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Does electronic government deter corruption?

Evidence from across the world.

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Abstract: Electronic government innovations are one of the most important changes in public administration in recent years. Governments in many countries have implemented e-government policies to foster efficiency and transparency, and to mitigate corruption. This paper explores the effects of e-government on corruption using longitudinal data for more than 170 countries for the period 2002-2017. Empirical results strongly support the hypothesis that e-government can be used to deter corruption. This result is robust to alternative indicators of corruption and e-government, as well as to a variety of estimation techniques. A novelty of our research is that we analyse under which conditions is e-government more effective in reducing corruption. Quantile regressions indicate that the potential of e-government to deter corruption is higher between quantiles 0.3 to 0.8 of the corruption distribution. E-government also reveals to be a more effective corruption deterrent in countries that are not classified as high-income countries and that are not in the extremes of the freedom of the press variable distribution.

Keywords: corruption; electronic government; governance; information; transparency

JEL Codes: D7, H1, O3, O5

1. Introduction

In the last decades, the fast development of the Information and Communication Technologies (ICT) has made the adoption of electronic government (e-government)[1] solutions a worldwide political trend (UNDESA, 2016).[2] The promotion of stronger institutions, through greater transparency in government, more accountable public officials and the engagement of citizens in public matters, has frequently been used to justify investments in e-government. Additionally, e-government is perceived as being capable of discouraging corrupt practices and influencing citizens' attitudes towards corruption (Elbahnasawy, 2014; Gans-Morse *et al*., 2018). Digital records improve the quality and make the data of transactions easier to maintain, facilitating their track and the detection of malpractice acts. Consequently, audits and preventive checks become more efficient. Moreover, movements such as the open government data increase citizens' and media's awareness on several domains of the public servants' activities, namely on public contracts and tenders, increasing accountability and the chances of detecting corrupt practices.

This paper empirically assesses whether e-government can be used to deter corruption and under which conditions it is more powerful in reducing it. We believe our analysis is important for several reasons. First, corruption is a serious problem in many countries, imposing severe negative effects on society, namely by harming innovation (Murphy *et al.*, 1993; Shleifer

[1] Despite de non-existence of a standard definition of e-government, the United Nations (UN) E-Government Survey of 2014 defines it as the use and application of information technologies on public administration to streamline and integrate processes, to effectively manage data and information, to enhance public service delivery and to expand communication channels for engagement and empowerment of people (UNDESA, 2014).

[2] In Europe, the European Commission has been advising member states to adopt electronic ID, interoperability and e-certification, among others, to promote transparency and accountability, and to reduce administrative burdens (European Commission, 2016).

and Vishny, 1993; Dincer, 2019), economic growth and sustainable development (Mauro, 1995; Murphy *et al*., 1991; Aidt, 2009; d'Agostino et al., 2016; Gründler and Potrafke, 2019). More corrupt countries tend to attract less foreign investment (Habib and Zurawicki, 2002), tax trade (Dutt and Traca, 2010), have higher public debts (Cooray *et al.*, 2017), a less developed financial sector (Cooray and Schneider, 2018) and a lower private investment (Zakharov, 2019). Second, large investments have been made on e-government, and therefore it is important to measure its benefits (and costs) for society. Third, we have built a large and detailed database comprising more than 170 countries and 16 years of data, which includes several proxies for corruption and e-government, as well as other economic and institutional variables, which allow us to obtain robust empirical results. Despite the relevance of the topic, only a few studies have used panel data to investigate the relationship between e-government and corruption and those studies are largely focused on average effects. Finally, we analyse under which conditions is e-government more effective in reducing corruption.

The paper is structured as follows. Section 2 reviews the literature on the determinants of corruption and discusses the role of e-government as a corruption mitigation tool. Section 3 describes the data and its sources. Section 4 explains the empirical methodology and section 5 presents the empirical results. Finally, the conclusion is presented in section 6.

2. Determinants of corruption and the role of electronic government

An extensive literature has analysed the causes and effects of corruption,[3] showing that countries with high levels of corruption are associated with high bureaucracy and low levels of education, income and development. However, no consensus has been reached on the causes of corruption. In the following lines, we briefly review the literature on the determinants of corruption.

[3] See Dimant and Tosato (2018) and Aidt (2018) for a survey.

Institutions and historical evolution play an important role in explaining a country's development and corruption levels. More politically and economically inclusive countries, that promote political participation and defend private property, tend to exhibit the highest levels of social and economic development (Acemoglu and Robinson, 2012). The type of colonization may also influence long-run rates of development and the geographic dispersion of corruption (Acemoglu *et al.*, 2001).[4] Whether or not a country is a democracy, and its type of democratic regime, may also influence corruption. Autocracies and recent democracies tend to exhibit higher levels of corruption. Recent democracies tend to have fragile institutions and free entry into the collection of bribes by the agencies that provide public goods, which contributes to higher corruption levels (Shleifer and Vishy, 1993). Additionally, there is evidence that cultural and social norms related to corruption are quite persistent and that legal enforcement matters in government officials' corruption decisions (Fisman and Miguel, 2007).

The lack of competition and government regulations may also yield more corruption (Pieroni and d'Agostino, 2013), as they can create an environment conducive to bribes generating higher rents for existing firms, and therefore higher incentives to bribe bureaucrats that control the rights of firms (Ades and Di Tella, 1999). Hence, openness to foreign companies and antitrust regulation can result in lower levels of corruption (Torrez, 2002). Bureaucracy is also presented as an important factor influencing the aggregate level of corruption since heavy and intrusive regulations may create higher incentives for bribes or for not fulfilling the legal requirements (Djankov *et al.*, 2002; Auriol and Walters, 2005; Dal Bó *et al.*, 2006). Finally, freedom of the press has also been shown to deter corrupt activities (Brunetti and Weder, 2003).

[4] The authors distinguish extractive colonization from inclusive colonization. Most countries where European colonizers set up extractive institutions have lower income levels today. Those countries are located near the Equator, where colonizers faced very high mortality rates.

