

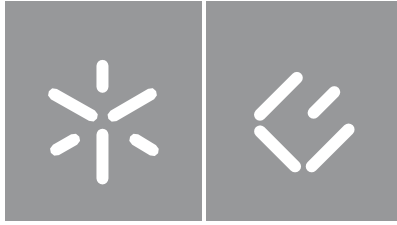
**Universidade do Minho**  
Escola de Economia e Gestão

João Martins | **Essays on the Socioeconomic Impacts of Digital Government**

João Luís Oliveira Martins

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Digital Government**





**Universidade do Minho**  
Escola de Economia e Gestão

João Luís Oliveira Martins

**Essays on the Socioeconomic Impacts of Digital  
Government**

Tese de Doutoramento  
Doutoramento em  
Economia

Trabalho efetuado sob a orientação de  
**Professora Linda Gonçalves Veiga**  
**Professor Miguel Portela**

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## **Statement of Integrity**

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## Resumo

A digitalização tem, ao longo das últimas décadas, trazido inúmeras alterações à atividade e atuação do setor público e à forma como os cidadãos interagem com o mesmo. Esta tese analisa alguns dos mais relevantes aspetos e impactos da digitalização do setor público. É composta por quatro ensaios independentes, cada um correspondente a um capítulo. O primeiro ensaio analisa empiricamente a contribuição do governo digital na redução dos encargos administrativos e regulatórios. Usa dados relativos a 169 países e ao período 2004-2018. Os resultados sugerem que o governo digital contribui para um melhor ambiente de negócios em várias áreas de regulação. Também sugerem que a eficácia da governação tem uma importante contribuição para a melhoria do ambiente de negócios. O segundo ensaio estuda o impacto do governo digital na corrupção, com base em dados relativos a 170 países e ao período 2002-2020. São analisadas as áreas da governação digital que afetam a corrupção, os tipos de corrupção que são mais afetados pelo governo digital e os contextos nos quais o governo digital é mais eficaz no combate à corrupção. A conclusão online dos serviços e a participação eletrónica são duas dimensões importantes para reduzir a corrupção, e o potencial do governo digital para este fim é maior em países com níveis de corrupção moderados ou altos e com um nível de desenvolvimento económico mais baixo. O terceiro ensaio foca-se na exclusão digital. Diferenças no uso da internet e dos serviços públicos online são o enfoque deste ensaio, que utiliza uma amostra de 21546 indivíduos de 5224 agregados familiares. Os resultados indicam que o nível de educação, a situação no mercado de trabalho, a nacionalidade, a idade e o papel no agregado familiar influenciam a probabilidade de um indivíduo utilizar quer a internet quer os serviços públicos digitais. O género apenas revela ser relevante no caso do uso da internet. As diferenças entre géneros na utilização dos serviços públicos online são explicadas por outras características individuais. O quarto ensaio analisa a execução dos contratos públicos, nomeadamente a existência de derrapagens orçamentais e de atrasos na execução. São utilizados dados da plataforma base.gov, o portal da contratação pública português. A incumbência dos fornecedores, a competição na atribuição dos contratos, os preços contratuais, o tipo de contrato e de adjudicatário afetam as derrapagens orçamentais e/ou os atrasos na execução. Contudo, para algumas destas variáveis, o efeito depende de o contrato ter sido atribuído por ajuste direto ou via concurso público.

Palavras-chave: contratação pública; corrupção; encargos administrativos; exclusão digital; governo digital.

## **Abstract**

Digitalisation has changed how the public sector operates and citizens' interactions with the government over the last few decades. This thesis analyses some of government digitalisation's main socioeconomic impacts and aspects. It comprises four independent essays, each corresponding to a chapter. The first essay empirically examines the contribution of digital government to administrative and regulatory burden reduction. It uses data covering 169 countries from 2004 to 2018. The results suggest that digital government facilitates business, creating a more business-friendly environment in several areas of business regulations. They also indicate that governance effectiveness plays a significant role for the same purpose. The second essay studies the impact of digital government on corruption, using data from more than 170 countries, covering the period 2002-2020. It also analyses which digital government domains affect corruption, which types of corruption are more affected by digital government and the circumstances under which digital government is more effective in reducing corruption. The results suggest that digital government deters corrupt activities. Online service completion and electronic participation are two important features for curbing corruption. The potential of digital government to deter corruption is also shown to be higher in countries where corruption is moderate or high and economic development is lower. The third essay focuses on one of the main challenges that digitalisation brings to societies: digital divides. The divides in the use of the Internet and online governmental services are the focus of this essay. The analysis uses a sample of 21,546 individuals and 5,224 households. It finds that education, employment status, nationality, role in the household or age influence the likelihood of using both the Internet and online governmental services. It also finds that gender is only a relevant explanatory variable in the internet use case. A gender divide exists in online governmental services use, but differences in other individual characteristics explain it. The fourth essay analyses execution outcomes in public procurement, namely cost overruns and delays. It uses data from base.gov, the Portuguese online portal for public procurement. Vendor incumbency, competition in the bidding process, contract prices, type of contract and contractor are revealed to affect cost overruns and/or delays in the execution of contracts. For some of the variables studied, the effects might depend on the contract being awarded directly or through a public tender.

Keywords: administrative burden; corruption; digital divides; digital government; public procurement.



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## List of Acronyms

- CCI** Corruption Control Index
- CPI** Corruption Perceptions Index
- DESI** Digital Economy and Society Index
- DTF** Distance to Frontier
- EA** Enumeration Area
- ECI** Executive Corruption Index
- EGDI** Electronic Government Development Index
- E-Gov** Electronic Government
- E-Part** Electronic Participation
- EPI** Electronic Participation Index
- EU** European Union
- ExecBCE** Executive Bribery and Corrupt Exchanges
- ExecET** Executive Embezzlement and Theft
- FDI** Foreign Direct Investment
- GCC** Gulf Cooperation Council
- GDP** Gross Domestic Product
- HCI** Human Capital Index
- ICT** Information and Communication Technologies
- ID** Identity
- IJC** Indicator of Judicial Corruption
- ILC** Indicator of Legislative Corruption
- ITU** International Telecommunication Union
- OECD** Organisation for Economic Cooperation and Development
- OSI** Online Services Index
- PCC** Public Contracts Code
- PCI** Political Corruption Index
- PSCE** Public Sector Corrupt Exchanges
- PSCI** Public Sector Corruption Index

**PST** Public Sector Theft

**RCI** Regime Corruption Index

**SDGs** Sustainable Development Goals

**SME** Small and Medium Enterprises

**TII** Telecommunication Infrastructure Index

**UN** United Nations

**UNDESA** United Nations Department of Economic and Social Affairs

**UNESCO** United Nations Educational, Scientific and Cultural Organization

**UNU-EGOV** United Nations University Operating Unit on Policy-Driven Electronic Governance

**VAT** Value Added Tax

**VIF** Variance Inflated Factors

**WDI** World Bank Development Indicators

**WGI** Worldwide Governance Indicators

# 1. Introduction

Since the 1960s, and particularly over the last few decades, Information and Communication Technology (ICT) solutions have been continuously introduced in government organisations all over the globe. This has changed how governments and public administrations operate internally, leading to new forms of communication, interaction, participation, and service delivery. Things such as digital service delivery, electronic participation tools, and the embedment of artificial intelligence tools as a support to the public sector and public services are already widespread, and the future only promises further innovations and technology development and embedment. Some of the critical motivations for those developments relate to their potential socioeconomic benefits, as the digital transformation of the public sector has been perceived as capable of decreasing bureaucracy, promoting accountability, efficiency and transparency, reducing corruption, and fostering sustainable development (e.g. Bertot *et al.*, 2010; Estevez & Janowski, 2013; Veiga *et al.*, 2016).

At a political and policy level, different institutions have also pushed for the digital transformation of governments and the development of digital services, intending to achieve some of the benefits mentioned above (e.g., European Commission 2016a), making the proliferation of digital services a global trend (UNDESA, 2022). Therefore, it is relevant for society and policymakers to study the socioeconomic impacts of digital government<sup>1</sup> to understand better the potential benefits and the challenges it brings.

This thesis studies some of the socioeconomic impacts and aspects of the digital transformation of governments. It is organised into four chapters, each corresponding to one paper. Therefore, although a general thematic area is shared across the thesis, each chapter constitutes an independent essay with its introduction, literature review, methodology and results. Thus, this Introduction is kept short as the motivation and relevance of each essay are further addressed in the following chapters. The approach of this thesis is mainly empirical, and both country- and individual-level are used in the analyses throughout the thesis.

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<sup>1</sup> Although it might not be entirely accurate, digital government and electronic government are used as synonyms for convenience and because most of the indicators used in this thesis do not distinguish between both concepts.



The first part of this thesis, comprising Chapter 2 and Chapter 3, focuses on two of the potential socioeconomic benefits of digital government. Chapter 2 analyses the contribution of digital government to reducing administrative and regulatory burdens and improving the business environment. Chapter 3 studies the role of digital government as an anti-corruption tool. These two chapters use country-level longitudinal data for the empirical analysis. In Chapter 4, the focus changes to the digital divide, one of the main challenges that the digital transformation of the public sector exacerbates. For this chapter, individual-level data from the Sultanate of Oman is used. Lastly, Chapter 5 does not study any specific impact of digital government per se but makes use of essential features of the government's presence online, public procurement portals and digitally available records of public contracts, to study contractual outcomes in public procurement, including in procedures that are mandatory to be electronic.

My motivation to research these topics comes from my interest in Public Economics and Applied Economics and my engagement with UNU-EGOV since the early stages of my Ph.D. studies. This institution has allowed me to participate in several research and consultancy projects on different topics revolving around the digital transformation of the public sector over the last six years and to strengthen my knowledge and interest in these themes. Chapter 4, in particular, results from a collaboration with a former UNU-EGOV Government Fellow, Hamed Al-Shekaili, from the Information Technology Authority of Oman, which started during his stay at UNU-EGOV in the second half of 2018. Although my original plan was to perform a similar type of study on a sample of Portuguese individuals, this collaboration allowed me to study a country in which some of the critical challenges associated with digital transformation are more pronounced than in a country like Portugal due to a lesser state of digital government development and differences at the social and cultural levels. The following paragraphs present a brief outline of each of the following chapters.

Chapter 2 studies the role of digital government as a business facilitator. Digital government innovations are seen as critical in the design of policies that promote government efficiency and economic competitiveness by reducing administrative and regulatory burdens (e.g., European Union, 2014; Veiga et al., 2016). The essay presented in Chapter 2 analyses whether digital government development, measured by the Electronic Government Development Index (EGDI), may impact administrative and regulatory burdens, proxied by the Ease of Doing Business indicators. It also studies which areas of business regulations might be more affected by digital government.

The study addresses a gap in the literature, as, to the best of our knowledge, no previous studies have quantitatively analysed the relationship between electronic government and administrative

burden using longitudinal data for many countries. The analysis used data covering 169 countries from 2004 to 2018. The Tobit and Fractional Probit (Papke & Wooldridge, 1996) models, in regressions that include country-level fixed effects, are used in the estimations. The results indicate that digital government may facilitate business in different areas of business regulations. The essay discusses how the results can influence policies and provides examples of concrete policies implemented in the past.

Chapter 3 studies how electronic government can act as an anti-corruption tool. Increasing accountability and transparency and decreasing corruption are essential motivations for adopting digital government technologies. Therefore, this essay empirically studies the relationship between digital government and corruption. It analyses which e-government domains affect corruption, which types of corruption are more affected by e-government and the circumstances under which e-government is more effective in reducing corruption. Several different measures of corruption and electronic government are used in this study. This provides a valuable contribution to the literature because previous studies have mainly focused on average effects and indicators of general corruption and electronic government development.

The study starts by overviewing the relationship between electronic government and corruption from a theoretical standpoint, based on the economics of crime, agency theory, and transaction cost economics perspectives. It then uses longitudinal country-level data, comprising more than 170 countries from 2002 to 2020, to perform the empirical analysis. The Fractional Probit (Papke & Wooldridge, 1996) is once again used as one of the main models to estimate the regression, as it is appropriate to deal with censored dependent variables. However, when analysing under which conditions electronic government might be more powerful in reducing corruption, this study uses the approach of Machado and Santos Silva (2019) for quantile regressions with fixed effects. Several robustness tests were conducted, including test methods of Oster (2019) and Diegert *et al.* (2023) for regression sensitivity and the Canay (2011) approach for the quantile regressions with fixed effects.

Chapter 4 studies internet and online governmental services use divides. Contrarily to the previous two chapters, this essay uses individual-level data instead of country-level data and is focused on a challenge of digital transformation instead of a potential benefit. It analyses, based on survey data covering 21,546 individuals and 5,224 households from the Sultanate of Oman, which individual characteristics explain the likelihood of an individual using the internet and online governmental services. It also addresses the main self-reported reasons for not using the internet.

As mentioned above, this dataset represented a unique opportunity to study digital divides in a society where digital transformation is not as well consolidated and where the traditional roles of men

and women are more pronouncedly different compared to most Western societies. Those gender differences are explored in this study. Given the data dependencies present in the data, resulting from the sampling strategy of including multiple individuals from the same household, the empirical analysis was conducted using multilevel probit models. The determinants of internet and digital government use are discussed at the end of the chapter.

Chapter 5 studies contract execution outcomes in Portuguese public procurement. Although this essay is not directly focused on a socioeconomic aspect of digital government, it constitutes an example of how digital government development, in this case through data portals, can foster transparency and provide essential resources for research. The analysis uses a database retrieved from the Portuguese procurement portal, *base.gov*, and explores how procedural, contractual, contractor and vendor characteristics affect the likelihood and the magnitude of cost overruns and delays in contract execution.

One of the challenges faced in this analysis was that the two dependent variables being studied had skewed distributions with a very high proportion of zeros. Therefore, as Boulton & Williford (2018) suggested, two-part models are used. The first-part model explains the likelihood of cost overruns or delays, using dummy variables as dependent variables and logit estimations. The second-part model uses only the nonzero values of the distribution of the dependent variable and explains the magnitude of cost overruns or delays. Vendor incumbency, contractual prices, competition in the bidding process and the type of contract and contractor are used as explanatory variables. The study also explores the differences between the two main types of awarding procedures, direct awarding and public tender, regarding contractual execution.

Lastly, Chapter 6 summarises the results of the four essays, overviews the policy recommendations and addresses directions for future research.

## 2. Digital Government as a Business Facilitator<sup>2</sup>

### 2.1. Introduction

Administrative and regulatory burden reduction is seen as a priority to improve governmental efficiency and economic competitiveness. In a world increasingly based on the electronic exchange of information, information and communication technologies (ICT) are key tools in designing policies to achieve efficiency and competitiveness. ICT-based solutions may reduce time, search and coordination costs associated with traditional bureaucratic procedures, to citizens, firms, and the government, and using digital technologies as an integrated part of governments' modernization strategies can unlock additional economic and social benefits for the society (European Commission, 2016a).

