyimah-Brempong (2002) or Knack and Keefer (1995).

There are also many transmission channels through which corruption can reduce economic growth. Mo (2001) applied Ordinary Least Squares (OLS) estimations and found that a 1% increase in the corruption level reduces the growth rate by about 0.72%. The most important channel is political instability, which accounts for about 53% of the total effect. Mistry and Jalal (2012) mentioned that the drivers of corruption, such as monopoly of power, discretion and the lack of accountability, are mitigated by the existence of strong legal systems and better equipped organizations. Current research provided an argument that efforts to challenge corruption are especially important in the developing world (Ahmad and Brookins, 2007; Mistry and Jalal, 2012; Kim, 2014). The literature also introduced another view on this topic. For example, Escresa and Picci (2017) proposed a new measure of corruption, the Public Administration Corruption Index (PACI) reflecting the propensity of public officials to accept bribes from foreign firms (cross-border corruption cases). Finally, empirical papers studying the determinants of corruption usually rely on the variation in corruption levels across countries (between-country variation) (Andersen, 2009).

E-government and its Anti-Corruption Effects

Prior to the use of e-government as an anti-corruption tool, administrative reforms were considered as an approach to reform public sector organizations. Other reforms include strategic planning, public sector downsizing, better monitoring of government expenditure, or the establishment of formalized rules (Armantier and Boly, 2011; Jain, 2001; Olken, 2009). However, with the rise of widely available and cost-effective ICT infrastructures and services, e-government has become a major topic of interest to practitioners and researchers (Kim et al., 2009; Kim, 2014; Linhartová, 2017; Lupu and Lazar, 2015; Mistry and Jalal, 2012; Shim and Eom, 2008).

Among factors influencing the growth of e-government, income levels, development status, strength of organizations and the commitment of the government to promote the use of e-government are the most important (Christou and Simpson, 2009; Pérez et al., 2005; Siau and Long, 2006; West, 2004). The level of e-government development is determined by the economic growth of the country (Kim, 2007; Mistry and Jalal, 2012; Siau and Long, 2006). Transparency is promoted as one of the most important visions against corruption (Lindstedt and Naurin, 2010). Bertot et al. (2010) studied the potential impacts of e-government and social media on cultural attitudes about transparency. In a follow up article, they examined the ways in which governments build social media and ICT into e-government transparency initiatives to facilitate collaboration between governments and other stakeholders (Bertot et al., 2012). Mistry and Jalal (2012) also stated that e-government

can improve the transparency of the bureaucratic process and therefore, promote accountability.

Ojha et al. (2008) connected a few theoretical frameworks that are relevant to corruption studies, and reviewed the mechanisms by which e-government reduces or eliminates corruption. As stated by Hopper et al. (2009), electronic delivery of services can reduce corruption by reducing interactions with officials, speeding up decisions, and reducing human errors. Therefore, the mechanisms through which e-government should work to reduce corruption lie in reducing contacts between corrupt officials and citizens (Andersen and Rand, 2006). An initial network surrounding ICT (particularly e-government) and corruption, and theorized the role of basic national organizations and stakeholder service systems into the mechanisms through which e-government affects corruption was proposed by Srivastava et al. (2016). Ramaswamy and Selian (2009) focused on the post-communist transitioning countries and proposed a two-stage framework to leverage e-government to combat public sector corruption by using new technologies in the form of e-government systems.

On the other hand, Kim et al. (2009) have pointed out that there are doubts whether ICT can effectively reduce corruption in reality or it has no measurable effect. Prasad and Shivarajan (2015) reported that there is no clear understanding of the process through which computer-mediated mechanisms reduce corruption. E-government and especially e-government projects may also provide new corruption opportunities. Although governments worldwide are trying to reduce corruption by introducing various frameworks, strategies and action plans, the successful implementation and deployment of these e-government systems vary. As an example, Aladwani (2016) discussed the potential role of corruption plays in shaping the failure of e-government projects. For this purpose, the author suggested a theoretical framework that depicts the likely influences of corruption on e-government project failure. Here, it should be also noted that unsuccessful projects as well as projects that are not finished on time or within budget may affect the perceptions of the public towards e-government development. However, none of the existing e-government development indices explicitly measure this effect.

Impact of E-government Development on the Level of Corruption

The relationship between e-government and corruption on the country/national level has been addressed by the following studies. Andersen and Rand (2006) examined a cross-section of countries and concluded that well-designed ICT policies are likely to be effective in the fight against corruption. Andersen (2009) found that the application of e-government can effectively control the tendency of government corruption. The control of corruption intentions can further improve the adoption of e-government innovations. The findings of Kim (2014) indicated that e-government could be an effective tool to curb corruption in government in spite of the fact that the rule of law is the most powerful predictor of anti-corruption and a fundamental precondition of a clean government.