During the last decades, innovations in information and communication technologies and their adoption by governments had an unprecedented impact on society and the way the public sector operates (Scholl, 2012).[5] Higher levels of access to information and of social media penetration help to promote accountability and to discipline corruption by exposing wrongdoings, particularly in less democratic countries, where traditional media is often censored (DiRienzo et al., 2007; Jha and Sarangi, 2017; Enikolopov *et al*., 2018). E-government and technology can impact corruption both by increasing the probability of conviction and the punishment per offence. Since electronic records are easier to store and access, e-government facilitates audits, preventive checks and ongoing investigations of corrupt acts, increasing the probability of exposure. Interoperability and integration of public services across agencies can also have the same effect. Additionally, digital information regarding corrupt acts is easier to disseminate, increasing the reputational damages for the individuals that commit them, making the punishment harsher. Recent trends such as open government and open data that promote transparency and collaboration may also reduce corruption by increasing citizens' ability to detect corrupt activities (Olken, 2009).

As far as we know, only a few studies (Andersen, 2009; Elbahnasawy, 2014; and Zhao and Xu, 2015) have empirically investigated the impact of e-government on corruption, using panel data for a large number of countries. Most of these studies use data that does not cover the last decade and they do not extensively investigate which factors condition the mitigating effect of e-government on corruption levels.

This paper improves on the previous literature for several reasons. First, we have built a large and detailed dataset that covers more than 170 countries, spans for more than a decade

[5] See Andersen *et al*. (2010) for a meta-analysis of the literature on e-government's impacts. For example, Veiga and Rohman (2017) and Elbahnasawy (2021) suggest that e-government decreases the size of the shadow economy, while Martins and Veiga (2018) reveal that it can facilitate business.

of e-government innovations, and includes several measures of corruption and e-government. As far as we know, this is the most comprehensive database ever used, which allows for robustness tests on several sub-samples and to cover the most recent innovations in e-government. Second, we have used several alternative measures of corruption and e-government, which reduce the potential biases resulting from a single measure.[6] Third, by considering different measures of e-government, that capture different dimensions of the general concept, we are able to explore which e-government dimensions (e.g. open data, pre-filled forms, e-government users) are more closely linked to corruption outcomes, which is clearly an under-researched topic. Fourth, we have tested the robustness of our results to a variety of estimation techniques, namely the maximum likelihood estimators that are particularly well-suited to deal with censored dependent variables. We have also used quantile regressions to explore whether the potential of e-government as an anti-corruption tool varies along with the conditional distribution of corruption outcomes. Finally, we investigated under which conditions is e-government more effective to deter corruption, which is a gap in the literature.

3. The data

Four alternative corruption indexes are used as proxies for corruption: The Control of Corruption Index (*CCI*) from the World Bank's Worldwide Governance Indicators (WGI), the Corruption Perceptions Index (*CPI*) compiled by Transparency International, the index of corruption of the International Country Risk Guide (*IC_ICRG*) from the PRS Group and the Public

[6] As corruption consists of illegal activities, which are hard to measure and document, a major difficulty of studies on corruption is measurement. Most empirical studies use indicators of perceived corruption as a proxy for corruption, which have been shown to be positively correlated with measures of actual corruption and to contain real information on corrupt practices (Olken, 2009).

Sector Corruption Index (*PSCI*) by the V-Dem Institute. The *CCI* measures the extent to which public power is exercised for private gain, considering both grand and petty forms of corruption, as well as the degree of state's capture by elites and private interests. The *CCI* aggregates indicators that combine the views of firms, citizens and experts obtained through surveys implemented in industrial and developing countries.[7] The *CPI* attempts to measure perceptions of corruption in the public sector by aggregating indicators from several data sources.[8] The *IC_ICRG* corruption index is a measure of corruption within the political system. Although it also takes financial forms of corruption into account, such as bribes, it is more focused on political forms of corruption such as job reservations, suspicious ties between business and politics, secret party funding, nepotism, exchange of favours or excessive patronage. Its construction is based on a subjective analysis of the political risks and information on financial and economic data by the IC_ICRG staff. Finally, the *PSCI* is solely focused on public sector corruption. It aims to capture the extent to which civil servants grant favours in exchange for bribes and kickbacks, defalcate, steal or use public resources for private use. The V-Dem Institute indicators combine factual information from official documents with subjective assessments from experts. As can be seen from Table 1, all four indexes are highly correlated, particularly the CCI with the CPI and the IC_ICRG.

<Table 1>

To measure the development of electronic government in each country we start by using the UNDESA's E-government Development Index (*EGDI*) and its components, which are

[7] For a detailed description of the methodology see Kaufmann *et al.* (2011).

[8] For more details see the "Technical methodology note" and the "Source description" available at https://www.transparency.org/news/feature/corruption_perceptions_index_2016.

narrower in scope. The *EGDI* is released biannually and is based both on primary data, from surveys implemented by UNDESA, and on secondary data from the International Telecommunications Union (ITU) and UNESCO. It covers 193 countries and is calculated as an arithmetic average of three sub-indexes: The Online Services Index (*OSI*), the Telecommunications Infrastructure Index (*TII*) and the Human Capital Index (*HCI*).[9] A subset of the *OSI*, focused on electronic participation related features, the e-Participation Index (*EPart*), is also made available. The *EPart* considers "the use of online services to facilitate the provision of information by governments to citizens ("e-information sharing"), interaction with stakeholders ("e-consultation") and engagement in decision-making processes ("e-decision-making")" (UNDESA, 2016; pp.141).

Besides the measures of e-government development, we consider other variables that previous literature has shown to be relevant to analyse corruption. The first is the log of the GDP per capita (*logGDP*) that, according to Treisman (2007), is the strongest predictor of corruption. Data for this variable was obtained from the World Bank's Development Indicators. Alternatively, we have also used dummy variables that assign each country to a certain income level (Low Income, Lower Middle Income, Upper Middle Income and High Income), based on the World Bank's Income Classification.

A second economic dimension considered is the degree of openness of the economy (*openness*), that measures the sum of exports and imports as a percentage of GDP. As more open economies have fewer monopolistic rents and are more exposed to external competitors,

[9] The TII is a weighted average of five indicators related to the use and development of telecommunications. The HCI is a weighted average of four schooling and literacy-related indicators. The OSI measures the development of governmental online services provided in each country and is based on an evaluation made through a survey by researchers from all over the world. The evaluated features include online service delivery, government approaches as a whole, open government data, multi-channel service delivery, e-participation mobile services, usage up-take, digital divide and innovative partnerships using ICT.

we expect them to be more transparent and less corrupt (Ades and Di Tella, 1999; Dutt 2009). The same reasoning applies to foreign direct investment inflows as a percentage of GDP (*fdi*). These two variables were collected from the WB's Development Indicators, as well as the percentage of urban population (*urban*). To proxy the level of bureaucracy, we follow Djankov *et al.* (2002) and use the Ease of Starting a Business Index (ease*startbus*) from the World Bank Ease of Doing Business project. We also consider the fixed broadband subscriptions per 100 people (*broadband*) from the WB's WDI.