Innovative electronic service delivery has long been pointed out as a driver of the public sector's modernization (e.g. Lenk, 2002; OECD, 2004; Torres *et al.*, 2005). At the policy level, the European Commission has encouraged EU Member States to adopt digital government innovations (e.g. electronic ID, interoperability, e-certification), aiming at public administration modernization, the achievement of an internal digital market, and the engagement of more citizens and businesses to improve the quality of the services (European Commission, 2016a). Not only in the EU but all over the world, there is a global trend towards higher levels of electronic government (e-gov) that is transforming the way the public sector works (UNDESA, 2016). These developments may improve the efficiency and effectiveness of public service delivery and reduce corruption and the scope of the informal economy (Elbahnasawy, 2014; Elbahnasawy, 2021; Martins *et al.*, 2021). Consequently, e-gov can play a role in the achievement of sustainable development.<sup>3</sup>

Since 2003, the Doing Business project, from the World Bank, has been publishing annual quantitative data on the main regulatory and administrative constraints affecting domestic small and medium-size enterprises throughout their life cycle. Significant efforts have also been made to measure

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<sup>2</sup> This chapter is co-authored with Linda Veiga and was published in *Information Economics and Policy* as Martins, J., & Veiga, L. G. (2022). Digital government as a business facilitator. *Information Economics and Policy*, 60, 100990.

<sup>3</sup> See Estevez and Janowski (2013) for a conceptual framework and a literature review on the relationship between e-gov and sustainable development.

progress in electronic government (e-gov). In this paper, we use the United Nations' E-Government Survey, which makes available a biannual evaluation of national online services, telecommunication infrastructure, and human capital in 193 countries. The relationship between e-gov and the ease of doing business is a topic that, so far, has received very little attention in the literature. This paper tries to fill this gap, by empirically analysing the relationship between these two concepts. Several other possible determinants of the size of regulatory burdens are also considered. The analysis is performed on a panel dataset, covering 169 countries from 2004 to 2018. The results show that e-gov developments can facilitate business in several dimensions.

The remainder of the paper is structured as follows. Section 2.2. presents the literature review. Section 2.3. describes the data while section 2.4. presents a descriptive analysis. Section 2.5. explains the econometric methodology. Section 2.6. reveals and discusses the empirical results, as well as the robustness tests that were implemented. Finally, section 2.7. concludes.

## **2.2. Literature Review**

The administrative and regulatory burdens' impact on economic outcomes has been the focus of research in several studies, over the last decades. Since Djankov *et al* (2002) presented a measurement methodology on the regulatory burdens of start-up firms, and the subsequent launch of the World Bank's Doing Business indicators, several studies analyzed the economic effects of regulatory burdens through them. Their results show that administrative burdens and other areas of business regulations may impact economic aspects such as firm creation, registration, and entry (Klapper & Love, 2011; Dreher & Gassebner, 2013; Braunerhjelm & Eklund, 2014; Canare, 2018), the attraction of foreign direct investment (Morris & Aziz, 2011; Corcoran & Gillanders, 2015; Nketiah-Amponsah & Sarpong, 2020), export performance (Portugal-Perez & Wilson, 2010), differences in income and productivity (Boedo & Mukoyama, 2012) and economic growth (Djankov *et al*, 2006; Barseghyan, 2008; Haidar, 2009). The Doing Business indicators are important not only for their utility for empirical research but also due to their effect on governmental policies. As shown by Doshi *et al*. (2019), they shape investors' perceptions and make governments respond by making reforms targeted to improve their rankings.

The relationship between administrative and regulatory burdens and economic outcomes has also been analysed through theoretical models and the evaluation of administrative reforms. Fonseca *et al*. (2001) explained theoretically the relationship between start-up costs and entrepreneurship, while

Poschke (2010) used a dynamic stochastic model of heterogeneous firms with technology choice, concluding that entry costs can explain nearly one-third of the observed aggregate productivity differences. Monteiro & Assunção (2012) analyzed the impact of a program for bureaucratic simplification and tax reduction on formality among Brazilian microenterprises. The program reduced the tax burden and the red tape involved in tax payments, therefore contributing to bypassing cumbersome procedures that increase the costs of being formal. Exploring changes in the Trade and Crafts Code in the sequence of the German unification, Prantl (2012) showed that more burdensome entry regulations reduce entry in self-employment and restrain long-living entrants. Additionally, Branstetter *et al.* (2014) analyzed the effects of an entry deregulation reform implemented in Portugal, in 2005, on firm and employment creation, obtaining conclusions that were favorable to the reform.

Studies on large panels of countries also concluded that high levels of administrative and regulatory burdens harm the economy. Working on a panel of 85 countries, Djankov *et al.* (2002) showed that stricter entry regulation is associated with higher levels of corruption and the size of the unofficial economy. Auriol & Walters (2005), studying 64 countries, presented evidence that higher fixed costs of entry into the formal economy may increase the size of the shadow economy. Klapper *et al.* (2006) measured the impact of costly regulations on new firm creation in Europe. Focusing on OECD countries, Alesina *et al.* (2005) concluded that product market regulatory reform is good for investment. Analyzing a panel of 54 countries, Levie & Autio (2011) demonstrated that a lighter burden of regulation is associated with a higher rate of entrepreneurial entry. Finally, using a dataset that covers 34 source countries and 152 host countries, Daude & Stein (2007) concluded that excessive regulatory burden is a major deterrent to FDI.

Administrative and regulatory simplification has been an important part of the European and OECD countries' agenda for more than a decade (OECD, 2004; Wegrich, 2009). Both the academic literature and policy guidelines by international organizations suggest that there is a great potential for innovations associated with e-gov to reduce the administrative and regulatory burdens, the informal economy, increase tax compliance, and reduce corruption (Bertot *et al.*, 2010; Luna-Reyes & Gil-Garcia, 2014; Elbahnasawy, 2014; Elbahnasawy, 2021; Martins *et al.*, 2021)<sup>4</sup>. Several measures

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<sup>4</sup> The e-gov concept has been evolving over time. Fang (2002: 1) defined e-gov as "a way for governments to use the most innovative information and communication technologies, particularly web-based Internet applications, to provide citizens and businesses with more convenient access to government information and services, to improve the quality of the services and to provide greater opportunities to participate in democratic institutions and processes." According to West (2004: 16) "e-government refers to the delivery of government information and services online through the Internet or other digital means." More recently, Janowski (2015) considered the digital government concept an evolution-like process, which evolved towards more

aimed at cutting the red tape, which include ICT, have been implemented over the last decade. Reports, e.g. EU (2014) and HLGAB (2014), described measures aiming at regulatory burden reduction that mostly rely on e-gov and ICT solutions and, to foster further reforms, the European Commission (EU, 2016) launched the EU eGovernment action plan 2016-2020, aiming at public administration modernization, the achievement of a digital internal market, and the engagement of more citizens and businesses to improve the quality of the services.

Governments are facing several new trends, which are unprecedented in their potential impacts and e-gov research could be instrumental in studying those impacts (School, 2012). However, empirical studies focusing on the determinants of the administrative and regulatory burdens and the effects of e-gov innovations on businesses are rare (Nielsen *et al.*, 2017). As far as we know Arendsen *et al.* (2014) is the only exception, but the analysis focuses on a specific case (the Netherlands). Even though during the last decade and a half, several indices were constructed to measure e-gov development across countries, studies that empirically analyze the relationship between electronic government development and the ease of doing business remain a gap in the literature. Additionally, to the best of our knowledge, while several studies analyzed the impact of the ease of doing business on different economic outcomes, no empirical study has studied the factors that determine countries' ease of doing business. In this article, we try to contribute to filling these gaps in the literature, by studying the effects of e-gov innovations on several Doing Business indicators, also considering other possible determinants of the administrative and regulatory burdens.

### **2.3. The data**

We use the indicators of the World Bank's Doing Business report as a proxy for administrative and regulatory burdens. These indicators attempt to measure the main regulatory constraints affecting small and medium-sized enterprises in a large panel of countries. The Doing Business reports have been published since 2003, and aggregate information from 11 areas of business regulation - starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts, labour market regulation and resolving insolvency - to develop an overall ease of doing business ranking, and an

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complexity and greater contextualization. Four main stages were identified in the digital government evolution: digitization or technology in government, transformation or electronic government, engagement or electronic governance and contextualization or policy-driven electronic governance.

overall distance-to-frontier (DTF) score.<sup>5</sup> The DTF scores capture the gap of each economy from the best regulatory performance observed across all economies of the Ease of Doing Business sample. The scores are defined on a scale from zero to 100, where zero represents the lowest and 100 the best performance. For example, a score of 80 means that a country is 20 percentage points away from the best regulatory performance of the sample, while a score of 20 means that a country is 80 percentage points away from the best performance. The data collection is made through the examination of laws and regulations, and interactions with local experts. In each business area, indicators such as the number of procedures required, the time and monetary costs involved, as well as other more specific components of each area, are considered.<sup>6</sup> The calculation of each DTF score has two main steps. In the first step, each indicator is rescaled using a linear transformation  $(worst - x) / (worst - best)$ , where  $x$  is the observed value, and *worst* and *best* are the worst and best performances on the sample, respectively. Both the worst and the best regulatory performance are established every five years and remain at that level for the five years regardless of any changes in data in interim years.<sup>7</sup> In the second step, the scores obtained in the first step for the individual indicators are aggregated through simple averaging into one DTF score, first for each area to obtain each area's DTF score and then across all the areas to obtain an Overall DTF.<sup>8</sup>

Our empirical analysis intends to study the determinants of the ease of doing business, attributing special attention to the effect of electronic government. Therefore, the most critical explanatory variable is an e-gov index. Among the indices currently available, we use the United Nations' E-Government Development Index (*EGDI*) due to its reliability, comprehensiveness and coverage, both in terms of years and countries (Purian, 2014). The *EGDI* is based on the biannual E-Government surveys implemented by UNDESA. Currently, these surveys make available a quantitative evaluation of national online services, telecommunication infrastructure, and human capital in 193 countries. The *EGDI* is a weighted average of three normalized indices: The Telecommunications Infrastructure Index (*TI*), based on data provided by the International Telecommunications Union; the Human Capital Index (*HC*), based on data provided by UNESCO; and the Online Service Index (*OS*),

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<sup>5</sup> The first edition of the Ease of Doing Business covered 133 countries and five of the eleven mentioned areas. The analysis was progressively expanded and currently covers around 190 countries and 11 areas. The labour market regulation area, although mentioned in the reports as one of the Doing Business topics, has not been analyzed nor considered for the overall ranking and the distance-to-frontier calculation since 2011.

<sup>6</sup> A full list of the indicators can be found through the link <http://www.doingbusiness.org/data>.

<sup>7</sup> If a country's observed value is better than what is being defined as the best performance of the sample, the value of 100 is assigned to that country. There are a few cases where the best performance is set not at the best-observed performance, but at the highest possible level of an index (e.g., the strength of legal rights index) or at the level of a given sample percentile of the overall distribution (e.g., 15<sup>th</sup> percentile for total tax rates).

<sup>8</sup> For additional details regarding the DTF scores and the Ease of Doing Business indicators see World Bank (2017).



based on data collected from an independent survey questionnaire that evaluates the national online presence of the United Nations Member States (UNDESA, 2016). While the *TII* and the *HCI*, attempt to capture the capability of access (the status of the development of telecommunication infrastructure) and the ability to use (human capital) e-gov services, the *OSI* seeks to measure the scope and quality of those services. The *OSI* data is collected through primary research performed by a group of more than 100 researchers under the supervision of UNDESA. Each country's national government website, including the national portal, e-services portal, e-participation portal, and websites of the ministries of education, labour, social services, health finance, and environment, is assessed in the native language. The availability of the e-tools and the easiness of the interaction are both considered. A weight of one-third is given to each of the three indices.<sup>9</sup>

Our analysis also includes data from the World Bank's World Development Indicators and the World Bank's Governance Indicators. We include three other variables in the model that we present in the following section. Controls for each country's economic situation, the share of government expenditures on GDP (*Gov\_Consumption*), and the openness (*Openness*) of the economy<sup>10</sup> were extracted from the World Bank's Development Indicators. The perceived government effectiveness (*Gov\_Effectiveness*) was used as a proxy for the governance and institutional quality of the country and was obtained from the World Bank's Governance indicators. This variable captures perceptions of the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Although more than one governance indicator from the World Bank's database could be used for our analysis (namely the regulatory quality or the rule of law), these indicators are highly correlated. Therefore, we have selected *Gov\_Effectiveness* because it is the indicator with the broadest definition. The data used in the regressions contains a maximum of 169 observations per year covering the years 2004, 2005, 2008, 2010, 2012, 2014, 2016, and 2018.

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<sup>9</sup> For technical details and a list of the variables that are included in the *TII* and the *HCI* see UN (2016).

<sup>10</sup> The log *GDP per capita* was also initially considered but was not included in the specifications due to high values in the variance inflated factors (VIF). However, the inclusion of this variable does not substantially change the results for the *EGDI* coefficients.

## 2.4. Descriptive analysis

Table 1 presents the overall and yearly mean values of the variables included in the empirical analysis. While *Openness* and *Gov\_Consumption* are measured as a percentage of GDP, the remaining variables are indices, measured in scales of standard units that range from zero to 100.<sup>11</sup> As can be seen from Table 1, *Resolving Insolvency* is the Doing Business indicator with the lowest average DTF, meaning that it is the indicator for which the differences between the average country and the leading country are higher. On the opposite side, *Starting a Business* is the Doing Business component with the highest average DTF. Table 1 also reveals the existence of a positive trend in most of the Doing Business variables over time. Regarding the *EGDI* and the *OSI*, a positive trend is also found along time, despite two years where the average value of the two indices dropped. These decreases are probably not due to an e-gov development backlash but rather to methodological changes in the UN's e-gov surveys and sub-indices.