According to Bussell (2011), the level of pre-existing corruption in a country is a robust predictor of e-government outcomes. More corrupt governments hinder the implementation of high-quality public service reforms using ICT. Shim and Eom (2008) found that both e-government and traditional anti-corruption factors have a positive impact on reducing corruption. In a follow up article, Shim and Eom (2009) argued that ICT has the potential to reduce unnecessary human intervention in government work processes, which reduces the need to monitor corrupt behaviour. Finally, e-government also reduces human asset specificity, but is redeployed using e-government (Prasad and Shivarajan, 2015). The findings of Elbahnasawy (2014) revealed that e-government is a powerful tool in reducing corruption, via telecommunication infrastructure and the scope and quality of online services, which is strengthened by greater Internet adoption. Shahkooh et al. (2008) applied a correlation analysis and clustering to show the relation between a country's corruption and e-government development levels. The models of Mistry and Jalal (2012) suggested that a 1% increase in the E-government Development Index (EGDI) may have resulted in a 1.17% decrease in corruption. Focusing on the practical side of this issue, Kim et al. (2009) developed an anti-corruption system called OPEN (Online Procedures ENhancement for civil application) to show how an e-government system for anti-corruption in a local government may evolve to become a prototype of a national system to be used for the same purpose.

Together, these studies indicate that it is critical to support easier access to information and public services using various e-government systems. More precisely, a high level of e-government development should result in the prevention of public officials' corrupt behaviour by transparently providing information about governmental policy making and service delivery processes through the Internet to the public (Kim et al., 2009; Kim, 2014; Mistry and Jalal, 2012; Prasad and Shivarajan, 2015; Shim and Eom, 2008; Shim and Eom, 2009).

Nowadays, the open government movement is a key part of e-government development and, as identified by Attard et al. (2015), corruption is the major problem that triggered open government data initiatives. The main goals of these efforts are enhancing collaboration, efficiency, innovation, participation, transparency, and fighting corruption. The most common approaches include open data portals at various levels in order to make these data available for reuse, providing advanced tools for data discovery, extraction, transformation and publication, and promote new services that use open data (Attard et al., 2015; Evans and Campos, 2013; Máchová and Lněnička, 2016a). The availability and use of these approaches, however, vary around the world; not only in terms of the number of datasets released and how they are presented and organized, but also in terms of the tools provided to increase usage of these data (Máchová and Lněnička, 2017). On the other hand, the public is allowed to analyse these data or comment on related issues through various communication channels to boost transparency of governmental actions. Therefore, this issue requires further research in the context of e-government development and how these trends of open government may affect it.

Methodology and Methods

To achieve the aim, well-established and internationally recognized measures of corruption and e-government development were examined. While it is important to obtain an adequate data sample, the global indices were used. Another selection criterion was the longevity of the index because effects of anti-corruption efforts and e-government projects are likely to take some time to show.

Measures of Corruption

The majority of data useful for the corruption analysis cannot be obtained in the form of free available statistics (hard data) and thus the indicators measuring the level of corruption are usually based on soft data gained in opinion polls. Standard methods of measuring corruption generally utilize conventional qualitative sociological methods. These qualitative assertions are then quantified and converted into indices that allow international or inter-annual comparisons. Most of them are unique because their construction was conducted in order to capture and analyse a specific purpose or phenomenon. The data are obtained on the basis of specific surveys conducted by various public organizations. These are represented by composite indices, which are based on the comprehensive and robust methodologies. It has been argued by Wei (2001) that there are four types of "*corruption ratings*" (measures): corruption ratings based on expert opinions, corruption ratings based on surveys of citizens or businesses, corruption ratings based on a poll of polls (composite indices), and corruption ratings based on more objective and harder data. Besides that, it is necessary to keep in mind that all these corruption indicators primarily measure the perception of corruption rather than objective and precise quantitative extent of corruption.

The dependent variable measures the level of corruption. In this study, two global composite indices were used. The World Bank's Corruption Control Index (CCI) is one of the six broad dimensions of governance for 215 countries since 1996. It captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as capture of the state by elites and private interests. The CCI takes values between -2.5 (weak) and 2.5 (strong) governance performance. It is based on a large number of individual data sources, which are then aggregated into one measure. This means that the aggregate measure is a weighted average of the underlying individual data sources, with weights reflecting the precision of each of the underlying data sources. According to Andersen (2009), the aggregate CCI is presumably more informative than any individual data source.

Transparency International has published the Corruption Perceptions Index (CPI) since 1995. It currently covers perceptions of public sector corruption in 168 countries on a scale from 0 (highly corrupt) to 100 (very clean). Until 2012, the scale was from 0 to 10. Countries' scores can be helped by open government where the public can hold leaders to account, while a poor score is a sign of prevalent bribery, lack of punishment for corruption and public organizations that do not respond to citizens' needs (Transparency International, 2016). The validity of the CPI has been tested by several researchers and a review of these studies can be found in Shim and Eom (2008). The CCI and the CPI were thus used as dependent variables.