Democracy, freedom, and political institutions can be important predictors of corruption (Persson *et al.*, 2003; Lederman *et al.*, 2005). To capture individual freedom and political rights we use the Political Rights variable (*political_rights*) from the Freedom House's Freedom in the World database, which is an index that ranges from 1 (greatest degree of freedom) to 7 (lower degree of freedom). This variable is based on external analysts' on-the-ground research, media information analysis and interaction with local contacts and considers the electoral process, the political pluralism and participation and the functioning of government. We also include in the analysis the Freedom of the Press Index by Reports Without Borders (*pressfree*).

Finally, from the World Religion Dataset, we take the percentages of Catholic population (*chatholic*), Islamic population (*islam*) and Protestant population (*protestant*).[10] These variables are used to proxy cultural norms that may influence corruption (Fisman and Miguel, 2007). We have also considered dummy variables that identify the continent and the colonial origins of the countries.

[10] Values for these variables exist for every five years, starting in 1945 and ending in 2010. The series were interpolated using the Stata ipolate command.

Table 2 provides descriptive statistics of the variables used in the empirical analysis, for the entire sample period (2002 to 2016).[11] To have all the variables in a similar scale and to facilitate the interpretation of the estimated coefficients we have rescaled the *open_budget*, *CCI*, *CPI*, *IC_ICRG*, *easestartbus*, *rule_law*, *political_rights* and *pressfree* to a 0 to 1 scale. For similar purposes, we have inverted the *CCI*, *CPI* and *IC_ICRG* so that higher scores represent higher levels of corruption, and the *political_rights* and *pressfree* so that higher scores represent, respectively, higher levels of political rights and more freedom of the press.

<Table 2>

4. Empirical methodology

We start by performing a cross-country analysis for the most recent year for which the data on corruption and e-government indexes is available. The baseline empirical model can be presented as follows:

$$CI_{it} = \beta_0 + \beta_1 egov_{it-1} + \gamma.Control'_{i,t-1} + \varepsilon_{it} \quad (1)$$

where t equals 2016 and *i* represents a country. *CI* stands for the corruption index (either the *CCI*, the *CPI*, the *IC_ICRG* or *PSCI*) and *egov* for the e-government index. *Control'* represents a vector of control variables, lagged one period to minimize endogeneity concerns. β_0, β_1 and γ are, respectively, coefficients and a vector of coefficients to be estimated. Finally, ε is the error term.

[11] During the 2002-2016 period, some countries (e.g.: Serbia and Montenegro, Sudan) were divided or suffered major redefinitions of their borders. These countries were removed from the sample. We did not consider 2017 in the descriptive statistics because this year is only considered in complementary regressions.

In the baseline model, we use as proxies for corruption and e-government the Control of Corruption Index from the World Bank (*CCI*), and the Online Service Index (*OSI*) from the United Nations, respectively. These are the indexes from which more observations are available and, among the e-government indexes analysed, the *OSI* is the one that is more closely related to the strict definition of e-government. The *OSI* is lagged one period to avoid endogeneity biases resulting from a possible influence of corruption on e-government maturity (Bussel, 2011; Khan and Krishnan, 2019).

Initially, we used a parsimonious set of control variables consisting of the log of the GDP per capita (*logGDP*), the degree of openness of the economy (*openness*), the political rights index (*political_rights*) and the ease of starting a business index (*easestartbus*).[12] In subsequent regressions, to verify if the results were sensitive to the control variables selected, we used the remaining variables, discussed in the previous section, as possible determinants of corruption.[13]

Given that we are using indexes as dependent variables and all the indexes were rescaled to range from 0 to 1, we have used the fractional probit method. As explained earlier, we have used the one-year lagged value of the *OSI* to mitigate possible endogeneity problems. To be even more cautious, we also estimate the cross-section model using Two-Stage Least Squares (2SLS). In the first stage, we instrument the *OSI* and in the second stage, we use the estimated values for the instrumented variable as an explanatory variable for corruption.[14]

[12] An alternative proxy is the index of Bureaucracy Quality from the ICRG, but this variable is only available for a smaller group of countries.

[13] Besides these variables, several other variables (economic, demographic, political and institutional) were tested in preliminary analyses but ended up being excluded because they created multicollinearity problems or had fewer observations and did not increase the explanatory power of the model.

[14] The instruments should be uncorrelated with the error term (exogeneity condition) and correlated with the instrumented variable (relevance condition). We have relied upon several statistical tests to validate

Following Andersen (2009), we start by using as instruments of e-government development the percentage of the population living in urban areas (*urban*) and the fixed broadband penetration of the population (*broadband*).[15] ICT adoption costs are lower in more densely populated urban areas, while broadband penetration is important for accessing the internet. Therefore, countries with higher broadband penetration and more people living in urban areas have more incentives to develop e-government, given the lower costs of adoption and the higher number of potential users. Complementing the 2SLS estimations, we also use lagged values of *e-gov* as instruments since while it is possible to argue that corruption can influence current e-government maturity, the same does not hold for past values of e-government development. Additionally, past values of e-government development are good predictors of the current one.

To extract the full potential of the large database built, we have extended the empirical analysis to panel data regressions. The panel covers the years for which values of the *OSI* are available: 2002, 2003, 2004, 2007, 2009, 2011, 2013 and 2015. The panel data model can be represented by equation (2):

$$CCI_{it} = \beta_0 + \beta_1 OSI_{it-1} + \gamma . Control'_{it-1} + \lambda_t + \mu_i + \varepsilon_{it} \quad (2)$$

that adds to equation (2) λ_t and μ_i that represents time and country fixed effects, respectively and allows *t* to assume different years. Aiming to investigate which e-government dimensions can be more helpful to deter corruption, we make use of our panel to explore the relationship between corruption outcomes and alternative measures of e-government. Namely, we use the European Commission *Digital Public Services Index*, which we will explain later, in section 5.2.

our procedure: the underidentification test, the weak identification test and the Sargan-Hansen test of overidentifying restrictions.

[15] Andersen (2009) uses the telephone line density, but we believe that given the technological progress, nowadays it is preferable to use the broadband penetration.