Table 1. Descriptive Statistics for the 2003-2018 period and yearly means for the regression years

<b>Variables:</b>	<b>Mean</b>	<b>Stand. Dev.</b>	<b>Obs.</b>	<b>Mean by Year</b>					
Overall_DTF	60.2	overall=13.0 between=12.9 within=2.9	N=1688 n=190	<b>2004</b>	<b>2010</b>	58.6	<b>2016</b>	59.9	
				<b>2005</b>	<b>2012</b>	60.2	<b>2018</b>	61.3	
				<b>2008</b>	<b>2014</b>	61.3			
StartingBusiness_DTF	72.7	overall=18.6 between=15.4 within=10.4	N=2703 n=190	<b>2004</b>	60.5	<b>2010</b>	72.7	<b>2016</b>	80.3
				<b>2005</b>	62.1	<b>2012</b>	75.1	<b>2018</b>	82.2
				<b>2008</b>	67.2	<b>2014</b>	77.1		
DealConstructPermits_DTF	60.1	overall=18.1 between=16.7 within=8.3	N=2403 n=190	<b>2004</b>	<b>2010</b>	59.5	<b>2016</b>	62.6	
				<b>2005</b>	<b>2012</b>	60.5	<b>2018</b>	63.5	
				<b>2008</b>	56.6	<b>2014</b>	61.7		
GettingElectricity_DTF	67.9	overall=18.7 between=17.9 within=7.2	N=1688 n=190	<b>2004</b>	<b>2010</b>	67.0	<b>2016</b>	64.8	
				<b>2005</b>	<b>2012</b>	68.2	<b>2018</b>	66.7	
				<b>2008</b>	<b>2014</b>	70.4			
RegisterProperty_DTF	61.2	overall=18.8 between=17.8 within=6.5	N=2558 n=190	<b>2004</b>	<b>2010</b>	61.9	<b>2016</b>	60.4	
				<b>2005</b>	57.6	<b>2012</b>	63.7	<b>2018</b>	61.1
				<b>2008</b>	58.9	<b>2014</b>	64.2		
GettingCredit_DTF	48.3	overall=23.8 between=21.9	N=2558 n=190	<b>2004</b>	<b>2010</b>	49.8	<b>2016</b>	46.9	
				<b>2005</b>	41.6	<b>2012</b>	53.3	<b>2018</b>	50.9

<sup>11</sup> The *EGDI*, *OSI* and *Gov\_Effectiveness* variables were originally in different scales but were rescaled from zero to 100 in order to be on the same scale as the doing business indices.

		within=10.5		<b>2008</b>	45.2	<b>2014</b>	55.3	
PayingTaxes_DTF	65.9	overall=19.1	N=2403	<b>2004</b>		<b>2010</b>	64.7	<b>2016</b> 69.7
		between=18.0	n=190	<b>2005</b>		<b>2012</b>	67.0	<b>2018</b> 68.6
		within=7.3		<b>2008</b>	61.9	<b>2014</b>	68.7	
ResolvingInsolvency_DTF	41.0	overall=23.1	N=2703	<b>2004</b>	39.6	<b>2010</b>	40.4	<b>2016</b> 42.8
		between=22.7	n=190	<b>2005</b>	38.7	<b>2012</b>	41.9	<b>2018</b> 44.1
		within=5.2		<b>2008</b>	39.6	<b>2014</b>	41.9	
ProtectMinorInvestors_DTF	49.2	overall=17.6	N=2470	<b>2004</b>		<b>2010</b>	49.2	<b>2016</b> 49.2
		between=16.3	n=190	<b>2005</b>		<b>2012</b>	50.2	<b>2018</b> 50.3
		within=6.7		<b>2008</b>	47.7	<b>2014</b>	51.3	
EnforcingContracts_DTF	55.8	overall=14.0	N=2703	<b>2004</b>	56.9	<b>2010</b>	56.1	54.9
		between=13.5	n=190	<b>2005</b>	56.4	<b>2012</b>	55.9	55.4
		within=3.77		<b>2008</b>	56.1	<b>2014</b>	55.8	
TradeAcrossBorders_DTF	64.9	overall=22.6	N=2403	<b>2004</b>		<b>2010</b>	63.9	<b>2016</b> 69.6
		between=20.3	n=190	<b>2005</b>		<b>2012</b>	65.5	<b>2018</b> 70.2
		within=9.9		<b>2008</b>	61.8	<b>2014</b>	66.5	
EGDI	44.6	overall=22.0	N=1718	<b>2004</b>	38.5	<b>2010</b>	42.1	<b>2016</b> 49.5
		between=20.3	n=194	<b>2005</b>	40.1	<b>2012</b>	49.1	<b>2018</b> 54.9
		within=8.7		<b>2008</b>	42.9	<b>2014</b>	47.4	
OSI	37.7	overall=26.5	N=1718	<b>2004</b>	29.6	<b>2010</b>	28.2	<b>2016</b> 46.5
		between=22.8	n=194	<b>2005</b>	33.7	<b>2012</b>	43.5	<b>2018</b> 56.9
		within=13.6		<b>2008</b>	35.0	<b>2014</b>	39.4	
TII	27.4	overall=24.6	N=1715	<b>2004</b>	17.7	<b>2010</b>	23.7	<b>2016</b> 37.1
		between=21.9	n=194	<b>2005</b>	18.0	<b>2012</b>	32.7	<b>2018</b> 41.5
		within=11.0		<b>2008</b>	21.1	<b>2014</b>	36.8	
HCI	71.2	overall=22.7	N=1699	<b>2004</b>	71.1	<b>2010</b>	79.9	<b>2016</b> 64.6
		between=20.2	n=194	<b>2005</b>	71.4	<b>2012</b>	72.0	<b>2018</b> 66.3
		within=11.2		<b>2008</b>	78.4	<b>2014</b>	66.0	
Gov_Effectiveness	50.0	overall=20.0	N=3327	<b>2004</b>	50.0	<b>2010</b>	50.0	<b>2016</b> 50.0
		between=19.7	n=212	<b>2005</b>	50.0	<b>2012</b>	50.0	<b>2018</b> 50.0
		within=3.6		<b>2008</b>	50.0	<b>2014</b>	50.0	
Gov_Consumption	16.5*	overall=6.9*	N=2558*	<b>2004</b>	16.5	<b>2010</b>	16.7	<b>2016</b> 16.9
		between=6.7	n=183	<b>2005</b>	16.1	<b>2012</b>	16.4	<b>2018</b> 16.1**
		within=2.5		<b>2008</b>	15.9	<b>2014</b>	16.7	
Openness	94.5*	overall=60.0*	N=2814*	<b>2004</b>	91.6	<b>2010</b>	94.2	<b>2016</b> 89.9
		between=55.8	n=197	<b>2005</b>	94.6	<b>2012</b>	98.4	<b>2018</b> 91.6**
		within=22.2		<b>2008</b>	101.8	<b>2014</b>	96.3	

Notes: \*values for the 2003-2017 period; \*\*values for 2017.

Figure 1 shows the correlation between the *Overall\_DTF* and the *EGDI* in 2018. As can be seen from the figure, there is a positive correlation between the two variables, which suggests that e-gov can contribute to a more business-friendly environment. The World Bank Doing Business Group highlights several examples of ICT-based public administration initiatives or reforms that may have had a positive impact, namely: online portals for business licenses; online one-stop shops for business registration; online portals to search for a company name; central collateral registry via online accessible databases; online platforms for public credit information and penalties for institutions that do not provide proper information to these platforms; online systems for banks to share credit information at the private credit bureau; online systems for data exchange between all banks and microfinance institutions and the central bank's credit registry; joint electronic payment of several taxes; online systems for filing and paying VAT and social security contributions; electronic processes to submit and track applications to get electricity; electronic availability connection map to determine new costumers for electricity connection points; electronic verification of prebuilding certificates; electronic processing of applications for building permits; allowance of construction companies to apply for safety certificates online; electronic data interchange systems for customs operations; electronic single-window systems, which reduce the time for border compliance and documentary compliance for both exporting and importing; or improvements in the geographic coverage of online registration.<sup>12</sup>

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<sup>12</sup> Additional details are provided at <http://www.doingbusiness.org/reforms>.

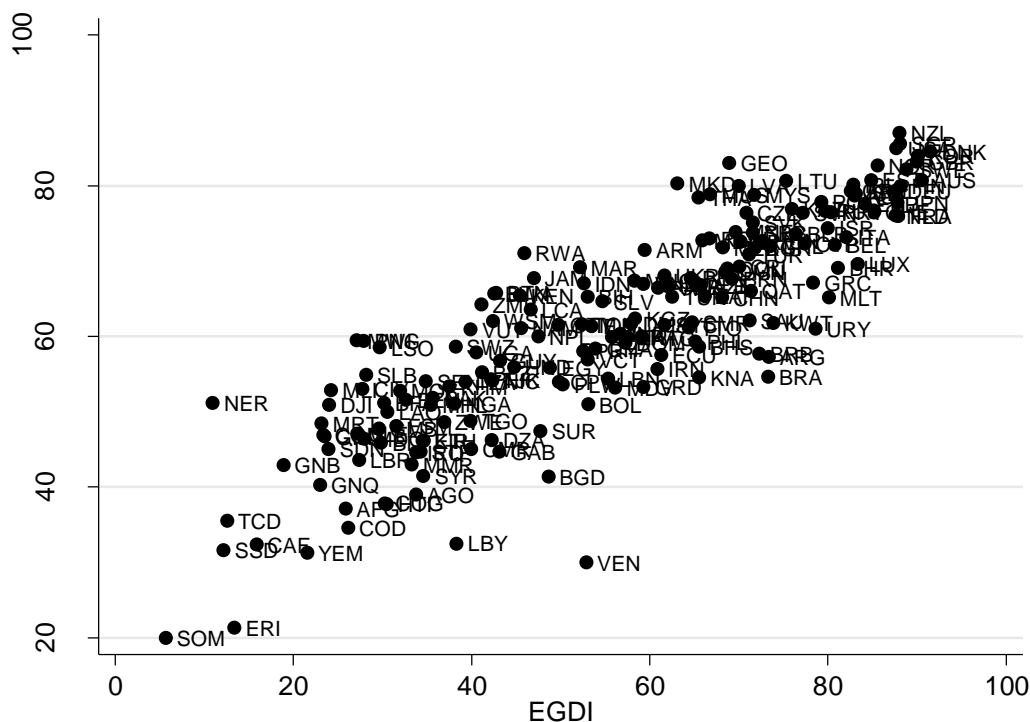


Figure 1. Correlation between the Overall\_DTF in the Ease of Doing Business and the EGD I (2018)

The Georgian case can be used as an example of the successful integration of e-gov initiatives in a public sector reform. During the last decade, the country implemented a large public sector reform and introduced its first formal national e-gov strategy (Nielsen & Goderdzishvili, 2017). Consequently, from 2010 to 2018, the *EGDI* increased by 26.5 points, the government effectiveness index improved by 6.1 points, and the *Overall\_DTF* raised 9.6 points.<sup>13</sup> Another successful example of an ICT-based public administration reform is provided by Kazakhstan (Bhuiyan, 2011 b). During the period considered, the country improved 20.2 points in the *EGDI*, 9.1 points in the government effectiveness index, and 19.7 points in the *Overall\_DTF*.

However, Figure 1 also reveals some outliers from the positive correlation between the *EGDI* and the *Overall\_DTF*. Libya and Venezuela present abnormal low levels in the *Overall\_DTF* given their *EGDI* levels. A possible explanation for these performances is that both countries have very low levels of *Gov\_Effectiveness*. In 2018, Libya's *Gov\_Effectiveness* was approximately 13.1 points, while Venezuela's was 18.4 points, which is far below the average of 50.0 points reported in Table 1. Moreover, both countries have been facing severe political and economic problems in recent years that may constitute a threat to the institutional development of the countries.

<sup>13</sup> We are considering the 2010-2018 period only because the *Overall\_DTF* is only available from 2010 onwards.

## 2.5. Empirical methodology

Our analysis is based on eleven different regression models, where the dependent variables are countries' overall DTF and the DTF for each of the ten regulatory areas analyzed. As the dependent variables are censored, and bounded between 0 and 100, we used the Tobit as the main estimation technique. Analytically, the models can be presented as follows:

$$DTF_{i,t} = \beta_0 + \beta_1 EGD I_{i,t} + \lambda_t + \theta (EGD I_{i,t} * \lambda_t) + \rho X'_{i,t} + V_i + \varepsilon_{i,t} \quad (1)$$

$$i = 1 \text{ to } 169; t = 2004, 2005, 2008, 2010, 2012, 2014, 2016 \text{ or } 2018$$

where  $DTF_{i,t}$  represents both the *Overall\_DTF* and the DTF of each of the 10 indicators analyzed for country  $i$  in year  $t$ . Among the explanatory variables, we highlight the  $EGD I_{i,t}$ , which is the *EGDI* of county  $i$  in year  $t$ .  $X'_{i,t}$  is a set of control variables and  $\lambda_t$  stands for time effects, which are captured by year dummies. In equation (1),  $V_i$  represents a set of country dummy variables to account for static differences per country. Finally,  $\beta_0$  and  $\beta_1$  are coefficients to be estimated,  $\rho$  and  $\theta$  are vectors of coefficients to be estimated, and  $\varepsilon_{i,t}$  is the error term.

Vector  $X$  includes the following economic and institutional variables:<sup>14</sup>

- *Gov\_Effectiveness* <sub>$i,t-1$</sub> : perceptions of government effectiveness;
- *Gov\_C* <sub>$i,t-1$</sub> : the lagged value of the share of government consumption on GDP;
- *Openness* <sub>$i,t-1$</sub> : the lagged value of the openness of the economy, measured by the sum of the percentages of exports and imports on GDP.

As can be seen from equation (1), in all models, the *EGDI* was interacted with the time dummies. This procedure addresses potential non-comparability issues of the *EGDI* over time due to occasional changes in the composition of its sub-indices.<sup>15</sup> Although these changes do not render the

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<sup>14</sup> The *GDP per capita* and several other variables were also tested, but not included, either because they created multicollinearity problems (high VIF values) or led to the loss of many observations without significantly improving the explanatory power of the regression. Some of these variables were the perceived regulatory quality, the perceived rule of law, the perceived control of corruption, the number of government crises, the weighted conflict index, the government fractionalization index, the judicial independence, the corruption index, the perceived voice and accountability and the democratic accountability. The Index of Economic Freedom was not used because it includes variables from the World Bank's Ease of Doing Business indicators in its calculation.

<sup>15</sup> The TII had four compositional changes during the sample period, which resulted from the need to update the index to the new technological trends (e.g. removing the number of television sets and the number of fixed internet subscriptions and including mobile broadband subscriptions). The *HCI* had one compositional change during the entire sample period. Until 2012, the index only combined the adult literacy and the gross enrollment ratio; from 2014

data incomparable across years, for caution, we interacted the *EGDI* (and the *OSI*) with year dummies, allowing the estimated coefficient associated with the e-gov index variable to change over time. All regressions were estimated with robust standard errors to avoid heteroskedasticity problems.

Our main hypothesis is that a higher *EGDI* leads to higher *DTFs*. We also evaluate which regulatory areas benefit most from developing e-gov. Regarding the other independent variables, we expect more effective governments to be more efficient in dealing with business regulations and bureaucracy, so *Gov\_Effectiveness* should have a positive influence on the *DTFs*. Given that in countries where the weight of public consumption in GDP is large, administrative and regulatory burdens are likely to be high, we expect the estimated coefficient for *Gov\_C* to be negative. Finally, as more open economies face more intense competition, the pressure to facilitate business, namely international business, is higher. Therefore, we predict the degree of openness of the economy to exert a positive impact on the *DTFs*.

## **2.6. Empirical results and robustness tests**

This section presents and discusses our main and complementary results, as well as the robustness tests that were implemented.