Measures of E-government Development

The key explanatory variable in this study is a measure of e-government development. In a global perspective, established indices include the United Nations' (UN) EGDI, the World Economic Forum's (WEF) Networked Readiness Index (NRI) and the International Telecommunication Union's (ITU) ICT Development Index (IDI). A comprehensive classification of these indices can be found in Máchová and Lněnička (2015). In the context of this study's aim, the EGDI, the IDI, and the NRI were used. A brief description of their structure and dimensions is in Table 1. Since the EGDI is published only every two years, the changes in the two years period between 2002 and 2016 were examined. This methodological approach is in line with Andersen (2009) because it only makes sense to study whether changes in e-government can explain changes in corruption over the time-span in which e-government has actually been in operation.

Table 1 Description of selected e-government development indices

Name	*Publisher*	*Years covered (no. of reports)*	*Countries covered (first – last report)*	*Dimensions (sub-indices)*
EGDI	UN	2001 – 2016 (9)	190 – 193	Online service, human capital, telecommunication infrastructure
IDI	ITU	2002 – 2016 (10)	154 – 175	Access, use, skills
NRI	WEF	2002 – 2016 (15)	82 – 139	Environment, readiness, usage, impact

Source: UN, ITU, WEF.

The EGDI, which assesses e-government development at the national level, is a composite measure based on the weighted average of three normalized sub-indices: Online Service Index (OSI), Telecommunication Infrastructure Index (TII) and Human Capital Index (HCI). Thus, it measures the adequacy of telecommunication infrastructure, the ability of human resources to promote and use ICT, and the availability of online services and content (United Nations, 2016).

The first sub-index of the IDI measures the availability of ICT infrastructure and access, the second one is focused on the level of ICT use, and the last one captures the capability to use ICT effectively, derived from relevant skills. The choice of indicators included in these sub-indices reflects the corresponding stage of evolution to the information society. The indicators in each sub-index can therefore change over time to reflect technological developments related to ICT and improvements in the availability and quality of data (International Telecommunication Union, 2016).

The NRI has evolved over time and currently assesses the state of networked readiness over these dimensions: environment sub-index, which measures the overall environment for technology use and creation (political, regulatory, business, and innovation); readiness sub-index, which captures the networked readiness in terms of ICT infrastructure, affordability, and skills; usage sub-index, which measures technology adoption and usage by these groups of stakeholders: government, the private sector, and private individuals; and impact sub-index, which captures the economic and social impact of the new technologies (World Economic Forum, 2016).

Measure of Economic Development

As discussed earlier, the level of economic development is significantly associated with corruption reduction (Bertot et al., 2012; Bussell, 2011; Elbahnasawy, 2014; Kim, 2007; Kim, 2014; Mistry and Jalal, 2012; Tanzi and Davoodi, 2001). As a result, it can be argued that changes in corruption may only be caused by the economic development of the country and ICT may not be associated with corruption (Mistry and Jalal, 2012). Therefore, economic development was controlled, by including the natural logarithm of GDP per

capita of the countries. The data are from the World Bank's database named the World Development Indicators.

Empirical Methodology and Data Analysis

The relationship was tested by proposing empirical models that examine how changes in e-government development in selected countries are linked to changes in their levels of corruption. The unit of analysis was the country and the period covered was 2002–2016. For this purpose, OLS regression models and correlation analysis were used. Correlations between defined variables were measured by the value of the Pearson's correlation coefficient. According to Nardo et al. (2008), several correlation measures (measures of association) can be used to validate the conformity of the rank methods for the indices. In this study, Spearman's and Kendall's rank correlation coefficients were used. Contrary to the Spearman's coefficient, the Kendall's coefficient is not affected by how far from each other ranks are but only by whether the ranks between cases are equal or not (Nardo et al., 2008).

For the purpose of exploring the existence of the relationship between corruption and e-government development, the OLS regression equation was previously validated for use by Andersen and Rand (2006); Knězáčková and Linhartová (2013), Linhartová (2017), Lupu and Lazar (2015), Mistry and Jalal (2012) and Srivastava et al. (2016). In contrast to these studies, this paper explored this relationship on the more detailed level of decomposed e-government development indices and therefore the equation was changed and applied in the multidimensional context. It is defined as illustrated in (1):

$$corruption\_index = \alpha + \beta * egovernment\_index + \gamma * country\_development + \varepsilon \quad (1)$$

where the dependent variable *corruption_index* is represented by the CPI and CCI in selected years, the independent variable *egovernment_index* is corresponding to dimensions of decomposed e-government development indices and *country_development* is the natural log of GDP. The parameter α determines the distance of intersection of the regression line with the y-axis (the value of the regression function for $x = 0$). The parameters β and γ are called the regression coefficients and show the variation of the dependent variable value when the value of the independent variable changes. The symbol ε is the residual variance, which is a graphical representation of the distance of points from the regression line.