Finally, we investigate under which conditions is e-government more powerful in reducing corruption. Motivated by the fact that the average corruption levels of high-income countries and the remaining ones are very different, we analyse if the impact of the e-government on corruption depends on the level of GDP. To investigate if the effect of the *OSI* on *CCI* varies with GDP levels, we start by splitting (according to the World Bank's income classification) the sample into two groups, where one group includes high income countries and the other group is formed by the remaining countries. With the same purpose, we estimate, for the full sample, the average marginal effects of the OSI on the conditional mean of the CCI for different levels of GDP per capita. Besides the GDP, we also study if freedom of the press has a mediating effect on the impact of e-government on corruption levels. Finally, to investigate the determinants of corruption along with the conditional distribution of the corruption index score, we estimate panel data quantile regressions. We follow the approach proposed by Machado and Santos Silva (2019) for quantile regressions with fixed effects. This approach improves on the previous literature by allowing the time-invariant individual effect to have different impacts on different regions of the conditional distribution of the dependent variable, instead of treating the fixed effect as a simple location shift, as it is observed in previous approaches (e.g. Canay, 2011).

5. Results

5.1. Cross-section results

As explained earlier, we started by estimating the model with the fractional probit method, with robust standard errors, for the year of 2016. Table 3 presents the estimation results for the marginal effects using the *CCI* as the dependent variable. Column 1 shows results for the baseline model that uses a parsimonious set of control variables. In column 2, the percentages of Catholic (*Catholic*), Islamic (*Islamic*) and Protestant (*Protestant*) population are

added and in column 3 the freedom of the press (*pressfree*) is also included.[16] As endogeneity of the e-government index is a potential concern, we proceeded by replacing the first lag of the *OSI* by its third lag (column 4) and by estimating 2SLS regressions. Column 5 reports the estimations in which the first lags of the broadband penetration and urban population are used as instruments, while column 6 shows the estimations in which lags of the *OSI* are used as instruments.

Estimation results presented in Table 3 show that higher levels of the *OSI* are associated with better corruption outcomes, supporting our main hypothesis. In all models, the *OSI* turned out to be positively signed and strongly statistically significant. There is also strong support for the hypotheses that GDP growth, the degree of openness of the economy,[17] and political rights and civil liberties reduce corruption. On the contrary, our proxy for bureaucracy, the ease of doing business index, never turned out to be statistically significant. Regarding religion, results suggest that a higher percentage of protestants is associated with less corruption. Finally, we find strong support for the hypothesis that freedom of the press prevents corruption practices. This variable was not initially included in the regressions because it has fewer observations. Given that the *pressfree* and *political_rights* variables exhibit a correlation of 0.68 it is not surprising that the inclusion of the former leads to a significant drop in the estimated coefficients associated with the latter.

[16] In preliminary estimations, we also included five dummies for the colonial origins of the countries: countries that were never colonized and countries colonized by Spain, Great Britain, France and other countries (e.g. Belgium, Portugal, the Netherlands). The results remained essentially the same.

[17] Besides the degree of openness of the economy, we also included in preliminary estimations a variable for foreign direct investment inflows (Torrez, 2002), to further test for positive effects of exposure to external agents and markets on corruption outcomes. However, this variable did not turn out to be statistically significant.

<Table 3>

Two robustness tests were implemented.[18] First, using the model of column 3 from Table 3, cross-section regressions for the other years were estimated. As in the regression for 2016, the *OSI*'s coefficient turned out to be negative and statistically significant in the remaining years. *LogGDP*, *political_rights*, *protestants* and *pressfree* also turned out to be statistically significant in all, or in most, of the remaining years. Second, following Brunetti and Weder (2003) we estimated a cross-section regression where the dependent variable is the five-year average of the perceived corruption index. This procedure avoids the potential problem of cross-section estimation results being influenced by shocks that affect perceived corruption in a specific year. Under this approach, the OSI's coefficient is still negative and significant, with a magnitude that is almost identical to the one obtained under the baseline approach.

Alternative measures of Corruption

Table 4 presents estimation results for models using the fractional probit and the same explanatory variables as in column 3 of Table 3, for the four alternative variables that can be used to proxy the level of corruption: the Control of Corruption Index (*CCI*) from the World Bank's Worldwide Governance Indicators, the Corruption Perceptions Index (*CPI*) compiled by Transparency International, the assessment of corruption of the International Country Risk Guide (*IC_ICRG*) from the PRS Group and the Public Sector Corruption Index (*PSCI*) compiled by the V-Dem Institute. As can be seen from Table 4, regardless of the corruption measure used, the *OSI* is always statistically significant, confirming that e-government can be used as a tool to deter corruption. Given that the *PSCI* is less correlated with the *CCI* than the *CPI* and the *IC_ICRG*, it is not surprising that the magnitude and the statistical significance of the *OSI*'s estimated

[18] Results are available from the authors upon request.

coefficient differs more from the one where the CCI is the dependent variable (column 1) when the *PSCI* is the dependent variable (column 4) than when the *CPI* or the *IC_ICRG* are the dependent variable (columns 2 and 3).

<Table 4>

5.2. Panel results for the whole sample

The results of the estimation of panel data fractional probit models including the year and country dummies to control for time and country fixed effects are reported in Table 5.[19] To facilitate the interpretation of the results, marginal effects are reported. The first three columns replicate, with panel data, the models of columns 2 to 4 of Table 3. Results once again reveal a negative relationship between progress in electronic government and corruption, regardless of whether we use the first or the third lag of the variable *OSI*. However, the size of the estimated coefficients associated with the *OSI* in Table 5 is significantly smaller than those reported in Table 3, suggesting that the cross-section estimations overestimate the effect of e-government on corruption. There is also strong evidence that GDP per capita and political rights reduce corruption levels. When using panel data, and controlling for country and time effects, the variables capturing the degree of openness of the economy and the freedom of the press stop being statistically significant. Since the variable *pressfree* did not turn out as statistically significant and fewer observations are available for this variable, it was excluded from the subsequent regressions.

[19] The variable *easestartbus* was not included in the regressions of Table 5 because it is not available for the first two years of the panel (2002 and 2003) and it never turned out to be statistically significant. Religion-related variables were also not included because these variables show a low within variation and we control for country fixed effects in the panel estimations. The *pressfree* variable is not available for 2002.