### **2.6.1. Main Results**

We started by estimating the models, using the methodology explained in the previous section for the *Overall\_DTF* and its components. Tables 2 and 3 contain the estimation results. The empirical results show that progress in electronic government can facilitate business, as suggested by the literature and argued by policy guidelines. As can be seen from Tables 2 and 3, the *EGDI*'s baseline coefficient is positively signed and statistically significant in the *Overall\_DTF* and seven out of the ten doing business areas: *Starting a Business*, *Dealing with Construction Permits*, *Registering Property*, *Paying Taxes*, *Getting Credit*, *Enforcing Contracts* and *Protecting Minority Investors*.

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onwards, the expected years of schooling and the average years of schooling were added to the composition of the *HCI*. From time to time, the survey questions used to compute the *OSI* were updated to incorporate new technological trends. The survey usually has more than 100 questions, and the vast majority of them remained unchanged from one edition to the other.

Table 2. Doing Business indicators - Tobit results (part I)

	(1)	(2)	(3)	(4)	(5)	(6)
	Overall	Starting Business	Construct Permits	Getting Electricity	Register Property	Paying Taxes
EGDI	0.048* (0.029)	0.356*** (0.055)	0.282*** (0.068)	0.010 (0.051)	0.107** (0.049)	0.124** (0.062)
Gov_Effect	0.156*** (0.034)	0.098 (0.065)	0.368*** (0.085)	0.214*** (0.053)	0.198*** (0.062)	0.476*** (0.078)
Gov_C	-0.636*** (0.098)	0.074 (0.108)	-0.164 (0.133)	-0.763*** (0.105)	-0.319*** (0.099)	-0.207* (0.122)
Openness	-0.020 (0.015)	-0.003 (0.015)	0.008 (0.018)	0.027* (0.015)	0.047*** (0.013)	0.030* (0.016)
2005		3.685* (1.982)				
2008		9.003*** (2.093)			4.633*** (1.748)	
2010		17.850*** (2.137)	3.542* (2.026)		8.332*** (1.795)	1.756 (1.847)
2012	1.149 (1.151)	23.154*** (2.093)	6.157*** (1.998)	1.440 (1.441)	10.428*** (1.731)	4.446** (1.821)
2014	4.848*** (1.145)	28.544*** (2.023)	8.641*** (1.957)	5.495*** (1.422)	14.237*** (1.675)	7.739*** (1.794)
2016	1.106 (1.276)	39.485*** (2.112)	8.409*** (2.040)	-9.167*** (1.479)	5.060*** (1.757)	8.116*** (1.870)
2018	2.540 (1.720)	46.740*** (2.373)	7.082*** (2.287)	-8.710*** (1.663)	4.499** (1.988)	2.788 (2.098)
EGDI.2005		-0.038 (0.040)				
EGDI.2008		-0.035 (0.042)			-0.055 (0.034)	
EGDI.2010		-0.101** (0.043)	0.001 (0.041)		-0.044 (0.036)	0.040 (0.038)
EGDI.2012	0.002 (0.020)	-0.187*** (0.040)	-0.064* (0.038)	-0.024 (0.028)	-0.074** (0.032)	0.008 (0.035)
EGDI.2014	-0.035* (0.020)	-0.249*** (0.039)	-0.068* (0.038)	-0.047* (0.028)	-0.119*** (0.032)	-0.006 (0.035)
EGDI.2016	0.026 (0.022)	-0.394*** (0.040)	-0.037 (0.038)	0.174*** (0.029)	-0.009 (0.032)	0.013 (0.035)
EGDI.2018	0.021 (0.026)	-0.475*** (0.041)	-0.007 (0.040)	0.194*** (0.030)	0.003 (0.034)	0.067* (0.037)
Observations	781	1,206	937	781	1,075	937
Pseudo R <sup>2</sup>	0.359	0.226	0.224	0.275	0.261	0.264
Log-Likelihood	-1991	-4043	-3088	-2456	-3389	-3015

Notes: All models were estimated with a constant and country dummy variables. Robust standard errors in parentheses.

Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.



Table 3. Doing Business indicators - Tobit results (part II)

	(7) Resolving Insolvency	(8) Getting Credit	(9) Trade Across Borders	(10) Enforcing Contracts	(11) Protect Minor Investors
EGDI	0.027 (0.039)	0.366*** (0.074)	0.068 (0.097)	0.118*** (0.030)	0.133** (0.061)
Gov_Effect	0.117** (0.048)	0.652*** (0.096)	0.493*** (0.122)	0.087** (0.036)	0.166** (0.076)
Gov_C	-0.086 (0.084)	-0.498*** (0.153)	-0.418** (0.189)	-0.060 (0.060)	-0.191 (0.118)
Openness	-0.005 (0.011)	-0.014 (0.021)	0.073*** (0.026)	0.011 (0.008)	0.029* (0.016)
2005	-0.257 (1.461)			0.335 (1.094)	
2008	5.623*** (1.545)	1.303 (2.667)		1.529 (1.155)	
2010	6.800*** (1.574)	6.986** (2.738)	3.934 (2.868)	1.624 (1.180)	2.945 (1.800)
2012	7.108*** (1.548)	18.426*** (2.681)	6.390** (2.828)	1.551 (1.155)	4.768*** (1.772)
2014	7.229*** (1.501)	24.900*** (2.588)	10.293*** (2.786)	3.980*** (1.117)	5.253*** (1.748)
2016	7.998*** (1.573)	19.699*** (2.727)	13.028*** (2.903)	1.407 (1.166)	-5.385*** (1.822)
2018	9.412*** (1.819)	26.075*** (3.105)	11.969*** (3.249)	1.387 (1.310)	-6.647*** (2.046)
EGDI.2005	0.016 (0.029)			-0.008 (0.022)	
EGDI.2008	-0.035 (0.030)	0.083 (0.053)		-0.022 (0.023)	
EGDI.2010	-0.038 (0.031)	0.084 (0.056)	-0.015 (0.059)	-0.017 (0.024)	-0.008 (0.037)
EGDI.2012	-0.012 (0.029)	-0.121** (0.050)	-0.062 (0.054)	-0.034 (0.022)	-0.043 (0.034)
EGDI.2014	0.003 (0.029)	-0.182*** (0.050)	-0.106* (0.054)	-0.080*** (0.022)	-0.028 (0.034)
EGDI.2016	0.013 (0.029)	-0.247*** (0.050)	-0.046 (0.055)	-0.048** (0.022)	0.163*** (0.034)
EGDI.2018	0.008 (0.031)	-0.295*** (0.053)	-0.025 (0.058)	-0.044* (0.023)	0.187*** (0.036)
Observations	1,206	1,075	937	1,206	945
Pseudo R <sup>2</sup>	0.361	0.209	0.197	0.315	0.248
Log-Likelihood	-3341	-3843	-3344	-3326	-3024

Notes: All models were estimated with a constant and country dummy variables. Robust standard errors in parentheses.

Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Besides progress in electronic government, other factors seem to influence the doing business DTFs, especially the institutional ones. The proxy for the quality of institutions (*Gov\_Effectiveness*<sup>16</sup>) is

<sup>16</sup> This variable was originally scaled from -2.5 to 2.5. To facilitate the interpretation of the estimated coefficients it was rescaled from zero to 100.

positively signed and statistically significant in the *Overall\_DTF* model, as well as in nine of the ten models of the business areas included in the Doing Business database. The statistically significant coefficients vary between approximately 0.1 and 0.7, indicating that the estimated effect of a one-point increase in this variable is between 0.1 and 0.7 points, depending on the business area being considered. The estimated coefficient associated with the lagged value of government consumption over GDP (*Gov\_C*) is, when significant, always negative, and it is statistically significant for the overall index, *Getting Electricity*, *Register Property*, *Paying Taxes*, *Getting Credit* and *Protecting Minor Investors*. The lagged value of the degree of openness of the economy (*Openness*) is positively and statistically significantly associated with a higher score in the *Overall\_DTF* and the *Getting Electricity*, *Register Property*, and *Trading Across Borders* areas.

In most of the estimated models, there are positive time effects on the DTFs. The majority of the estimated coefficients associated with the time dummies are statistically significant and positively signed, and their magnitude increases over time, revealing a global approximation between the average country and the top-performing country in each area of the Ease of Doing Business indicators. There are only a few exceptions to this general tendency in some business areas for the years 2016 and 2018. An explanation for those exceptions is the methodological changes in the composition of those indices from 2014 to 2016, which, as can be seen in Table 1, made the average scores of those indices fall. Therefore, in these cases, the coefficient associated with the time dummy is capturing the methodological change in the computation of the index.

Since the composition of the *EGDI* changed over time, it is important to check if its correlation with the Doing Business indicators varies over time. Therefore, the *EGDI* was interacted with the time dummies. The estimated coefficients for the interaction variables are reported in Tables 2 and 3, while the marginal effects of e-gov in each year<sup>17</sup> are shown in Tables 4 and 5.

In several cases, the coefficient associated with the *EGDI* varies over time and becomes smaller after 2012. Until 2012, the largest estimated coefficients for the *EGDI* were obtained for *Starting a Business* and *Getting Credit*. According to the estimations, in the base years, a one-point increase in the *EGDI* (on a scale from zero to 100) is associated with an increase of 0.36 and 0.41 points in each of these DTF's, respectively. In both cases, the correlations decrease over time. For *Dealing with Construction Permits*, *Paying Taxes*, *Enforcing Contracts* and *Protecting Minority Investors* the estimated marginal effect of e-gov, is statically significant in all years for which data is available, or in all

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<sup>17</sup> Empty cells in the time dummies and the interaction terms appear when the base year of the regression is not 2004. Some indicators only started being considered in the Doing Business reports in 2005 or later, and therefore, there is no data before these years.

except one, and varies between 0.07 and 0.32. For *Getting Electricity* and *Protecting Minority Investors*, the change in the magnitude of the coefficients over time was different from the general tendency: the larger coefficients were obtained for 2016 and 2018.

Table 4. Marginal effects of the EGD I (part I)

	(1) Overall	(2) Starting Business	(3) Construct Permits	(4) Getting Electricity	(5) Register Property	(6) Paying Taxes
2004		0.356***				
2005		0.319***			0.107**	
2008		0.321***	0.282***		0.052	0.124**
2010	0.048*	0.255***	0.283***	0.010	0.063	0.164**
2012	0.050	0.170***	0.218***	-0.014	0.033	0.132**
2014	0.014	0.107**	0.214***	-0.037	-0.012	0.117**
2016	0.074**	-0.037	0.250***	0.184***	0.098**	0.137**
2018	0.069*	-0.118**	0.274***	0.204***	0.110**	0.191***
Observations	781	1,206	937	781	1,075	937
Pseudo R <sup>2</sup>	0.359	0.226	0.224	0.275	0.261	0.264
Log-Likelihood	-1991	-4043	-3088	-2456	-3389	-3015

Notes. Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Estimated models include the set of variables reported in Table 2.

Table 5. Marginal effects of the EGD II (part II)

Variables	(7) Resolving Insolvency	(8) Getting Credit	(9) Trade Across Borders	(10) Enforcing Contracts	(11) Protect Minor Investors
2004	0.027			0.118***	
2005	0.043			0.110***	
2008	-0.008	0.366***	0.068	0.097***	0.133**
2010	-0.011	0.449***	0.052	0.102***	0.125*
2012	0.015	0.245***	0.006	0.084***	0.090
2014	0.030	0.184**	-0.038	0.039	0.105*
2016	0.040	0.119	0.022	0.070**	0.296***
2018	0.035	0.071	0.043	0.074**	0.320***
Observations	1,206	1,075	937	1,206	945
Pseudo R <sup>2</sup>	0.361	0.209	0.197	0.315	0.0579
Log-Likelihood	-3341	-3843	-3344	-3326	-3787

Notes. Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Estimated models include the set of variables reported in Table 3.

An explanation for the variations in the estimated coefficients associated with *EGDI* over time is the methodological changes in the *EGDI* construction. As previously mentioned, a relevant *HCI* change occurred in 2014. Additionally, in what regards the *OSI*, according to the UNDESA (2016), “each edition of the Survey has been adjusted to reflect emerging trends in e-gov strategies, evolving knowledge of best practices in e-gov, changes in technology and other factors” (UNDESA, 2016: 133), and a similar process occurred with the *TII*. Another possible explanation for some of the results being weaker in the final years of data is the upward trend for most of the DTFs, making it more difficult to obtain additional progress.

### **2.6.2. Complementary Results**

Amongst the *EGDI* sub-indices, the *OSI* is the one that is directly related to the development of online governmental services provided in each country, while the *TII* and the *HCI* try to capture citizens’ capacity to participate in the online society. Therefore, we estimated models using the *OSI* as the main independent variable, and the *TII* and *HCI* as additional control variables.<sup>18</sup> As there are compositional changes in the *HCI* from 2012 to 2014, the *HCI* was interacted with a *post2012* dummy. Tables 6 and 7 report the results for the marginal effects of the *OSI*, as well as the estimated coefficients for the *TII* and the *HCI*. The results corroborate the hypothesis that the scope and quality of online governmental services may facilitate business. The coefficient associated with the *OSI* turned out to be positive, and statistically significant, in two regressions for the base year, and to be statistically significant for at least two years in the regressions for seven of the business areas (*Starting a Business, Dealing with Construction Permits, Getting Electricity, Paying Taxes, Getting Credit, Enforcing Contracts and Protecting Minority Investors*). Comparing the results obtained for the *EGDI* with the ones obtained for the *OSI*, although statistically significant results were obtained, in most of the cases, for the same business areas, the *OSI*’s coefficients tended to have a smaller magnitude and not to be statistically significant as often. This is not surprising if we consider that the two sub-indices left out, the *TII* and *HCI*, turned out to be positive and statistically significant in some of the business areas, as Tables 6 and 7 demonstrate. The *TII* is statistically significant in the regressions for the *Starting a Business, Dealing with Construction Permits, Getting Electricity, Paying Taxes, Resolving Insolvency, and Getting Credit* areas, while the *HCI* is positive and statistically significant in the regressions for the *Starting a*

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<sup>18</sup> The full results are not presented for parsimonious reasons but are available from the authors upon request. We also estimated regressions where the *OSI* is interacted with the *TII* or the *HCI*, but the results for the interaction did not reveal to be consistently statistically significant.