The OLS regression methodology with robust standard errors was used. These Eicker-Huber-White standard errors are intended to control for the possible presence of heteroscedasticity in the sample. White test is then a statistical test that establishes whether the variance of the errors in a regression model is constant (White, 1980). The analysis was performed on the sample of countries, regardless of their geographic location or political regime. Data collection was made through open data sources. All calculations and graphics were done in Statistica 10 and Microsoft Excel 2010.

Results and Discussion

At first, relevant statistical indicators for the indices are presented in Table 2. In the case of mean value that was calculated as a simple average, there can be seen an increase in e-government development through the years. This means that the impact of ICT on citizens' everyday life within the public sector is constantly increasing worldwide. The level of corruption is stable worldwide or the score slightly decreases. This implies that there are some factors helping to reduce corruption.

The higher mean compared to the median indicates that the distribution of values for all these indices is skewed to the left, i.e. there are more countries with lower values than higher ones. However, these results can be slightly affected by the changes in the index's construction and calculation methodology, especially in the case of the CPI and IDI. Moreover, as the number of countries covered increases every year and mostly includes only developing countries, this fact may also influence the summary statistics. Finally, the Kolmogorov-Smirnov test did not indicate a departure from normality. White's test for heteroscedasticity supported constant variance.

Table 2 Summary statistics of the indices included in the study

Index	*Measure*	*2002*	*2004*	*2006*	*2008*	*2010*	*2012*	*2014*	*2016*
CCI	Number of cases	197	206	206	207	211	210	210	209
	Mean (value)	-0.020	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	Mean (% change)	-	0.4	0	0	0	0	0	0
	Std. dev. (value)	1.005	0.998	0.998	0.998	0.998	0.998	0.998	0.998
	Std. dev. (% change)	-	-0.1	0	0	0	0	0	0
	Min. / Max.	-1.8 / 2.5	-1.8 / 2.5	-1.8 / 2.5	-1.9 / 2.5	-1.7 / 2.4	-1.6 / 2.4	-1.6 / 2.4	-1.8 / 2.3
CPI	Number of cases	102	146	163	180	178	176	175	168
	Mean (value)	4.558	4.164	4.091	4.022	4.008	43.267	43.189	42.571
	Mean (% change)	-	-8.6	-1.8	-1.7	-0.4	-	-0.2	-1.4
	Std. dev. (value)	2.361	2.218	2.146	2.101	2.080	19.618	19.714	20.043
	Std. dev. (% change)	-	-6.1	-3.3	-2.1	-1.0	-	0.5	1.7
	Min. / Max.	1.2 / 9.7	1.5 / 9.7	1.8 / 9.6	1.0 / 9.3	1.1 / 9.3	8 / 90	8 / 92	8 / 91
EGDI	Number of cases	191	191	191	192	192	193	193	193
	Mean (value)	0.364	0.385	0.400	0.428	0.420	0.488	0.471	0.492
	Mean (% change)	-	5.8	3.9	7.0	-1.9	16.2	-3.5	4.5
	Std. dev. (value)	0.216	0.220	0.223	0.207	0.194	0.211	0.217	0.215
	Std. dev. (% change)	-	1.9	1.4	-7.2	-6.3	8.8	2.8	-0.9
	Min. / Max.	0 / 0.9	0 / 0.9	0 / 0.9	0 / 0.9	0 / 0.9	0 / 0.9	0 / 1	0 / 0.9
IDI	Number of cases	154	181	154	159	152	167	166	175
	Mean (value)	2.477	0.402	3.399	3.553	4.076	4.373	4.772	4.943
	Mean (% change)	-	-	-	4.5	14.7	7.3	9.1	3.5
	Std. dev. (value)	1.442	0.191	1.904	1.936	2.094	2.170	2.209	2.215
	Std. dev. (% change)	-	-	-	1.7	8.2	3.6	1.8	0.3
	Min. / Max.	0.5 / 6.1	0 / 0.8	0.8 / 7.5	0.8 / 7.8	0.8 / 8.4	1 / 8.6	1 / 8.9	1.1 / 8.8
NRI	Number of cases	82	102	122	127	133	142	148	139