We then considered alternative measures of e-government, namely the e-government development index (*EGDI*) and the e-participation index (*EPart*), both provided by UNDESA. The *EGDI*, as previously explained, is a broader measure of e-government than the *OSI*. Besides the Online Service Index, the *EGDI* also considers the Telecommunications Infrastructure Index and the Human Capital Index. The *EPart* is a subset of the *OSI* that aims to capture the citizens' access to information without demand, their possibility of engaging in decision making and empowerment through co-design and co-production of policies and services. Therefore, it is a narrower measure of e-government than the *OSI*. The marginal effects of the fractional probit estimates of models including these two variables are reported in columns 4 and 5 of Table 5. The magnitude of the estimated coefficient associated with the broader measure of e-government (*EGDI*) is larger than the estimated coefficient associated with the *OSI*, suggesting that human capital and telecommunication infrastructures also play a role in deterring corruption. However, the variable *EPart*, which is a narrower measure of e-government, did not turn out as statistically significant indicating that e-participation tools *per se* may not be enough to reduce corruption levels.

<Table 5>

Finally, we have used the European Commission's Digital Public Services indicators, to further explore alternative measures of e-government. These are a subset of the Digital Economy and Society Index (DESI) of the European Commission and have the advantage of being computed on a yearly basis and of being disaggregated into several distinct e-government components, namely *e-government Users*, *Pre-Filled Forms*, *Online Service Completion* and

Digital Public Services for Business.[20] These indicators allow us to investigate which e-government-related domains have a higher impact on corruption. The drawback is that they are available, at best, from 2014 and for the European Union member states (28 countries), which are typically high-income and low-corruption countries. Given these limitations, the estimation results using the DESI indicators should be interpreted with caution.

Table 6 shows the marginal effects of estimations using the fractional probit model and the first lag of the DESI indicators of e-government for which at least four years of data are available. Given the low number of observations, country fixed effects were not included.[21] However, to account for correlation between errors of the same country, standard errors were clustered by country. Control variables are the same as those used in the estimation results presented in column 2 of Table 5.

Results presented in Table 6, support the idea that a higher percentage of e-government users and more digital public services for business and online service completion mitigate corruption. This is not surprising given that the three indicators signal a greater use of online rather than face-to-face interactions, therefore reducing the proximity between individuals and potentially corrupt civil servants. Higher online service completion and digital public services for business reduce the extent to which civil servants have discretionary power on bureaucratic processes, and therefore, may decrease the likelihood of corrupt behaviour. A higher percentage of e-government users also suggests that more people are informed about the public sector and can act as whistle-blowers of corruption. No statistically significant effects were found for the pre-filled forms component.

[20] Additional dimensions which have also been included in the index are *Open Data* and *eHealth Services*, but these dimensions were not included in the analysis due to the small number of observations.

[21] In initial regressions, time dummies were also included, but they were never statistically significant and Wald tests for their joint significance revealed that they could be excluded.

<Table 6>

5.3. Under which conditions is e-government more powerful in reducing corruption?

The mitigating effects of e-government on corruption may depend upon several conditions. This section starts by analysing possible mediating effects of GDP and freedom of the press on the marginal effects of e-government on corruption levels. It then investigates the effects of e-government at different levels of corruption.

Mediating effects of the explanatory variables

High-income countries exhibit much lower corruption levels (average *CCI* = 0.271) than non-high-income countries (average *CCI* = 0.597).[22] Therefore, one might expect the relationship between e-government and corruption to differ between these two groups of countries. To investigate this hypothesis, we split the sample into two and we estimated fractional probit panel models with country and time fixed effects for both groups, as well as a model for the full sample including an interaction variable between the *logGDP* and the *OSI*. Results for the estimated marginal effects are reported in Table 7. The variable *pressfree* was not included because it decreases the number of observations and it was never statistically significant.

<Table 7>

[22] Although the World Bank classifies countries in four income groups (Low Income, Lower Middle Income Upper Middle Income, and High Income), we have split the sample in just two groups because there is a significant difference between high-income countries and the remaining ones in terms of corruption outcomes. Differences in corruption levels are much smaller among the remaining income groups.

As can be seen from columns 1 and 2 of Table 7, the *OSI* is only marginally statistically significant in the sub-sample of countries that are classified as high-income countries by the World Bank, but it is highly statistically significant in the sample with the remaining countries. Column 3, that presents the results for the full sample of a regression including an interaction term between the *OSI* and the *logGDP*, reveals that the estimated coefficient for the interaction terms is positive and statistically significant. To further analyse how the effect of e-government on corruption varies according to levels of GDP per capita, Figure 1 shows the average marginal effects of *l.OSI* on the conditional mean of the *CCI*. The figure indicates that for levels of GDP per capita below around 9,897 USD (logGDP = 9.2), e-government can be used to mitigate corruption, but above this level, the effect is no longer statistically significant.

<Figure 1>

Press freedom is also likely to influence the ability of e-government to reduce corruption by magnifying scandals in case of wrong-doing by public servants. To test this hypothesis, we estimated the average marginal effects of e-government on the conditional mean of the corruption levels for different levels of the variable *pressfree*. Results presented in Figure 2 reveal that only for the extreme values of *pressfree*, below 0.4 and above 0.9, e-government does not reduce corruption. If we consider that values of *pressfree* below 0.4 correspond to the lowest 5% values of the distribution and above 0.9 to the highest 10%, the former result is not surprising. In countries where media freedom is extremely low, investments in e-government without other complementary measures is not likely to have a significant impact on reducing corruption. Furthermore, in nations where media freedom is extremely high, e-government may not influence corruption, most likely because corruption levels are already very low.

<Figure 2>

The effects of e-government at different levels of corruption

To further explore the relationship between progress in e-government and corruption levels, we have estimated quantile regressions, which allow for an analysis of the relationship between the CCI and the OSI along with the conditional distribution of the CCI. Table 8 presents the estimation results for quantile regressions with fixed effects, using the approach proposed by Machado and Santos Silva (2019). As our panel has a relatively high ratio of countries over time periods, we have used the Jacknife bias correction of Dhaene and Jochmans (2015).[23] Results are reported for quantiles 0.25, 0.50 and 0.75. The *OSI's* coefficient is statistically significant for the quantiles 0.5 and 0.75 of the *CCI* conditional distribution, where typically non-high-income countries are located,[24] but not for the quantile 0.25. When exploring in higher detail the regions of the *CCI*'s conditional distribution in which the *OSI*'s coefficient is statistically significant, we have found that it is statistically significant, approximately, from quantile 0.3 to quantile 0.8.[25] This reveals that online government solutions are less effective in reducing corruption in the extremes of the distribution, that is, when corruption levels are very high or very low. In more corrupt countries, investments in e-government alone may not be enough to mitigate the problem, unless they are accompanied by other initiatives to fight corruption, namely policies aimed at strengthening institutions, increasing the digital literacy of the population, and improving ICT infrastructures. On the other extreme, in less corrupt countries, additional progress in the corruption levels is hard to attain and, typically, these countries

[23] As a rule of thumb, Machado and Silva (2019) advise implementing this correction whenever the ratio between the number of individuals and the number of time periods is greater than 10.