*Business, Dealing with Construction Permits, Registering Property and Protecting Minority Investors* areas.<sup>19</sup>

Table 6. Marginal effects of the OSI and estimated coefficients for the TII and HCI (part I)

	(1) Overall	(2) Starting Business	(3) Construct Permits	(4) Getting Electricity	(5) Register Property	(6) Paying Taxes
<i>Marginal Effects for the OSI:</i>						
2004		0.132***				
2005		0.104***			0.048	
2008		0.126***	0.062		-0.002	0.044
2010	0.012	0.074**	0.064*	0.038	0.006	0.085**
2012	0.009	0.004	0.011	-0.003	-0.019	0.072**
2014	-0.024	0.091***	0.009	-0.056**	-0.057**	-0.018
2016	0.022	-0.011	0.064*	0.123***	0.040	0.007
2018	0.027	-0.069*	0.088**	0.146***	0.059**	0.030
<i>Estimated coefficients for TII and HCI:</i>						
TII	0.081***	0.065*	0.155***	0.139***	-0.005	0.144***
HCI	-0.077***	0.215***	0.217***	-0.139***	0.140***	-0.112*
HCI_post2012	-0.064*	-0.039	0.177**	-0.083*	0.127**	-0.018
Observations	780	1,204	935	780	1,073	935
Pseudo R <sup>2</sup>	0.353	0.228	0.226	0.282	0.260	0.267
Log-Likelihood	-2006	-4027	-3074	-2429	-3382	-2998

*Notes.* Statistical significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Estimated models include the set of variables reported in Table 2.

<sup>19</sup> Contrary to our expectations, the estimated coefficient for the *HCI* turned out negatively signed and statistically significant in the regressions for the *Getting Electricity* and the *Enforcing Contracts* areas, although in the latter only after 2012. However, these results are not robust since, in both cases, when regressions are run by standard FE or RE, the estimated coefficient for the *HCI* becomes positively signed, although not statistically significant. Additionally, for the *Getting Electricity* area, there is a negative correlation between the *HCI* and the price of electricity (US cents per kWh), one of the indicators considered in this area, that may partially help explaining this result.

Table 7. Marginal effects of the OSI and estimated coefficients for the TII and HCI (part II)

	<b>(7) Resolving Insolvency</b>	<b>(8) Getting Credit</b>	<b>(9) Trade Across Borders</b>	<b>(10) Enforcing Contracts</b>	<b>(11) Protect Minor Investors</b>
<i>Marginal Effects for the OSI:</i>					
2004	-0.026			0.024	
2005	-0.028	0.093**		0.011	
2008	-0.055**	0.145***	0.060	0.002	0.059
2010	-0.050**	0.147***	0.050	0.010	0.047
2012	-0.040*	-0.012	0.015	0.004	0.004
2014	-0.024	-0.020	-0.046	0.031*	-0.004
2016	-0.012	-0.053	-0.036	0.073***	0.153***
2018	-0.008	-0.094*	-0.002	0.082***	0.182***
<i>Estimated coefficients for TII and HCI:</i>					
TII	0.063**	0.280***	0.003	0.026	0.018
HCI	0.099	0.059	0.030	0.047	0.170***
HCI_post2012	0.094	-0.032	0.082	-0.070**	0.203***
Observations	1,204	1,073	935	1,204	943
Pseudo R <sup>2</sup>	0.362	0.209	0.197	0.319	0.249
Log-Likelihood	-3328	-3836	-3338	-3302	-3012

Notes: Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Estimated models include the set of variables reported in Table 3.

In discussing Figure 1, we posited that the reason why there are outliers is that governance is poor in these outlying countries. That is, it seems likely that the correlations between the *EGDI* and the *DTFs* depend on the quality of governance. To test this hypothesis, we included an interaction term between *EGDI* and *Gov\_Effectiveness* in the model. Because the *EGDI* is also interacted with the year dummy variables, those models have triple interactions between the *OSI*, *Gov\_Effectiveness* and the year dummies. Statistically significant and positive signs for these interactions were found in multiple years for the overall regressions and in the regressions for the *Starting a Business*, *Dealing with Construction Permits*, *Getting Electricity*, *Resolving Insolvency* and *Enforcing Contracts* areas, which supports the idea of a positive complementarity between e-gov services and the effectiveness of government on the reduction of administrative and regulatory burdens.<sup>20</sup>

To further investigate how electronic government developments facilitate business, and because all the *DTFs* are composite indicators, we estimated regressions for all the Doing Business individual indicators that compose the *DTFs* of the areas for which we found statistically significant results in the

<sup>20</sup> These results are available from the authors upon request.

analysis above.<sup>21</sup> The results corroborated our expectations that e-gov can help to reduce time, paper-handling, wait, coordination problems and costs of the bureaucratic processes. For example, the analysis shows that a higher *EGDI* is associated with fewer procedures and less time required to start a business. A higher *EGDI* is also related to a lower number of procedures and less time required to register a property; a lower number of tax payments and less time spent on paying taxes; and a greater extent of investor protection, extent of disclosure, extent of director liability and ease of shareholder suits (*Protecting Minority Investors* area).

### **2.6.3. Robustness tests**

Several robustness tests were implemented. To complement the Tobit results, we also estimated the main regressions, with the same set of independent variables, using another method that is appropriate for censored variables, the Fractional Probit (Papke & Wooldridge, 1996), obtaining very similar results to the ones reported in Tables 2 and 3.<sup>22</sup> Additionally, we estimated those regressions using the fixed or random effects models (according to the Hausman test results). The results for the coefficients associated with the *EGDI* were similar to the ones reported in Tables 2 and 3, except that the *EGDI* coefficient for the baseline year did not turn out to be statistically significant for the *Registering Property* and *Paying Taxes* areas and was statistically significant for the *Getting Electricity* area. Regressions that included the logged GDP *per capita* were also estimated, and the results were also similar to the ones reported in section 2.6.1.<sup>23</sup>

To minimize potential problems of simultaneity and omitted variable bias, we estimated regressions where the *EGDI* was lagged by two additional periods. Overall, the main results of these estimations were similar to the ones reported in Tables 2 and 3.

Finally, as the methodology to compute the *EGDI* has been updated over time, three additional robustness tests were implemented. First, cross-sectional regressions for each year with available data were estimated. As the dependent variable is censored, the Tobit model was used in these estimations. The general tendency was for coefficients associated with the *EGDI* variable that were already significant in the panel regressions to have a larger magnitude than the ones reported in Tables 4 and 5 and for coefficients that were not statistically significant to become significant and to have a larger

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<sup>21</sup> For sub-indicators that were added to the ease of doing business indicators from 2014 onwards, it was only possible to run regressions with, at most, three observations per country. For this reason, those sub-indicators were excluded from this complementary analysis.

<sup>22</sup> For the fractional probit estimations, the variables were converted to a zero to one scale. The results will be provided by the authors upon request.

<sup>23</sup> Given the very high correlation between the logged GDP and Gov\_Effectiveness, we removed the Gov\_Effectiveness from those regressions.

magnitude. The exceptions were the *Dealing with Construction Permits* area, where the coefficients were smaller and often non-significant and the *Paying Taxes* and *Trading Across Borders* areas, for which the results only followed the general tendency in the most recent years of data. Second, given that the main change in the *EGDI* composition occurred from 2012 to 2014, we performed an additional robustness test by interacting the *EGDI* with a *post\_2012* dummy variable. The results were similar to the ones reported in Tables 2 to 5. The baseline *EGDI* coefficient turned out to be positive and statistically significant in the regressions for five *DTFs* (the same as in Tables 2 and 3, except for the *Registering Property* and *Protecting Minority Investors* areas). The interaction between the *EGDI* and the *post\_2012* dummy was statistically significant in the regressions for five *DTFs*, and the signs of the statistically significant interaction terms were totally in line with the signs of the interactions between the *EGDI* and the dummies for 2014, 2016, and 2018 reported in Tables 2 and 3. Lastly, we also estimated separate regressions for all the *DTFs* until 2012 and from 2014 onwards. Statistically significant results for the *EGDI* were obtained for six business areas.<sup>24</sup>

## 2.7. Conclusions

Using longitudinal data for 169 countries from 2004 to 2018, our empirical results indicate that innovations in public administration, based on electronic government, may be used to create a more supportive environment for business. Our estimates indicate that higher e-gov development levels may facilitate business by decreasing the burden of regulations in several business areas. The main results were revealed to be robust to a battery of robustness tests and alternative empirical strategies. This, in turn, may contribute to a more dynamic and competitive economy, as well as to the attraction of foreign investment and economic growth (e.g. Barseghyan, 2008; Klapper & Love, 2011; Dreher & Gassebner, 2013; Braunerhjelm & Eklund, 2014; Corcoran & Gillanders, 2015). Our analysis is based on the Doing Business reports which focus only on SMEs and ignore large firms. As SMEs usually have more trouble dealing with ICT-based solutions than large firms (OECD, 2004; Haller & Siedschlag, 2011), one would expect the estimated benefits of e-gov improvements to be higher if large enterprises were also considered.

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<sup>24</sup> Estimating separate regressions for the two periods leads to a considerable drop in the number of observations and, therefore, to a significant loss in the number of degrees of freedom in all the estimated regressions. The former is particularly strong in the areas where the data is not available since the beginning of the sample period.



For reforms in digital governance to be successful in reducing burdensome regulation and creating a supportive environment for business, all stakeholders involved in the process should be consulted and actively involved. The successful implementation of ICT policies, therefore, requires a thorough analysis of the specific context, continuous incremental action, and the adoption of measures to address the ongoing issues as they emerge (Stanforth, 2006). Simply transferring ICT solutions from one country to another is likely to be insufficient, given the differences in institutional, cultural, and administrative contexts (Gil-Garcia & Pardo, 2005; Schuppan, 2009). This is particularly relevant for developing countries, where infrastructure and human capital are less developed and may constitute an obstacle to fully collecting the benefits of modernization initiatives, and for rural areas where economic agents may not fully perceive the administrative burden significance for entrepreneurship (Ntaliani & Costopoulou, 2017). Our results also suggest an important role of government effectiveness in explaining administrative and regulatory burdens, corroborating the idea that more effective governments are also more efficient in dealing with business regulations and bureaucracy.

We hope that this paper contributes to a more informed discussion of the topic and stresses the benefits of including ICT-based solutions as a relevant part of public administration reforms. In a constantly evolving world, in which only the most innovative remain competitive, we think that governments can play a strategic role as business facilitators.

## 3. Digital Government as a Corruption Deterrent<sup>25</sup>

### 3.1. Introduction

Corruption is a severe problem that causes significant harm to society. Finding policy instruments to mitigate it is paramount, as recognised by Goal 16 of the UN 2030 Agenda for Sustainable Development.<sup>26</sup> The promotion of stronger institutions through greater governmental transparency, more accountable public officials, and the engagement of citizens in public matters has frequently been used to justify investments in electronic government (e-government).<sup>27</sup> E-government is perceived as being capable of discouraging corrupt practices and influencing citizens' attitudes towards corruption (Elbahnasawy, 2014; Gans-Morse *et al.*, 2018). With the rapid development of Information and Communication Technologies (ICT) in recent decades, adopting e-government solutions has become a worldwide political trend (UNDESA, 2016).<sup>28</sup> However, despite the importance of the topic, only a few studies have investigated the effectiveness of e-government in combating corruption using longitudinal data for many countries. Furthermore, existing studies use aggregate indicators that do not account for the diverse forms of corruption or capture the various dimensions of e-government (Andersen, 2009; Elbahnasawy, 2014; Zhao & Xu, 2015).

This paper aims to contribute to the debate by analysing which types of corruption are more impacted by e-government, which e-government domains affect corruption, and under which conditions e-government is most effective in curbing corruption. We have built a large and detailed dataset covering more than 170 countries, spanning almost two decades of e-government innovations and

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<sup>25</sup> This chapter is co-authored with Linda Veiga and Bruno Fernandes and was published in *Economics & Politics* as Martins, J., Veiga, L., & Fernandes, B. (2023). Are electronic government innovations helpful to deter corruption? Evidence from across the world. *Economics & Politics*, 1–27. <https://doi.org/10.1111/ecpo.12255>

<sup>26</sup> This Goal calls on states to 'substantially reduce corruption and bribery in all their forms.'

<sup>27</sup> Despite the 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 in 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).

<sup>28</sup> 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).

including different measures of e-government and corruption. By using various corruption measures, we can reduce potential biases resulting from a single measure and explore which forms of corruption are more impacted by e-government. Moreover, by considering different measures and dimensions of e-government, we explore which e-government dimensions (e.g. online service completion, digital services for business) are more closely linked to corruption outcomes, which is a gap in the literature. Finally, we analyse whether the effectiveness of e-government tools to deter corruption may vary depending on the context, namely on the extent of corruption, GDP, and political rights.

The paper is structured as follows. Section 3.2. briefly reviews the literature on the determinants of corruption and discusses the role of e-government as an anti-corruption tool. Section 3.3. describes the data and its sources. Section 3.4. discusses the main hypotheses and explains the empirical methodology and section 3.5. reports the observed results. The conclusions are presented in section 3.6.

### **3.2. Corruption: effects and causes, and the potential of e-government in reducing it**

Corruption is a complex social phenomenon with multifaceted motivations and expressions. The definitions of corruption vary depending on the context, legal system, cultural norms, and research purposes (Jain, 2001; Aidt, 2003; Kurer, 2005). While several definitions of corruption exist, most emphasise the abuse of entrusted power for private purposes (Školník, 2020).<sup>29</sup> This section starts by providing an overview of the literature on the effects and causes of corruption. It then elaborates on the potential of e-government in preventing and controlling corruption.

#### **3.2.1. Consequences and causes of corruption**

Over the last two decades, a substantial body of literature has analysed the effects and drivers of corruption.<sup>30</sup> Concerning economic consequences, research has shown that corruption harms innovation (Murphy et al., 1993; Shleifer & Vishny, 1993; Dincer, 2019), economic growth, and sustainable development (Mauro, 1995; Murphy et al., 1991; Aidt, 2009; d'Agostino et al., 2016; Gründler & Potrafke, 2019). Additionally, corrupt countries tend to attract less foreign investment (Habib & Zurawicki, 2002), tax trade (Dutt & Traca, 2010), have higher public debts (Cooray et al.,

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<sup>29</sup> For early seminal articles on corruption see Nye (1967) and Rose-Ackerman (1975).

<sup>30</sup> See Aidt (2018) and Dimant and Tosato (2018) for surveys on the economic analysis of corruption and Školník (2020) for a literature review on how corruption affects political participation.

2017), less developed financial sectors (Cooray & Schneider, 2018) and lower private investment (Zakharov, 2019). Concerning political participation, most studies, particularly at the national level, conclude that corruption hinders political participation (Školník, 2020). However, some research suggests it can enhance approval of and participation in public protests (Kostadinova & Kmetty, 2019; Školník, 2022).

Various social, economic, political, organisational, and individual factors contribute to corruption. Institutions and historical backgrounds play an essential role in explaining corruption levels. The type of colonisation (Acemoglu *et al.*, 2001; Goel & Nelson, 2010), whether a country is a democracy, and the type and maturity of a democratic regime may also influence corruption (Shleifer & Vishy, 1993; Kunicova & Rose-Ackerman, 2005), with autocracies and recent democracies exhibiting higher levels of corruption.