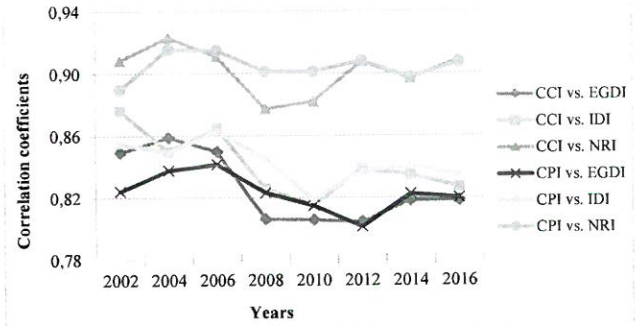
Mean (value)	3.963	3.590	3.848	3.930	3.870	3.957	4.011	4.142
Mean (% change)	-	-9.4	7.2	2.1	-1.5	2.3	1.4	3.3
Std. dev. (value)	0.978	0.837	0.904	0.838	0.786	0.885	0.907	0.922
Std. dev. (% change)	-	-14.4	8.0	-7.3	-6.2	12.6	2.5	1.7
Min. / Max.	2.1 / 5.9	2.1 / 5.5	2.2 / 5.7	2.4 / 5.8	2.6 / 5.7	2.3 / 5.9	2.2 / 6.0	2.2 / 6.0

Source: Authors' compilation based on the data of World Bank, Transparency International, UN, ITU and WEF.

Then, the relationship between the selected indices in different time periods was examined. Here, the null hypothesis defined that the compared variables are not in correlative relationship. Verification of this hypothesis was based on the subsequent comparison of the level of significance with a p-value. The correlations between the indices were calculated in order to see how strong the linear dependence is. The indices were evaluated for 14 years and the correlations between them were calculated. At first, as results indicated, the two corruption indices are strongly correlated. This means that 0.987 as mean value is an almost perfect correlation, which is also stable over the years, i.e. 2002 (0.969), 2004 (0.983), 2006 (0.984), 2008 (0.990), 2010 (0.992), 2012 (0.995), 2014 (0.994), 2016 (0.991).

In Figure 1, there can be seen the progress of Pearson's correlation coefficients for the indices between examined years on the significance level 0.05, giving a value between +1 and −1, where 1 is total positive correlation, 0 is no correlation, and −1 is total negative correlation. Thus, a positive correlation relationship was found among the variables in examined years. This led to the rejection of the null hypothesis. As mentioned above, high values of e-government development index indicate higher quality of the country's technological and telecommunication infrastructure and the ability of its citizens, businesses and governments to adopt, use and benefit from modern technologies. Higher values of a corruption index indicate less corruption in the country, i.e. it is perceived to be very clean with strong governance performance and a stable political and economic situation. It may be suggested that there is a relationship between the level of corruption and e-government development as represented by the indices in the compared countries. The NRI has also stronger relationship with both the CPI and CCI than other indices. Thus, these results suggested that the NRI is a better predictor of the level of corruption than the EGDI and IDI.

Figure 1 The progress of correlations coefficients among the indices through the years



Source: Authors.

Moreover, there was found a decline between 2008 and 2010, i.e. that the strength of this relationship has decreased. It is probably due to the financial crisis that started at the end of 2007 and led to the global recession, which affected the economies of countries around the world. As reported by Ivlevs and Hinks (2015), households hit by crisis are more likely to bribe and, among people who bribe, crisis victims bribe a wider range of public officials than non-victims. The crisis victims are also more likely to pay bribes because public officials ask them to do so and less likely because of gratitude. Furthermore, one of the key causes of the financial crisis is the loose monetary policy (cheap money policy), which combined with the political focus on stimulating economic growth (the growth of public debt), may accelerate the extent of corruption perception in the economy.

Máchová and Lněnička (2016b) then evaluated the influence of selected indicators on e-government development in order to uncover similarities and identify areas that were affected by the crisis and need improvement. They found that the variables in the ICT infrastructure and broadband quality dimension were not affected by the global recession. Therefore, the IDI did not report any significant decline through the years. This claim is also supported by the results in Table 2, where a percentage change of the IDI mean value increases constantly with the passage of time. Therefore, it may be concluded that the perception of corruption is getting worse faster due to some kind of crisis than the level of e-government development.

Table 3 with Spearman rank order correlations confirmed these results. All the correlations were statistically significant at a level of 0.05. The indices measuring the level of corruption ranked countries similar to each other while the indices of e-government development were slightly different. These results were also confirmed by Kendall tau correlations and showed that the CPI ranked countries more similar to e-government development indices than the CCI. Hence, it was used in the following regression models as the only measure of corruption.

Table 3 Spearman rank order correlations

Year / index	2002		2004		2006		2008	
	CCI	CPI	CCI	CPI	CCI	CPI	CCI	CPI
EGDI	0.636	0.789	0.661	0.751	0.688	0.770	0.691	0.758
IDI	0.699	0.806	0.802	0.826	0.752	0.800	0.723	0.751
NRI	0.900	0.881	0.912	0.913	0.861	0.897	0.841	0.873
Year / index	2010		2012		2014		2016	
	CCI	CPI	CCI	CPI	CCI	CPI	CCI	CPI
EGDI	0.669	0.741	0.734	0.740	0.724	0.741	0.690	0.759
IDI	0.735	0.765	0.765	0.752	0.772	0.763	0.751	0.771
NRI	0.831	0.882	0.834	0.839	0.827	0.819	0.823	0.833

Source: Authors.