[24] There is a positive correlation between corruption and income levels.

[25] A p-value of 0.092 is found for q=0.3 and a p-value of 0.099 is found for q=0.8.

already have sophisticated e-government systems where it is difficult to make significant improvements.

<Table 8>

As mentioned earlier, the Dhaene and Jochmans (2015) jacknife bias correction was used in the estimations presented in Table 8. Nevertheless, as a robustness test, we also estimated the same regressions without this correction, obtaining very similar results. An additional robustness test was to include the freedom of the press (*pressfree*) as an independent variable.[26] The OSI variable remained statistically significant for the quantiles 0.5 and 0.75 and non-statistically significant for the quantile 0.25. The absolute value of the magnitude of the coefficients in quantiles 0.5 and 0.75 increased, both when applying and not applying the jacknife bias correction.

6. Conclusions

Corruption is a global and major problem that reduces trust in government and imposes severe negative consequences on society. Countries with lower corruption levels use their resources more efficiently, attract more investment and grow faster. Therefore, the design of successful anti-corruption policies is a major challenge across the world. This requires a concerted action by the various groups in society (the government, the private sector, citizens, and civil society organizations) and an interdisciplinary approach that takes advantage of the latest technological progress. E-government tools may be used to obtain, scrutinize, and share data to prevent, detect, and restrain corrupt behaviour.

[26] This variable is only included as a robustness test because it is only available from 2003 onwards, leading to a loss of observations in the regressions.

Using longitudinal data for more than 170 countries and data from 2002 to 2017, this paper analyses if electronic government tools can be used to deter corruption. Empirical results strongly support the hypothesis that e-government reduces corruption levels. This result is robust to several econometric techniques, as well as to different proxies of corruption and e-government. Since corruption comes in different forms and is difficult to measure, we use four alternative proxies of corruption proposed by major international organizations. Corruption can be tackled in different ways, so we examine which e-government domains are more successful in reducing it. Using data for E.U. countries, there is evidence that a higher percentage of e-government users, more digital public services for business and a higher degree of online service completion reduces corruption. This conclusion is preliminary, as this data on e-government is still scarce. However, as more years of data are released, this question deserves further investigation as it is critical to the definition of e-government strategies capable of confronting corruption.

Previous studies on the relationship between e-government and corruption (Andersen, 2009; Elbahnasawy, 2014; Zhao and Xu, 2015) mainly focused on average effects. A contribution of this paper is to analyse if the capacity of e-government to restrain corruption is different at different levels of GDP, freedom of the press and corruption. The results indicate that the potential of e-government as an anti-corruption tool is larger in countries that are not high-income countries, that are not in the extremes of the freedom of the press variable and in those situated in quantiles 0.3 to 0.8 of the corruption distribution. In countries with very low levels of corruption, achieving further progress is difficult and these countries typically already have sophisticated e-government systems. On the other extreme, in countries where corruption is very high, innovative technologies to strengthen public sector performance and confront corruption have a lower likelihood of effectiveness probably because most of these countries also have low educational levels of the population, lack of appropriate infrastructures and weak institutions. In sum, our results suggest that although e-government alone may not be enough

to curb corruption, when properly integrated in a correct strategy, it can be used to successfully address corruption and help to foster greater trust and accountability in government.

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Table 1 - Correlation between the four corruption indexes (year: 2016)

	CCI	CPI	IC_ICRG	PSCI
CCI	1			
CPI	0.993	1		
IC_ICRG	0.967	0.965	1	
PSCI	0.875	0.865	0.821	1

Table 2 - Descriptive statistics (2002-2016)

Variable		Mean	sd	Obs
EGDI	overall	0.431	0.218	N=1536
	between		0.203	n=194
	within		0.079	
OSI	overall	0.351	0.254	N=1536
	between		0.226	n=194
	within		0.116	
E-Part	overall	0.239	0.260	N=1536
	between		0.204	n=194
	within		0.163	
e-government Users	overall	0.603	0.193	N=78
	between		0.186	n=27
	within		0.055	
Pre-Filled Forms	overall	0.475	0.268	N=84
	between		0.266	n=28
	within		0.052	
Online Service Completion	overall	0.760	0.156	N=84
	between		0.152	n=28
	within		0.043	
Digital Public Services for Business	overall	0.716	0.162	N=84
	between		0.154	n=28
	within		0.056	
CCI	overall	0.500	0.200	N=3114
	between		0.197	n=212
	within		0.036	
CPI*	overall	0.429	0.198	N=872
	between		0.196	n=180
	within		0.019	
IC_ICRG	overall	0.568	0.195	N=2081
	between		0.186	n=139
	within		0.060	
PSCI	overall	0.509	0.302	N=2493
	between		0.297	n=168
	within		0.060	
logGDP	overall	8.598	1.528	N=2963
	between		1.544	n=201
	within		0.145	
openness	overall	94.033	59.676	N=2830
	between		55.058	n=197
	within		22.468	
fdi	overall	6.33	23.466	N=2834
	between		43.354	N=193
	within		14.443	
urban	overall	55.541	23.567	N=2863
	between		23.581	n=193
	within		2.034	
easestartbus	overall	0.724	0.191	N=2322
	between		0.164	n=189
	within		0.099	
broadband	overall	8.945	11.601	N=2658
	between		9.955	n=204
	within		5.926	
political_rights	overall	0.522	0.306	N=2887
	between		0.299	n=194

	within		0.073	
pressfree	overall	0.726	0.162	N=2396
	between		0.145	n= 178
	within		0.071	
catholic	overall	0.286	0.312	N=2866
	between		0.311	n=192
	within		0.031	
islam	overall	0.241	0.357	N=2866
	between		0.357	n=192
	within		0.0197	
protestant	overall	0.147	0.204	N=2866
	between		0.202	n= 192
	within		0.0292	

Note: * As from 2012 onwards the CPI is not comparable with the previous years (Gründler and Potrafke, 2019), the data for *CPI* spans from 2012 to 2016.