The lack of competition and government regulations may result in more corruption (Pieroni & d'Agostino, 2013), creating an environment conducive to bribes and influencing the incentives to bribe bureaucrats (Ades & Di Tella, 1999). Therefore, openness to foreign companies and antitrust regulation can result in lower levels of corruption (Torrez, 2002). Heavy and intrusive regulations may create higher incentives for bribes or for not fulfilling the legal requirements (Djankov *et al.*, 2002; Auriol & Walters, 2005; Dal Bó *et al.*, 2006). Media freedom has also been demonstrated to deter corrupt activities (Brunetti & Weder, 2003; Kalenborn & Lessmann, 2013). Lastly, there is evidence that cultural and social norms related to corruption are persistent and that legal enforcement matters in government officials' corruption decisions (Fisman & Miguel, 2007; North *et al.*, 2013).

### **3.2.2. E-government as an anti-corruption tool**

In the past few decades, governments' adoption of information and communication technologies has unprecedentedly impacted society and the public sector.<sup>31</sup> The potential role of e-government as an anti-corruption tool can be established through the literature on the economics of crime, the agency theory, and the studies on transaction cost economics.

The economics of crime views the act of crime as a utility-maximising decision, which depends on factors such as the probability of conviction and the severity of punishment (Becker, 1968). Since e-government enhances the chances of detection and prosecution (Ojha *et al.*, 2008; Ojha & Palvia,

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<sup>31</sup> See Andersen *et al.* (2010) for an earlier meta-analysis of the literature on e-government's impacts. More recently, Veiga & Rohman (2017) and Elbahnasawy (2021) suggested that e-government decreases the size of the shadow economy, while Martins & Veiga (2022) argued that it could facilitate business.

2012), it can reduce corruption. E-government can improve interoperability, integration and information sharing among government agencies, increasing the likelihood of detecting corrupt behaviour. Furthermore, electronic records are easier to maintain, archive, and access than paper records, facilitating audits, preventive checks, and ongoing investigations of corrupt activities.

The agency theory studies situations where a principal delegates tasks to an agent in the context of conflicting interests between the parties and information asymmetry (Linder & Foss, 2015). In the public sector, civil servants (agents) have more information about the administration than elected governmental officials (principals) and citizens (clients), and corruption may arise when civil servants use their entrusted powers to act opportunistically (Elbahnaswy, 2014). In this context, electronic and online information can mitigate the information asymmetry problem and the risk of corruption (Ojha & Palvia, 2012; Srivastava *et al.*, 2016). Moreover, the digitalisation of processes and services reduces the discretionary power of public officials, promoting disintermediation and reducing or eliminating the agent's role (Ojha & Palvia, 2012).

As discussed by Husted (1994), transaction cost economics is also a valuable framework for studying corruption. This framework analyses transactions based on three dimensions: asset specificity, uncertainty, and frequency. When it comes to corruption, the specificity of the public official involved in a transaction plays a significant role. If the assets required for a transaction are not specific, the likelihood of opportunism and bribes is low. One-stop shops and other governmental portals provide multiple services that can be accessed from multiple locations, either autonomously or with the support of a civil servant. This stands in contrast to conventional service delivery, where a clerk is responsible for a single service or a limited set of services, resulting in a higher degree of specialisation in service delivery and asset specificity. Therefore, e-government has the potential to mitigate corruption by diminishing asset earmarking through the parallel delivery of services at multiple counters and the digitisation of service delivery (Ojha & Palvia, 2012). Moreover, e-government can decrease transactional uncertainty with the government by offering additional information and knowledge regarding procedures, rules, and deadlines, fostering their simplification, and expanding service accessibility hours (Ojha & Palvia, 2012; Prasad & Shivarajan, 2015). In this regard, decreased uncertainty for citizens or business entities utilising these services reduces the likelihood of opportunistic behaviour from civil servants and, consequently, the occurrence of bribes.

E-government can also reduce corruption by fostering citizen participation through e-participation (Khan *et al.*, 2021). E-participation facilitates citizen involvement and the demands for government information, promoting openness and transparency (Zheng, 2016). It allows citizens to

report experiences of corrupt activities (Kim *et al.*, 2009) and question governmental procedures, decisions, and actions (Choi, 2014). Higher levels of access to information and social media penetration help to promote accountability and discipline corruption by exposing wrongdoings, particularly in less democratic countries, where traditional media is often censored (Jha & Sarangi, 2017; Enikolopov *et al.*, 2018).

To our knowledge, only a few studies (Andersen, 2009; Elbahnasawy, 2014; Zhao & Xu, 2015) have empirically investigated the impact of e-government on corruption using longitudinal data for many countries. Using an extensive and updated dataset, we improve on previous papers by addressing different forms of corruption, exploring which e-government dimensions are more impactful in curbing corruption, and analysing the conditions that facilitate the effectiveness of e-government as an anti-corruption tool.

### **3.3. The data**

We start this section by discussing the challenges of measuring corruption and the indices available and used in the empirical analysis. We then describe the e-government indices available, detailing the different dimensions of e-government. Finally, the data on the control variables are specified.

#### **3.3.1. Corruption indexes**

The biggest challenge of empirical research on corruption is finding reliable measures for corruption (Lambsdorff & Schulze, 2015). Corruption is difficult to measure due to its hidden nature, social stigma, and wide range of definitions and expressions (Philip, 2016). Most empirical studies on corruption use indirect measures based on firm and household surveys and expert assessments. However, the subjectivity of perceptions of corruption adds to the difficulties in constructing objective and reliable indicators. Despite these challenges, there is evidence that perceived corruption measures contain accurate information about corruption practices (Mocan, 2008; Olken, 2009) and are relevant themselves, as they influence the decisions of businesses and households (Kaufmann *et al.*, 2011).

Our data comprises three general indicators of corruption and eight specific indicators of different types of corruption. By using multiple indicators, we better understand the complex and multidimensional nature of corruption and enhance the robustness of our research findings.

The three general indicators of corruption used are the Control of Corruption Index (*CCI*) from the World Bank's Worldwide Governance Indicators (WGI), the Corruption Perceptions Index (*CPI*)

compiled by Transparency International, and the Political Corruption Index (*PCI*) from 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 and the degree of state capture by elites and private interests. The *CCI* aggregates indicators that combine the views of firms, citizens, and experts obtained through surveys implemented in developed and developing countries.<sup>32</sup> The *CPI* measures perceptions of corruption in the public sector by combining surveys and assessments of corruption on experts and business executives of several reputable institutions.<sup>33</sup> Indicators from the V-Dem Institute are computed by combining information from official documents with subjective assessments from experts. The *PCI* intends to quantify the pervasiveness of political corruption. It is obtained by averaging the Public Sector Corruption Index (*PSCI*), the Executive Corruption Index (*ECI*), the Indicator of Legislative Corruption (*ILC*), and the Indicator of Judicial Corruption (*IJC*). Therefore, the V-Dem Corruption Index is more comprehensive than the Control of Corruption Index and the Corruption Perceptions Index.

Data from the V-Dem Institute allows for investigating eight different forms of corruption and whether e-government is more effective in reducing particular forms of corruption. The *PSCI* is focused on corruption in the public sector and captures the extent to which public sector employees grant favours in exchange for bribes and kickbacks, defalcating, and stealing or using public resources for family or private use. This index is computed based on two variables: the Public Sector Corrupt Exchanges (*PSCE*), which measures how routinely public sector employees grant favours in exchange for bribes, kickbacks, or other material inducements, and the Public Sector Theft (*PST*), which quantifies how often public sector employees steal, embezzle, or misappropriate public funds or other state resources for personal or family use. The *ECI* measures how often members of the executive (the head of state, the head of government, and cabinet ministers) grant favours in exchange for material inducements such as bribes or kickbacks and how often they embezzle, misappropriate, or steal public funds for personal or family use. The *ECI* is computed based on two variables: Executive bribery and corrupt exchanges (*ExecBCE*) and Executive embezzlement and theft (*ExecET*). The *ILC* quantifies how much legislature members abuse their position for financial gains. Finally, the *IJC* measures how often

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<sup>32</sup> For a detailed description of the methodology, see Kaufmann *et al.* (2011).

<sup>33</sup> For more details, see the “Technical methodology note” and the “Source description” available at <https://www.transparency.org/en/cpi/2020/index/nzl>.

businesses and citizens make payments or bribes to speed up judicial processes, delay them, or obtain favourable decisions.<sup>34</sup>

As can be seen from Table 8, the general corruption indicators are highly correlated, particularly the *CCI* with the *CPI*, which correlate to 0.989. As the two indexes measure the same phenomenon, we mainly use the *CCI* as the dependent variable, as more data is available for this variable. Amongst the V-Dem Institute indicators, the correlations are still high but often lower than 0.900, suggesting that they measure different forms of corruption.

Table 8. Correlation between the corruption indexes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) CCI	1										
(2) CPI	0.989	1									
(3) PCI	0.900	0.897	1								
(4) PSCI	0.883	0.888	0.953	1							
(5) PSCE	0.905	0.911	0.924	0.960	1						
(6) PST	0.905	0.906	0.928	0.961	0.936	1					
(7) ECI	0.858	0.842	0.948	0.918	0.891	0.894	1				
(8) EXECBCE	0.888	0.883	0.927	0.888	0.905	0.895	0.959	1			
(9) EXECET	0.864	0.850	0.912	0.898	0.891	0.914	0.963	0.922	1		
(10) ILC	0.825	0.822	0.896	0.802	0.814	0.824	0.816	0.839	0.804	1	
(11) IJC	0.875	0.873	0.927	0.864	0.871	0.872	0.834	0.857	0.820	0.796	1

*Note:* The correlations involving the *CPI* were computed using the observations for the period spanning from 2012-2020. The other correlations were computed using the entire sample period (2002-2022)

<sup>34</sup> Data for the Regime Corruption Index (*RCI*), which intends to measure the extent to which politicians use the political office for political or private gain, was also collected. However, it is based on the indicators for executive embezzlement (*ExecET*), executive bribes (*ExecBCE*), legislative corruption (ILC) and judicial corruption (IJC), which are also used to compute the *PCI*. Therefore, it was not used in the analysis.



### 3.3.2. E-government indices

To measure each country's electronic government development level, we start by using the UNDESA's E-government Development Index (*EGDI*) and its sub-indexes. The *EGDI* is released biannually based on primary data from surveys implemented by UNDESA and 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*). The *TII* is a weighted average of several indicators related to the use and development of telecommunications provided by ITU. The *HCI* is a weighted average of schooling and literacy-related indicators provided by UNESCO.<sup>35</sup> The *OSI* measures the sophistication of online governmental services offered in each country and is based on an evaluation made through a survey conducted by researchers from all over the world under the supervision of UNDESA. The survey assesses the countries' national and ministerial websites and portals, their tools and infrastructure if they provide information about services, laws, regulations, and government data, which e-participation services exist, and if several public services are provided online. Therefore, among the UNDESA indicators, the *OSI* is the one that more directly measures the sophistication of e-government services. A subset of the *OSI* focuses on electronic participation-related features, the e-Participation Index (*EPart*), 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).

In addition to UNDESA's indices, we use the European Commission's Digital Public Services indicators to investigate the impact of different e-government-related domains on corruption. These indicators are available every year for the EU countries and the UK and are a subset of the Digital Economy and Society Index (DESI) of the European Commission. The Digital Public Services indicators are disaggregated into distinct sub-indicators covering different e-government dimensions: *e-Government Users*, *Pre-Filled Forms*, *Online Service Completion*, *Digital Public Services for Business*, and *Open Data*. The *e-Government Users* measures the share of the population that used the internet to send filled forms to the public authorities in the last 12 months. The *Pre-Filled Forms* measure the amount of pre-filled data in the forms of online governmental services. The *Online Service Completion* assesses the share of bureaucratic steps related to certain public services that can be done online. The *Digital Public Services for Business* estimates the percentage of public services necessary for starting a

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<sup>35</sup> The goal of the *TII* and the *HCI* is to proxy the capacity of participating in the online society by the citizens of each country.

business and conducting regular business operations that can be performed online. Lastly, the *Open Data* evaluates the extent to which countries have an Open Data policy and the functionalities, data availability, and usage of the national data portal. Table 9 shows the correlations between the e-government variables mentioned above. The table shows that the correlations between the different e-government dimensions are generally low or moderate, with the highest correlations occurring between the *OSI* and *EGDI*, *OSI* and *EPart*, and *Online Service Completion* and *Digital Public Services for Business*.

Table 9. Correlation between the e-government indexes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) OSI	1									
(2) EGD I	0.900	1								
(3) TII	0.774	0.891	1							
(4) HCI	0.479	0.726	0.493	1						
(5) EPART	0.894	0.787	0.747	0.329	1					
(6) E-GOV USERS	0.460	0.437	0.345	0.321	0.402	1				
(7) PRE-FILLED FORMS	0.430	0.366	0.371	0.296	0.233	0.386	1			
(8) ONLINE SERVICES COMPLETION	0.685	0.610	0.598	0.396	0.468	0.406	0.743	1		
(9) DIGITAL PUB. SERV. FOR BUSINESS	0.625	0.533	0.596	0.310	0.441	0.370	0.629	0.830	1	
(10) OPEN DATA	0.538	0.278	0.631	0.417	0.383	0.175	0.188	0.361	0.360	1

*Note:* The correlations between *EGDI*, *OSI*, *TII*, *HCI* and *EPart* were computed using the 193 annual observations for those variables spanning from 2002-2019. As for the remaining correlations, data was solely available for the EU countries and the UK. Each pair of variables used the maximum available years of data (2014-2020) for the calculations.

### 3.3.3. Other variables

In addition to using e-government indicators as explanatory variables for corruption, our analysis considers other variables that are relevant in explaining corruption. The first is the log of the GDP per capita (*logGDP*), which Treisman (2007) has identified as the strongest predictor of corruption. We obtained the data for this variable from the World Bank's Development Indicators (*WDI*). We also consider foreign direct investment inflows as a percentage of GDP (*fdi*) and the degree of openness of the economy (*openness*)<sup>36</sup> as relevant variables. More open economies and economies with more foreign direct investment have fewer monopolistic rents and are more exposed to external competitors, which we expect will make them more transparent and less corrupt (Ades & Di Tella, 1999; Torrez, 2002; Dutt, 2009). We collected data for both *fdi* and *openness* from the WB's Development Indicators. To proxy the level of bureaucracy, we use the Ease of Starting a Business Index (*easestartbus*) from the World Bank Ease of Doing Business project. This index is a useful proxy for measuring the regulatory burden that businesses face when starting and operating in a particular country (Djankov *et al.*, 2002).

Research has also suggested that democracy, freedom, and strong political institutions are relevant predictors of corruption (Persson *et al.*, 2003; Lederman *et al.*, 2005). To account for these factors, we include two additional predictor variables: the Political Rights variable (*political\_rights*) from the Freedom House's "Freedom in the World" database<sup>37</sup> and the Freedom of the Press Index by Reports Without Borders (*pressfree*).