The results for the composite indices are in agreement with those obtained by Grönlund and Flygare (2011). They found that while the level of corruption is very consistently measured by the CCI and CPI between the years 2003 and 2008, e-government development indices vary widely as predictors. According to their results, the Economist Intelligence Unit's (EIU) e-government index and IDI are the best predictors. The EGDI scored fairly well but none of the other tested indices could serve as a predictor, i.e. the Waseda index. It should be noted that the EIU was last published in 2010. Therefore, it was not used in this research study. The Waseda index was not used because it covered only 23 countries when it was firstly published in 2005 (in 2016 it covered 65 countries) and, hence, it cannot be accurately compared with others as this index does not fully reflect the wide variety of countries in the world.

Furthermore, a new finding was that the NRI, which was omitted in the study of Grönlund and Flygare (2011), is a better predictor than the EGDI and IDI. It could be argued that this result is due to the composition of its benchmarking framework. Therefore, a major implication for practice is the importance of monitoring the new trends in ICT and incorporating them into benchmarking frameworks (Máchová and Lněnička, 2015). The indices that are most ambitious on these trends score best such as in the case of the NRI. Thus, the best index should contain institutional, policy, and social analysis on top of available statistics on factors pertaining to these trends.

The next step was to explore how far the dimensions can explain the changes of the level of the dependent variable (corruption). Table 4 shows the Pearson's correlation coefficients between each of e-government development indices and their dimensions and corruption indices calculated using values from examined years. As the table indicates, there is a wide variety in correlation ranging from a moderate 0.60 to a very strong 0.92. Thus, the statistical findings of the study indicated that the various dimensions have different implications in the context of decreasing the corruption level.

Table 4 The correlation matrix for the dimensions of e-government development indices

Year	Index	EGDI			IDI			NRI			
Dimensions		HCI	OSI	TII	Acc.	Skills	Use	Env.	Read.	Usage	Imp.
2002	CCI	0.627	0.619	0.903	0.889	0.649	0.837	0.910	0.876	0.885	N/A
	CPI	0.619	0.582	0.887	0.865	0.619	0.833	0.896	0.862	0.859	N/A
2004	CCI	0.641	0.699	0.903	N/A	N/A	N/A	0.922	0.901	0.893	N/A
	CPI	0.627	0.663	0.897	N/A	N/A	N/A	0.916	0.884	0.892	N/A
2006	CCI	0.646	0.678	0.900	0.858	0.642	0.873	0.919	0.855	0.888	N/A
	CPI	0.616	0.662	0.911	0.853	0.612	0.887	0.928	0.844	0.898	N/A
2008	CCI	0.616	0.618	0.864	0.827	0.589	0.834	0.901	0.808	0.859	N/A
	CPI	0.618	0.635	0.885	0.844	0.601	0.858	0.921	0.835	0.884	N/A
2010	CCI	0.585	0.614	0.863	0.821	0.561	0.825	0.928	0.750	0.849	N/A
	CPI	0.579	0.632	0.869	0.821	0.559	0.833	0.940	0.778	0.868	N/A
2012	CCI	0.602	0.706	0.809	0.826	0.594	0.853	0.936	0.774	0.895	0.870
	CPI	0.603	0.702	0.805	0.822	0.599	0.851	0.937	0.775	0.893	0.872
2014	CCI	0.696	0.652	0.844	0.813	0.592	0.860	0.925	0.749	0.902	0.849
	CPI	0.705	0.654	0.847	0.814	0.603	0.869	0.927	0.751	0.900	0.849
2016	CCI	0.712	0.629	0.853	0.820	0.581	0.844	0.930	0.772	0.901	0.885
	CPI	0.735	0.611	0.860	0.824	0.600	0.849	0.930	0.774	0.896	0.882
Mean value	CCI	0.641	0.652	0.867	0.836	0.601	0.847	0.921	0.811	0.884	0.868
	CPI	0.638	0.643	0.870	0.835	0.599	0.854	0.924	0.813	0.886	0.868

Source: Authors.

According to these results, the key e-government development dimensions for prevention of corruption and coordination of anti-corruption activities are: the environment sub-index, which assesses the extent to which a country's market conditions and regulatory framework support entrepreneurship, innovation, and ICT development; the usage sub-index, which assesses the level of ICT adoption by a society's main stakeholders; and the telecommunication infrastructure sub-index, which measures a country's ICT infrastructure capacity.

On contrary, it was found that dimensions related to human capital and skills, i.e. indicators such as adult literacy rate, secondary and tertiary gross enrolment ratio or mean years of schooling have only moderate impact on the level of corruption. Further, there is no significant improvement in these dimensions through the years. It may be concluded that both correlated factors showed a similar rate of growth, except in the time of the crisis. This means that higher levels of e-government development are associated with lower levels of corruption in the compared countries.