Table 3 – Cross-section results (year: 2016)

	(1)	(2)	(3)	(4)	(5)	(6)
	FracP	FracP	FracP	FracP	2SLS	2SLS
l.osi	-0.132**	-0.150***	-0.236***		-0.779***	-0.380***
	(0.055)	(0.052)	(0.053)		(0.247)	(0.074)
L3.osi				-0.243***		
				(0.057)		
l.logGDP	-0.069***	-0.068***	-0.059***	-0.051***	-0.009	-0.046***
	(0.010)	(0.009)	(0.009)	(0.011)	(0.025)	(0.010)
l.openness	-0.037*	-0.044**	-0.039**	-0.041**	-0.085***	-0.050***
	(0.020)	(0.019)	(0.019)	(0.019)	(0.024)	(0.014)
l.political_rights	-0.222***	-0.207***	-0.056	-0.079*	0.054	-0.033
	(0.035)	(0.038)	(0.043)	(0.042)	(0.084)	(0.047)
l.easestartbus	-0.073	-0.044	-0.038	-0.033	0.190	0.019
	(0.074)	(0.070)	(0.060)	(0.061)	(0.119)	(0.060)
l.Catholics		0.070**	0.056*	0.043	0.043	0.051
		(0.035)	(0.034)	(0.034)	(0.048)	(0.035)
l.Islamic		0.031	0.030	0.028	-0.006	0.024
		(0.031)	(0.031)	(0.031)	(0.049)	(0.032)
l.Protestants		-0.141**	-0.130**	-0.120*	-0.163**	-0.121**
		(0.060)	(0.062)	(0.063)	(0.071)	(0.051)
l.pressfree			-0.616***	-0.522***	-0.973***	-0.720***
			(0.168)	(0.156)	(0.258)	(0.166)
# Countries	171	169	156	157	153	156
R2 (or Pseudo R2)	0.0833	0.0862	0.0949	0.0948	0.624	0.776
Log-pseudo likelihood	-108.7	-107	-97.85	-98.47		
Instruments					broadband urban	l3.osi l5.osi
Under identification test					16.121	41.256
Weak identificat. test F					7.402	99.109
Hansen test (p-value)					0.388	0.947

Notes: All models were estimated with dummies for continents and robust standard errors.

Standard errors in parentheses. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 4 – Alternative measures of corruption: cross-section (2016), marginal effects

Dependent variable:	(1) CCI	(2) CPI	(3) IC_ICRG	(4) PSCI
OSI	-0.236*** (0.053)	-0.175*** (0.047)	-0.217*** (0.054)	-0.147* (0.089)
# Countries	156	149	126	147
Pseudo R2	0.0949	0.0907	0.0925	0.203
Log-pseudo likelihood	-97.85	-92.91	-78.96	-80.93

Notes: All models were estimated by fractional probit with robust standard errors and with the same set of independent variables as the model of column 3 in Table 3. Standard errors in parenthesis. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 5 – Panel Data Estimation Results

	(1)	(2)	(3)	(4)	(5)
l.osi	-0.024**	-0.030*			
	(0.010)	(0.016)			
l3.osi			-0.033***		
			(0.009)		
l.EGDI				-0.041**	
				(0.018)	
l.EPart					-0.007
					(0.007)
l.logGDP	-0.057***	-0.071***	-0.071***	-0.057***	-0.058***
	(0.010)	(0.012)	(0.011)	(0.010)	(0.010)
l.openness	-0.008	0.001	-0.009	-0.000	-0.000
	(0.006)	(0.007)	(0.007)	(0.000)	(0.000)
l.political_rights	-0.090***	-0.083***	-0.081***	-0.089***	-0.091***
	(0.013)	(0.014)	(0.013)	(0.012)	(0.013)
l.pressfree		-0.024			
		(0.016)			
# Observations	1,386	1,092	1,217	1,386	1,386
# Countries	179	164	179	179	179
R2 (or Pseudo R2)	0.121	0.127	0.122	0.121	0.121
Log-pseudo likelihood	-843.9	-660.3	-740.4	-843.9	-843.9

Notes: All models were estimated by Fractional Probit, with the year and country dummy variables and robust standard errors. Standard errors in parenthesis. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 6 – EU Digital Public Services indicators of e-government

Variables	(1) e-government users	(2) Pre-filled forms	(3) Online serv. completion	(4) Digital pub. serv. for business
l.e-gov indicator	-0.192***	-0.075	-0.176*	-0.190**
	(0.049)	(0.061)	(0.094)	(0.088)
l.logGDP	-0.170***	-0.160***	-0.143***	-0.145***
	(0.024)	(0.029)	(0.024)	(0.024)
l.openness	0.013	0.015	0.012	0.017
	(0.016)	(0.018)	(0.017)	(0.018)
l.political_rights	-0.011	0.311	0.381	0.392
	(0.176)	(0.249)	(0.246)	(0.242)
l.pressfree	-0.769**	-1.220***	-1.351***	-1.291***
	(0.346)	(0.457)	(0.416)	(0.433)
# Observations	78	84	84	84
# Countries	26	28	28	28
Pseudo R2	0.089	0.080	0.081	0.081
Log-pseudo likelihood	-42.85	-47.16	-47.11	-47.10

Notes: The dependent variable is *CCI*. All models were estimated by the Fractional Probit with dummies for years and standard errors clustered by country. Standard errors in parentheses. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 7 – High-income versus non-high-income countries

	(1) High income	(2) Non-high-income	(3) Full sample
l.OSI	-0.030*	-0.032***	-0.031**
	(0.016)	(0.012)	(0.010)
l.logGDP	-0.039*	-0.044***	-0.052***
	(0.022)	(0.012)	(0.010)
l.openness	-0.035***	-0.005	-0.009
	(0.012)	(0.007)	(0.006)
l.political_rights	-0.127**	-0.091***	-0.088***
	(0.055)	(0.014)	(0.012)
l.OSI*logGDP			[0.040]**
			(0.019)
Observations	355	1,031	1,386
Countries	56	144	179
Pseudo R2	0.121	0.0474	0.121
Log-pseudo likelihood	-179.3	-664.4	-843.9