Table 10 provides descriptive statistics for all the variables used in the empirical analysis for the entire sample period (2002 to 2020). To have all the variables on a similar scale and to facilitate the interpretation of the estimated coefficients, we have rescaled the *CCI*, *CPI*, *PSCE*, *PST*, *ExecBCE*, *ExecET*, *ILC* and *IJC*, *easestartbus*, *rule\_law*, *political\_rights*, and *pressfree* to a 0 to 1 scale, and the variables *fdi* and *openness* were divided by 100. For similar purposes, we have inverted the *CCI*, *CPI*, *PSCE*, *PST*, *ExecBCE*, *ExecET*, *ILC*, and *IJC* 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.

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<sup>36</sup> *Openness* is the sum of exports and imports over GDP.

<sup>37</sup> This variable is an index that ranges from 1 (greatest degree of freedom) to 7 (lower degree of freedom). It is based on external analysts' on-the-ground research, media information analysis, and interaction with local contacts. The index considers various factors, namely the electoral process, political pluralism and participation, and the functioning of government.

Table 10. Descriptive statistics (2002-2020)

Variable	Mean	Standard Deviation			Observations	Countries
		Overall	Between	Within		
CCI	0.516	0.199	0.196	0.038	3591	190
CPI	0.572	0.193	0.191	0.025	1562	177
PCI	0.513	0.304	0.300	0.055	3256	172
PSCI	0.491	0.304	0.299	0.060	3259	172
PSCE	0.518	0.149	0.147	0.028	3259	172
PST	0.498	0.190	0.187	0.037	3259	172
ECI	0.496	0.306	0.297	0.078	3259	172
ExecBCE	0.502	0.191	0.186	0.045	3259	172
ExecET	0.499	0.195	0.189	0.049	3259	172
ILC	0.521	0.170	0.165	0.035	3259	172
IJC	0.488	0.186	0.183	0.033	3256	172
OSI	0.394	0.269	0.228	0.144	1921	193
EGDI	0.460	0.224	0.203	0.097	1921	193
TII	0.301	0.260	0.221	0.137	1918	193
HCI	0.708	0.225	0.198	0.110	1902	193
EPart	0.304	0.293	0.207	0.207	1921	193
e-government Users	0.631	0.185	0.179	0.063	189	28
Pre-Filled Forms	0.517	0.259	0.249	0.085	196	28
Online Service Completion	0.818	0.137	0.117	0.075	196	28
Digital Public Serv. for Business	0.786	0.153	0.130	0.084	196	28
Open Data	0.417	0.177	0.099	0.148	168	28
logGDP	8.546	1.474	1.485	0.164	3531	190
openness/100	0.889	0.515	0.522	0.154	3233	181
fdi/100	0.078	0.523	0.314	0.421	3298	188
easestartbus	0.739	0.182	0.144	0.111	3007	186
political_rights	0.601	0.360	0.350	0.092	3650	193
pressfree	0.680	0.221	0.199	0.093	2860	176

*Notes:* Data for *EGDI*, *OSI*, *E-Part*, and *pressfree* was only available until 2019. From 2012 onwards, the *CPI* is not comparable with the previous years (Gründler & Potrafke, 2019), so the data for *CPI* spans from 2012 to 2020.

To provide a first glimpse of the empirical relationship between e-government development and corruption levels, Figure 2 presents a scatter plot with the *CCI* on the vertical axis and the *OSI* on the horizontal axis for 2019. Country isocodes are included as labels for each observation. A negative

correlation between the two variables is visible in Figure 2, with countries with higher levels of corruption typically presenting a lower *OSI*.

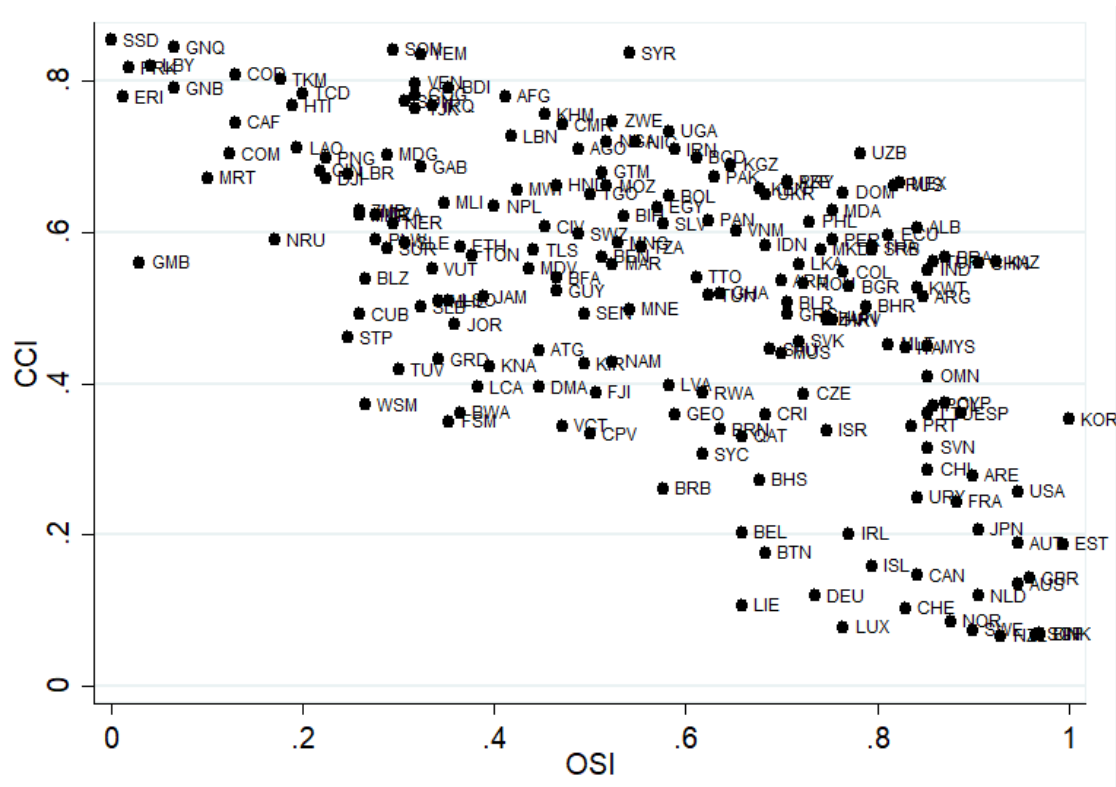


Figure 2. CCI and OSI in 2019 (country isocodes as labels)

### 3.4. Main hypotheses and empirical strategy

This subsection outlines the hypotheses that will be tested in the empirical analysis.

#### 3.4.1. General hypothesis and e-government dimensions affecting corruption

As discussed in Section 3.2.2., e-government has the potential to curb corruption for several reasons. Firstly, e-government systems diminish the opportunities for bribery and other corrupt practices by reducing direct interactions between citizens and government officials. Through online transactional services, citizens can engage in government-related activities without the need to physically visit government offices or interact with officials. Secondly, e-government reduces the incentives to engage in corrupt activities by mitigating information asymmetry between citizens and civil servants and limiting the discretionary power of the latter in service provision. Thirdly, e-government

acts as a deterrent against corrupt practices by increasing the likelihood of their detection and exposure. The promotion of information disclosure and the facilitation of tracking via e-government enhance external oversight and accountability. Digital records are easier to maintain, track, and monitor than paper records. This facilitates the identification of instances of malpractice or suspicious behaviour, thereby improving the efficiency of audits and preventive checks. Open government data empowers citizens and media by granting them greater access to government information, thus enabling better monitoring of public servants' activities. As discussed by Lindstedt & Naurin (2010), when citizens have access to more information about the misconduct of their representatives and subsequently act upon that information (e.g., through voting), and when mediators such as the mass media, investigative journalists, or civil society organisations gain increased access to information, corrupt behaviour becomes more perilous. This heightened risk necessitates greater effort in concealing wrongdoing and compels the employment of more sophisticated cover-up strategies, thereby discouraging corruption.<sup>38</sup>

Based on the discussion above, our general hypothesis **(H1)** is that e-government has a negative effect on corruption levels. We start by testing this hypothesis on a panel that covers the years for which both the indexes of general corruption (*CCI*, *CPI*, and *PCI*) and lagged values of the e-government index from the United Nations are available: 2003, 2004, 2005, 2008, 2010, 2012, 2014, 2016, 2018 and 2020.<sup>39</sup> The panel data model can be represented by equation (2):

$$CI_{it} = \beta_0 + \beta_1 egov_{it-1} + \gamma \cdot Control'_{it-1} + \lambda_t + \mu_i + \varepsilon_{it} \quad (2)$$

where  $t$  represents years and  $i$  the country.  $CI$  represents the general corruption index and  $egov$  the e-government index.  $Control'$  is a vector of control variables.  $\beta_1$  and  $\gamma$  are, respectively, coefficients and a vector of coefficients to be estimated.  $\lambda_t$  represents time fixed effects and  $\mu_i$  country fixed effects. Finally,  $\varepsilon_{it}$  is the error term.

We use the Control of Corruption Index (*CCI*) as the main proxy for corruption, as this is the index for which more observations are available. However, in the baseline estimations, we also test the Corruption Perception Index (*CPI*) and the Political Corruption Index (*PCI*) as dependent variables. For e-government, we use the Online Service Index (*OSI*) from the United Nations, which is the one that is

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<sup>38</sup> Žuffová (2020) also shows that open government data and freedom of information laws may lead to lower corruption, particularly in countries with higher media freedom.

<sup>39</sup> As mentioned in section 3.2., the UNDESA's EGD is currently published biannually. The index was initially released annually for the first three editions, and starting from 2007, data collection and publication have occurred every two years. Therefore, when combining it with the other variables in the regressions, data for the following years is available 2003, 2004, 2005, 2008, 2010, 2012, 2014, 2016, 2018 and 2020.

more closely related to the concept of e-government among the UNDESA e-government indexes. The *OSI* is lagged one period because it takes time for e-government initiatives to impact corruption.

To account for factors that prior research has identified as relevant in explaining corruption levels, we start by including in our regression models the logarithm of GDP per capita (*logGDP*), the foreign direct investment inflows as a percentage of GDP (*fdi*),<sup>40</sup> the political rights index (*political\_rights*).<sup>41</sup> In subsequent regressions, we include the remaining variables discussed in the previous section as potential corruption determinants to test our results' sensitivity to the control variables selected. Since we use indexes as dependent variables and all the indexes were rescaled to range from 0 to 1, we use the fractional probit to estimate the regressions.

Aiming to investigate which e-government dimensions can be more helpful to deter corruption, we use our panel to explore the relationship between corruption outcomes and alternative measures of e-government. Namely, we use all the UNDESA's e-government sub-indexes and the Digital Public Services indicators that measure five different e-government dimensions, as mentioned in section 3.3.2. Regarding the UNDESA's e-government sub-indexes, although digital public services, technology infrastructure, and literacy are all critical dimensions of socioeconomic development, we expect the *OSI* and the *EPart* to be more impacting on corruption outcomes than the *TII* and the *HCI* because the latter are less directly related to e-government **(H2)**.

Regarding the Digital Public Services indicators, there are reasons to expect that most may be associated with lower corruption outcomes **(H3)**. A higher share of *e-government Users* may translate into less corruption, or it can amplify the potential effects of e-government as an anti-corruption tool **(H3a)**. A higher level of *Online Service Completion* means fewer interactions between citizens and public employees and less interference in public service delivery, namely in transactional services. Therefore, fewer opportunities exist for bribes and other corrupt practices, which should translate into lower corruption outcomes **(H3b)**. The same reasoning applies to *Digital Services for Business*. The more developed these services are, the lesser the need for in-person services, meaning less discretionary power for public employees and fewer opportunities for bribes and kickbacks, which should negatively impact corruption outcomes **(H3c)**. As *Open Data* is closely linked and frequently associated with good practices regarding transparency and accountability, we expect it to be associated

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<sup>40</sup> For most regressions, *fdi* is preferred over *openness* because it has more observations and is statistically stronger.

<sup>41</sup> Other variables (economic, demographic, political and institutional) were tested in preliminary analyses. However, they were excluded from the condensed set of control variables because they created multicollinearity problems or had fewer observations and did not increase the model's explanatory power. The variable *easestabus* is not available for 2002 and 2003, and the variable *pressfree* is not available for 2003. Therefore, their inclusion in the regressions leads to a decrease in observations, and we only include them for robustness checks.

with less corruption **(H3d)**. Lastly, regarding *Pre-Filled Forms*, a possible direct relationship with corruption is less evident from a theoretical standpoint, and a minor or no effect should be expected **(H3e)**.

### **3.4.2. Types of corruption affected by e-government**

With the richness of our dataset, we can investigate which forms of corruption are more likely to be mitigated by e-government, which is a novel contribution to the literature.<sup>42</sup> We hypothesise that e-government is likely to reduce corruption at all four levels considered: public sector, legislature, executive, and judicial **(H4)**, but we expect its effect to be more salient in the public sector **(H4a)**. Regarding the types of corrupt activities, our data distinguishes between bribery and corrupt exchanges and embezzlement and theft. We expect e-government to contribute to the reduction of both types of activities. By reducing the interaction between citizens and public officials, e-government may diminish the opportunities for public officials to receive bribes, kickbacks, or other material inducements for improperly performing their duties **(H4b)**. Moreover, as e-government development facilitates audits, access, and data sharing, it may amplify the probability of detection and the reputational damage of wrongdoings. Therefore, we expect e-government to deter stealing, embezzlement, and misappropriating state resources for private use **(H4c)**.

### **3.4.3. The conditions under which e-government is a more powerful anti-corruption tool**

Finally, we investigate the conditions under which e-government is more powerful in reducing corruption. The potential of e-government to curb corruption may depend on the corruption level of each country **(H5)**. In countries with low corruption levels, the potential for online services to reduce theft in the public sector, embezzlement, or bribes could be lower, as, in those countries, such forms of corruption are not a severe problem **(H5a)**. Conversely, in countries with very high levels of corruption, technology may be less effective in curbing corruption, as such countries typically face severe structural corruption problems, have low educational levels, lack appropriate infrastructures, and have weak institutions, which may decrease the effectiveness of the introduction of new technologies **(H5b)**.

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<sup>42</sup> Our hypotheses are formulated having in mind the data made provided by the V-Dem project on various types of corruption. These variables are explained in section 3.1. In the empirical section, we estimate regressions using each of the eight indicators of specific types of corruption explained in section 3.1. as the dependent variable.



Therefore, we investigate the determinants of corruption along the conditional distribution of the corruption index score using panel data quantile regressions.