As presented above, the CPI has stronger relationship with all the e-government development indices. Also, the NRI is the best predictor of the level of corruption, thus, this relationship was investigated more thoroughly. The natural logarithm of GDP per capita

was used as a control variable. The regression estimate using equation (1) is then presented in Table 5, including the parameters of models in examined years and the coefficient of determination (R^2), which indicates the proportion of the variance in the dependent variable that is predictable from the independent variable. Number of cases represents the number of countries that are benchmarked by both the CPI and NRI. This table reports OLS regressions with robust standard errors, which are in the parenthesis.

The results indicated that coefficient estimate for the NRI in all years is positive and statistically significant. The overall R^2 for all these models are very high. Further, after checking the residual plots in order to validate the model, it can be concluded that e-government development has a significant impact on the level of corruption. These models explain and predict future outcomes very well. The decline in R^2 that has been occurred since 2012 may be explained by the digital divide caused by the consequences of the crisis, where developed countries invested more in ICT than developing countries (Aladwani, 2016; Prasad and Shivarajan, 2015). Finally, it may be suggested that the GDP may be used with another control variable(s) and thus more models may be investigated.

Table 5 Impact of e-government development on the level of corruption

Year (model)	*Number of cases*	*α constant*	*β for NRI*	*γ for GDP*	*Overall model R^2*
2002	80	-8.368 (1.732)	1.559 (0.250)	0.781 (0.272)	0.817
2004	100	-4.498 (0.921)	2.717 (0.232)	-0.070 (0.171)	0.851
2006	120	-4.318 (0.743)	2.316 (0.170)	-0.007 (0.130)	0.840
2008	124	-5.087 (0.719)	2.254 (0.175)	0.081 (0.124)	0.818
2010	129	-5.995 (0.676)	2.331 (0.173)	0.153 (0.115)	0.821
2012	138	-25.230 (7.155)	20.099 (1.641)	-0.871 (1.240)	0.771
2014	140	-23.307 (7.897)	18.574 (1.804)	-0.532 (1.393)	0.727
2016	129	-25.830 (8.440)	19.468 (1.966)	-0.869 (1.549)	0.755

Source: Authors.

Overall, the results of this study add to the literature regarding the relationship between e-government development and the level of corruption by exploring this relationship on the level of decomposed sub-indices (dimensions) to avoid the possible negative effects of one aggregate value represented by the composite index. Since this research approach has never been specifically used to investigate this issue, this paper provided important benchmark data, regression models as well as offered deeper insights into the benefits of using ICT to combat and reduce corruption.

According to UN's E-government Survey 2016, countries in all regions are increasingly utilizing ICT to deliver services and engage people in decision-making processes (United Nations, 2016). At the same time, policy makers and practitioners need accurate information about the availability and use of ICT to make appropriate decisions (International Telecommunication Union, 2016). Hence, e-government could be an effective tool to curb corruption in the public sector if the high levels of country's market conditions and regulatory framework, ICT adoption by a society's stakeholders, and country's ICT infrastructure capacity are fundamental preconditions of a government's vision. More importantly, this study indicated that a high e-government development could play a significant role in anti-corruption efforts and if governments will support these dimensions, these efforts could effectively lower the corruption level in the public sector. Therefore, practitioners and policy makers should make concerted efforts in enhancing e-government development by focusing on the growth and maturity of these dimensions. Besides that, the results should serve as a guide to countries trying to manage corruption and advance e-government development on what to focus their resources and capabilities on.

Finally, it may be concluded that if the findings of this study will be taken into account in the context of anti-corruption efforts, then, any policy that will lead to the elimination of corruption and the transparency of the market environment, will be a successful and cost-effective economic policy. Weakening links between economic and political power, increasing transparency of processes, and the elimination of unnecessary regulations that burdened the economy will lead to enhance the credibility of the country, the reduction of unwanted corrupt behaviour in the economy and to the satisfaction of the public.

Limitations and Future Research

Although ICT provide an opportunity for public organizations to be more transparent, it has to be ensured that ICT do not build on extant bureaucratic processes, thereby reinforcing the existing inefficiencies (Srivastava et al., 2016). As stated by Ramaswamy and Selian (2009), combating corruption has to be "*an evolutionary process, characterized by both top down and bottom up buy in, so that it can be accepted with minimum resistance by the bureaucracy as a whole.*" At the same time, advances in e-government must go hand in hand with efforts to bridge the digital divide (United Nations, 2016). Closer consideration showed that there are still very considerable variations between different regions, and particularly between countries in different development categories (International Telecommunication Union, 2016). In this regard, the first limitation is the existence of outliers among the evaluated countries in which the relationship between e-government development and the level of corruption requires more research to be done. For example, the success rate of ICT projects' and e-government systems' implementation in the Czech Republic is quite low and deeper understanding of these effects would require a comparative analysis with other similar countries. Another way of solving this issue is to conduct a cluster analysis to determine if the relationship is different between these groups (Máchová and Lněnička, 2016b).