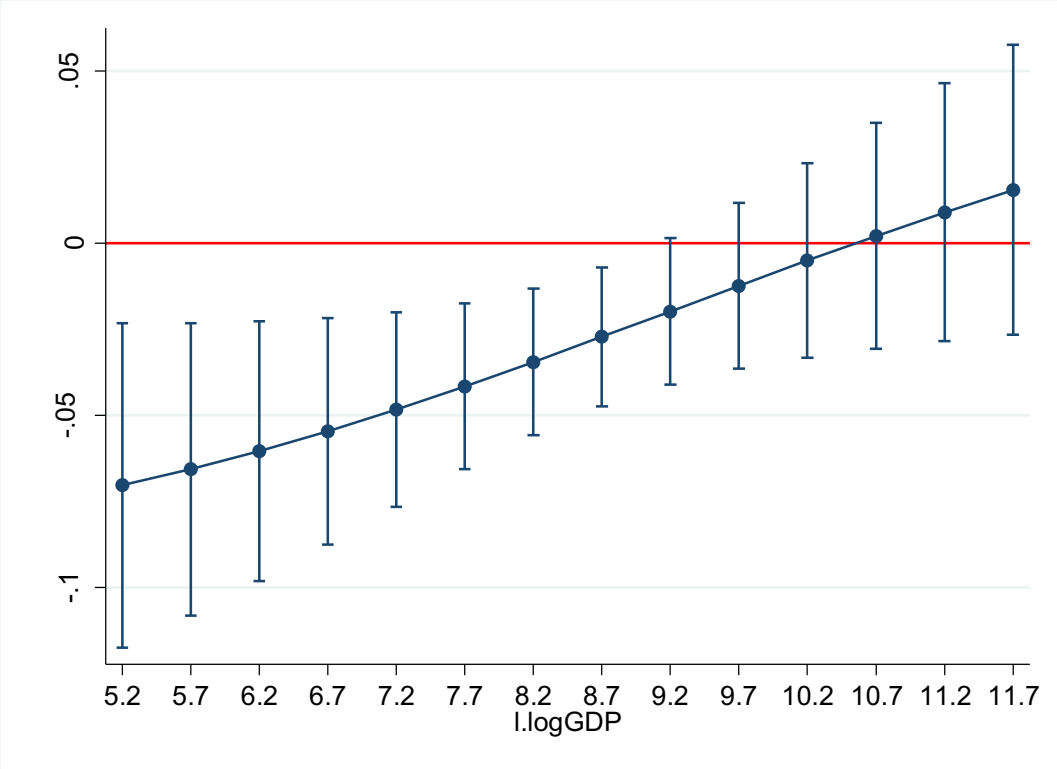
Notes: The dependent variables is CCI. All models were estimated with country and year fixed effects and robust standard errors. Standard errors in parenthesis. Fractional probit estimation coefficient in brackets. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 8 – Estimation results for Quantile regressions

	q=0.25	*q=0.5*	*q=0.75*
	(1)	(2)	(3)
l.OSI	-0.023	-0.026**	-0.029*
	(0.014)	(0.011)	(0.015)
l.logGDP	-0.064***	-0.057***	-0.051***
	(0.014)	(0.011)	(0.015)
l.openness	-0.001	-0.005	-0.010
	(0.009)	(0.007)	(0.009)
l.political_rights	-0.101***	-0.095***	-0.089***
	(0.018)	(0.014)	(0.020)

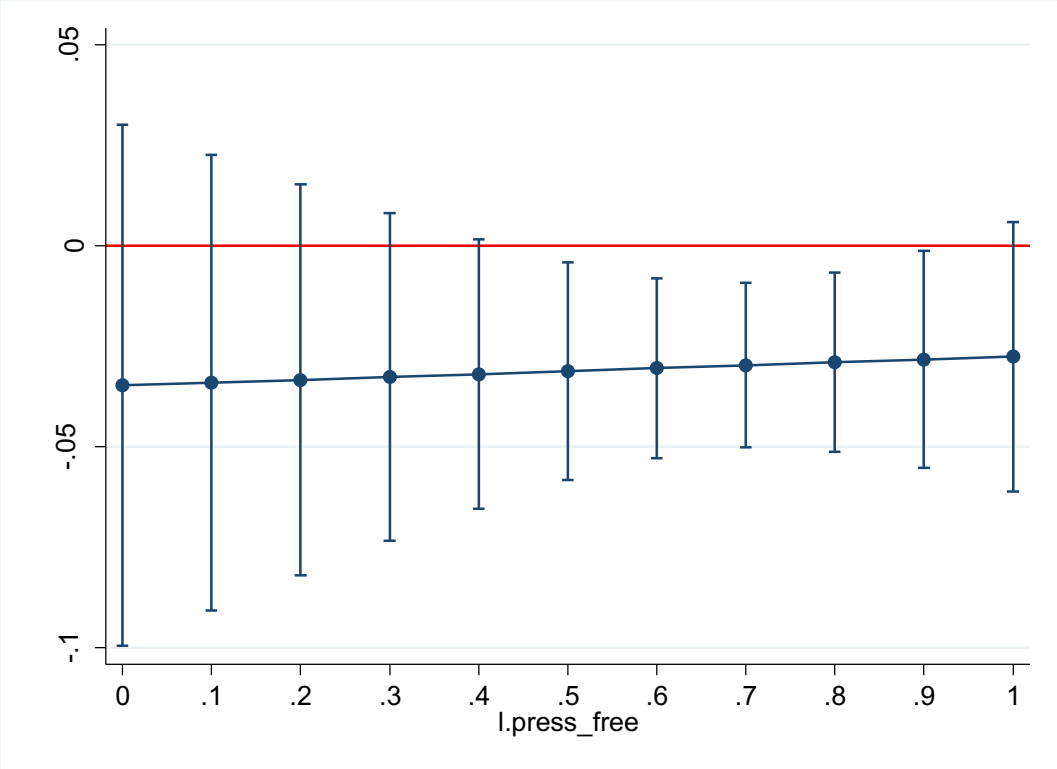
Notes: All models were estimated with country fixed effects, year dummies and robust standard errors. Quantile regressions with 1312 observations. Standard errors in parenthesis. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1.

Figure 1 - Average marginal effects of l.OSI for different levels of GDP



Note: 95% confidence interval.

Figure 2 - Average marginal effects of e-gov on different levels press freedom



Note: 95% confidence interval.

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