The second limitation may be the fact that most of the widely used corruption indices are perception-based measures that may have weak correlations with actual experiences of corruption (Olken, 2009; Seligson, 2006). However, as these cross-national measures are based on surveys assessing first-hand experiences of corruption and their results are affected by respondents' reticence in answering questions related to their participation in corrupt activities (Escresa and Picci, 2017; Treisman, 2007; Wei, 2001); it is more suitable to use established indices. Furthermore, proposing to use judicial statistics to develop a cross-national measure of corruption may appear ungainly. These differences could be so important that they could even imply a negative correlation between actual and ob-

served corrupt transactions (Escresa and Picci, 2017). After all, where corruption is endemic, the judiciary may also be corrupt or vulnerable to threats (Van Aaken et al., 2010). In this case, more consistent results may be achieved by dividing countries into groups according to their population, income level, unemployment rate, etc., as suggested, for example, by the United Nations' report on e-government (United Nations, 2016), or geographic location as a geopolitical regional group of states (Lupu and Lazar, 2015).

The scope of this study was limited in terms of data available, i.e. the use of secondary data, utilizing data points that were present across all the data sources and collected in a uniform way by the secondary organizations. Another limitation of this research is the composition of aggregated indices and their indicators through the time, especially when many other country-specific factors that might affect corruption could not be easily captured in such a quantitative analysis (Grönlund and Flygare, 2011; Lindstedt and Naurin, 2010; Shim and Eom, 2009). The methodology behind the calculation of these indices can thus affect the reliability of the results of measurements. Since various factors may have different influences from year to year, these changes have to be taken into account when discussing the results. This may also limit the research questions.

But, taking into consideration that these indices have been formulated by reputable and authorized organizations using several suitable statistical procedures for assessing their validity and reliability, relying upon these data sources provides a cost-effective way for conducting this study. Finally, the scope of this study was limited in terms of the economic perspective. Because of that, none other factors were used in the regression models, although some authors, such as Andersen (2009), Elbahnasawy (2014); Kim (2014), Krishnan et al. (2013), Prasad and Shivarajan (2015) or Shim and Eom (2009), mentioned some of them. This limitation will be addressed in future studies.

On the basis of the findings, work on the remaining issues is continuing and will be presented in future papers. More precisely, these data will be used to explore the impact of other factors (independent variables), such as government effectiveness, political stability or press freedom, and to expand the proposed regression models and their quality. Another possible area of future research would be to investigate the effects of open government and open data on the level of corruption (Máchová, 2017; Máchová and Lněnička, 2016a). As mentioned earlier, combining transparency of information with open and big data analytics has a growing potential. It can help track service delivery and lead to gains in efficiency. It can also provide governments with the necessary tools to focus on prevention rather than reaction, notably in the area of disaster risk management (Lněnička, 2014; United Nations, 2016).

Furthermore, as stated by Bussell (2011), new ICT provide governments with opportunities to deliver public services more effectively to their citizens. For example, these trends were identified in Máchová and Lněnička (2015) and especially the role of open government and open data portals should be examined more thoroughly. Additionally, future studies should focus on the various administrative levels, i.e. the impact of e-government on corruption at more granular levels of analysis, as well as ICT infrastructure in various countries.

Conclusion

This paper empirically examined the potential effects of e-government represented by decomposed e-government development sub-indices (dimensions) in reducing corruption in the period between 2002 and 2016. It introduced new insights regarding the relationship between these two factors and helped to understand these effects on more detailed levels of e-government development represented by various dimensions in time.

With respect to the first research question, the empirical findings confirmed that there is a relationship between e-government development and the level of corruption on the national level. A progress in the trend of this relationship between examined years was also found and described. These results suggested that, generally speaking, the perception of corruption is getting worse faster due to some kind of crisis than the level of e-government development. E-government development indices consistently predict corruption. It was found that the best predictor is the NRI. Dimensions with the strongest relationship with the level of corruption are the environment sub-index, the usage sub-index and the telecommunication infrastructure sub-index of the NRI. On the other hand, dimensions related to human capital and skills have only moderate impact on the level of corruption.

The focus of this empirical study is unique in that the previous studies focused on either using only single index of e-government development or evaluated only selected years. It offered useful insights into the progress of this relationship between e-government development and the level of corruption. It also examined the effects of each dimension of e-government development independently on the level of corruption that can provide deeper insights into the benefits of using ICT to combat and reduce corruption. Moreover, this paper filled an important gap in the extant literature on how to examine the impact of e-government development and the level of corruption in the context of various dimensions in time. In this regard, it complemented the stream of research that uses theoretical models and empirical analysis to examine the importance of ICT in reducing corruption. Finally, the importance of open government movement in providing new channels and tools to combat corruption was also discussed as a possible future research topic.

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