Quantile estimations are well-suited for this purpose as they allow stratifying the distributional effect of the regressors on the dependent variable into different quantile ranges, providing information that is not accessible through conditional mean estimation. For quantile regressions with fixed effects, we follow the method of moments quantile regression with fixed effects proposed by Machado & Santos Silva (2019). While resilient to outliers, previous approaches for quantile regressions with fixed effects (e.g., Koenker, 2004; Lamarche, 2010; Canay, 2011) consider models where the individual effects only cause parallel or location shifts of the distribution of the response variable. The method of moments estimation enables individual effects to impact the entire distribution, meaning that the impact of the time-invariant characteristics, similarly to other explanatory variables of the model, can have different impacts on different regions of the conditional distribution of the dependent variable.<sup>43</sup>

Countries with different political contexts and socioeconomic development face different structural socioeconomic situations. Therefore, we expect the effectiveness of information technologies as anti-corruption to vary accordingly **(H6)**. To explore this, we analyse whether the coefficient associated with our main independent variable, the *OSI*, varies significantly depending on the level of the remaining independent variables. Specifically, 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, foreign direct investment, and political rights. To calculate the average marginal effects, we use fractional probit estimates of models similar to equation (2) that include an interaction term between the *OSI* and each of the other explanatory variables in the model.

### **3.5. Empirical results**

#### **3.5.1. Results for the general indices of corruption and e-government dimensions**

As the previous section explains, we estimate the model with general corruption indices as dependent variables and the Online Service Index (*OSI*) as the main independent variable. The results for the marginal effects of the estimation of panel data fractional probit models with country and year fixed effects are reported in Table 11. In the models of columns 1 and 2, the most parsimonious set of control variables is used. The dependent variables are the Control of Corruption Index (*CCI*) from the

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<sup>43</sup> See Machado & Santos Silva (2019) for technical details regarding the estimator, its derivation and theorems and propositions that sustain and establish the conditions for its validity.

World Bank and the Corruption Perception Index (*CPI*) from Transparency International. When the *CCI* and the *CPI* are used as indicators of corruption (columns 1 and 2), the coefficient associated with the *OSI* is always negative and statistically significant. Therefore, the results support the general hypothesis (**H1**) that e-government negatively affects corruption levels. Columns 1 and 2 also show that a higher GDP *per capita*, higher political rights, and more foreign direct investment inflows are associated with less corruption.

Table 11. Results for the General Indexes of Corruption

Dependent var.	(1) CCI	(2) CPI	(3) PCI	(4) PCI	(5) CCI	(6) CCI	(7) CCI
I.OSI	-0.028*** (0.009)	-0.026** (0.011)	-0.022 (0.014)				
I.EPart				-0.027*** (0.010)	-0.010 (0.006)		
I.TII						-0.004 (0.015)	
I.HCI							-0.031 (0.019)
I.logGDP	-0.075*** (0.008)	-0.055*** (0.014)	-0.015 (0.013)	-0.014 (0.014)	-0.076*** (0.008)	-0.077*** (0.008)	-0.079*** (0.008)
I.fdi	-0.012*** (0.004)	-0.036** (0.016)	-0.006 (0.005)	-0.006 (0.005)	-0.013*** (0.004)	-0.013*** (0.004)	-0.013*** (0.004)
I.political_rights	-0.090*** (0.010)	-0.101*** (0.016)	-0.136*** (0.019)	-0.136*** (0.019)	-0.090*** (0.009)	-0.090*** (0.009)	-0.090*** (0.009)
N. observations	1,798	833	1,642	1,642	1,798	1,797	1,790
Pseudo R <sup>2</sup>	0.118	0.110	0.301	0.301	0.118	0.118	0.118
Log-likelihood	-1099	-508	-795.4	-795.4	-1099	-1098	-1093

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

As shown in column 3, when the Political Corruption Index (*PCI*) from the V-Dem Institute is used as a dependent variable, the *OSI* does not turn out statistically significant. Recall that the *CCI* and the *CPI* are highly correlated (Table 8) and seem to measure the same phenomenon, while the *PCI* is less correlated with the other two indices. Therefore, we investigate if the e-Participation Index (*EPart*), a subset of the *OSI*, is statistically significant. The *EPart* focuses on electronic participation-related features and aims to capture the citizens' access to information without demand, their possibility of engaging in decision-making, and empowerment through the co-design and co-production of policies

and services. Column 4 reveals that e-participation tools, proxied by the *EPart* variable, may play a role in reducing political corruption. As previously explained, the *EGDI* also considers a Telecommunications Infrastructure Index (*TII*) and a Human Capital Index (*HCI*). The *TII* measures the suitability of the telecommunications infrastructures for supporting e-government systems, and the *HCI* evaluates the population's literacy and education levels. Although the coefficients associated with the *TII* and *HCI* in columns (5) and (6) are negative, they are not statistically significant. Thus, as hypothesised in **H2**, the *OSI* and the *EPart* are the *EGDI* sub-indexes most closely related to corruption outcomes.

To further explore which e-government dimensions may impact corruption, we use the European Commission's Digital Public Services. As previously mentioned, the Digital Public Services indicators are a subset of the Digital Economy and Society Index (DESI). They are disaggregated into five e-government dimensions: *e-Government Users*, *Pre-Filled Forms*, *Online Service Completion*, *Digital Public Services for Business*, and *Open Data*. Since data on these five dimensions are available, it is possible to explore which e-government-related domains may be more helpful in fighting corruption. The drawback is that they are available, at best, from 2014 onwards and only for the European Union member states and the UK, typically countries with low levels of corruption and high levels of e-government development. This implies that the number of observations in the regressions is considerably smaller and that the dispersion of the data is lower when compared to data from across the globe.

Table 12 shows the marginal effects of the estimations using the fractional probit model, the *CCI* as the dependent variable, and the first lag of the DESI indicators of e-government.<sup>44</sup> Given the fewer observations in these regressions, we estimate the model without (panel A) and with country fixed effects (panel B). The control variables are the same as those used in the model of column 1 of Table 11. Results suggest that four of the five e-government dimensions may contribute to mitigating corruption: a higher percentage of e-government users (*e-Government Users*), more pre-filled forms (*pre-filled forms*), a higher degree of online service completion in public services (*Online Service Completion*) and more digital public services for business (*Digital Public Services for Business*). However, when including country fixed effects in the regressions (panel B), the absolute value of the coefficients becomes smaller, and only the coefficient associated with the *Online Service Completion*

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<sup>44</sup> The *CCI* is used as the dependent variable because our usual approach is to use the *CCI* whenever a general index of corruption is used as the dependent variable. This decision was made because, as mentioned in section 3.4.1., the *CCI* has more observations than the *CPI* and the *PCI*, enabling us to estimate the regressions with a larger sample. Furthermore, the correlation between the three variables is relatively high, particularly between the *CCI* and the *CPI*.

variable is statistically significant. Therefore, **H3b** is supported by the results, while **H3a**, **H3c**, **H3d**, and **H3e**, have weak or no support. The results for *Online Service Completion* are unsurprising, given that this indicator signals a greater use of online rather than face-to-face interactions, reducing the proximity between citizens and potentially corruptible public officials. A higher online service completion means that a higher share of administrative procedures related to public services can be performed online, reducing the extent to which public servants have discretionary power on bureaucratic processes and, consequently, the opportunities for corrupt behaviour. However, given the small number of observations, these results must be interpreted cautiously.

Table 12. Results for Different e-Government Dimensions: EU Digital Public Services indicators

	(1) e-government users	(2) Pre-filled forms	(3) Online serv. completion	(4) Digital pub. serv. for business	(5) Open Data
Panel A: W/o Fixed Effects					
I.e-gov indicator	-0.254*** (0.029)	-0.123*** (0.029)	-0.201*** (0.048)	-0.144*** (0.037)	0.040 (0.073)
N. observations	161	168	168	168	140
Pseudo R2	0.0841	0.0728	0.0713	0.0813	0.0688
Log-Likelihood	-89.45	-95.13	-95.28	-94.25	-79.67
Panel B: With Fixed Effects					
I. e-gov indicator	0.016 (0.022)	0.020 (0.021)	-0.059** (0.025)	-0.015 (0.025)	-0.007 (0.068)
N. observations	161	168	168	168	140
Pseudo R <sup>2</sup>	0.102	0.0999	0.0999	0.0999	0.0993
Log-pseudo likelihood	-87.72	-92.35	-92.35	-92.35	-77.06

*Notes:* The dependent variable is *CCI*. All models were estimated by the Fractional Probit with dummies for years and robust standard errors. Other independent variables included: *logGDP*, *fdi*, and *political\_rights*. Standard errors are in parentheses. Statistical significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

### 3.5.2. Results for different types of corruption

Corruption activities can take many forms. We explore the V-Dem Institute data on different types of corruption to analyse which are impacted by e-government. Table 13 presents the estimation results for models using the fractional probit and the same explanatory variables as in the fourth column of Table 11 for all the V-Dem Institute's variables that can be used to proxy different forms of

corruption in the public sector (*PSCI*, *PSCE*, *PST*) and the executive (*ECI*, *ExecBCE*, *ExecET*), legislative (*ILC*) and judicial levels (*IJC*). Recall from section 3.3.1 that both the Public Sector Corruption Index (*PSCI*) and the Executive Corruption Index (*ECI*) comprehend two variables: Public Sector Corrupt Exchanges (*PSCE*) and Public Sector Theft (*PST*), and Executive Bribery and Corrupt Exchanges (*ExecBCE*) and Executive Embezzlement and Theft (*ExecET*), respectively.

Table 13. Results for Different Types of Corruption and E-Participation

Dependent var.	(1) PSCI	(2) PSCE	(3) PST	(4) ECI	(5) ExecBCE	(6) ExecET	(7) ILC	(8) IJC
<i>I.EPart</i>	-0.021** (0.010)	-0.006 (0.005)	-0.015** (0.006)	-0.027* (0.014)	-0.024*** (0.009)	-0.005 (0.009)	-0.022*** (0.006)	-0.016*** (0.006)
N. observations	1,644	1,644	1,644	1,644	1,644	1,644	1,605	1,642
Pseudo R2	0.297	0.0641	0.107	0.296	0.108	0.111	0.0851	0.105
Log-likelihood	-800.3	-1066	-1017	-802.2	-1017	-1012	-1017	-1018

*Notes:* All models were estimated by fractional probit with robust standard errors and included year and country dummy variables. Other independent variables included: *logGDP*, *fdi*, and *political\_rights*. Standard errors in parenthesis. Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Empirical results indicate that e-government can contribute to curbing corruption at the four levels considered. The coefficient associated with the *EPart* is negatively signed in the regressions for all forms of corruption and is statistically significant in six of the eight columns of Table 13. There is evidence that e-participation reduces public sector theft (*PST*), executive bribery and corrupt exchanges (*ExecBCE*), legislature corrupt activities (*ILC*), and judicial corruption, proxied by the frequency that individuals or businesses make undocumented extra payments or bribes to speed up or delay the process or to obtain a favourable judicial decision. Therefore, we find supportive evidence for hypotheses **H4**, **H4b**, and **H4c** but not for **H4a**.

Similarly to the results presented in Table 12, we investigate which types of corruption may be more impacted by the components of the European Commission's Digital Economy and Society Index. Despite the low number of observations, the results reveal<sup>45</sup> that *Online Service Completion* and the *Open Data* variables are negatively signed and marginally statistically significant when the Public Sector Corruption Index (*PSCI*) and Public Sector Theft (*PST*) are used as dependent variables. This reinforces

<sup>45</sup> Complete results are available from the authors upon request.

the idea that e-government, as an anti-corruption tool, facilitates access to information and promotes reducing the discretionary power of public employees and the opportunities for corrupt behaviour.

### **3.5.3. Under which conditions is e-government more powerful in reducing corruption?**

To further explore the relationship between e-government development and corruption levels, we analyse the relationship between the *CCI* and the *OSI*, along with the conditional distribution of the *CCI*. Table 14 presents the estimation results for quantile regressions with fixed effects using the approach proposed by Machado & Santos Silva (2019) for quantiles 0.1, 0.25, 0.5, 0.75, and 0.9.<sup>46</sup> These results suggest relevant differences across different points in the conditional distribution of the *CCI*. At the lower end of the distribution, the coefficients for the *OSI* are statistically insignificant; however, they are negative and significant above the 0.25 quantile. This suggests that at the bottom of the conditional distribution of the *CCI*, e-government innovations do not reduce corruption. In contrast, at the upper quantiles of the distribution, they are beneficial, with other things being held equal.<sup>47</sup>

As the estimated coefficients associated with the *OSI* increase in absolute value as we move up in the conditional distribution of corruption, the results support **H5a**, according to which online government solutions are less effective in reducing corruption when the magnitude of corruption is low. On the contrary, hypothesis **H5b** is not entirely corroborated: e-government seems to be an effective anti-corruption tool even in contexts of high corruption. It is also worth noticing that in the quantile regressions, the absolute size of the estimated coefficient associated with political rights is very stable across the conditional distribution of the *CCI*, while the parameter estimated for GDP decreases (in absolute terms) when we move from lower to upper quantiles.

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<sup>46</sup> Results for other quantiles can be provided upon request.

<sup>47</sup> A similar pattern is observed when we use the E-part variable as a proxy for e-government. The coefficient associated with E-part increases (in absolute terms) as we move from lower to upper quantiles. However, in this case, the coefficient is only statistically significant for some regions of the *CCI*'s conditional distribution, located between the 0.5 and 0.75 quantiles. When using the jackknife bias correction in the estimations, the EPART's coefficient is statistically significant for quantile 0.75.

Table 14. Estimation Results for Quantile Regressions

	(1)	(2)	(3)	(4)	(5)
	q=0.1	q=0.25	q=0.5	q=0.75	q=0.9
l.OSI	-0.017 (0.017)	-0.021 (0.013)	-0.028*** (0.009)	-0.034*** (0.012)	-0.039** (0.171)
l.logGDP	-0.082*** (0.015)	-0.079*** (0.011)	-0.074*** (0.008)	-0.069*** (0.011)	-0.065*** (0.015)
l.fdi	-0.007 (0.011)	-0.009 (0.008)	-0.012* (0.006)	-0.014* (0.008)	-0.016 (0.011)
l.political_rights	-0.093*** (0.019)	-0.094*** (0.014)	-0.094*** (0.010)	-0.092*** (0.013)	-0.094*** (0.019)

*Notes.* The dependent variable is *CCI*. All models were estimated with country fixed effects, year dummies, and robust standard errors. Quantile regressions with 1,798 observations. Standard errors in parenthesis. Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

The literature has shown that the causes of corruption depend on the context, particularly the country's income level (e.g., Treisman, 2007). Corruption is much more salient in low-income countries than in high-income countries, and the causes of corruption differ. Low salaries and poor working conditions may explain a high share of the corruption in the former but not in the latter. To analyse under which conditions e-government may be more helpful for decreasing corruption levels, we estimate how the effect of e-government on corruption varies according to the other variables of the baseline panel data model: *logGDP*, *fdi*, and *political\_rights*. Figure 3 reveals the results for estimations using the *OSI* as the proxy for e-government. In each graph, percentile 5 of the relevant variable was set as the lower limit and percentile 95 as the upper limit.

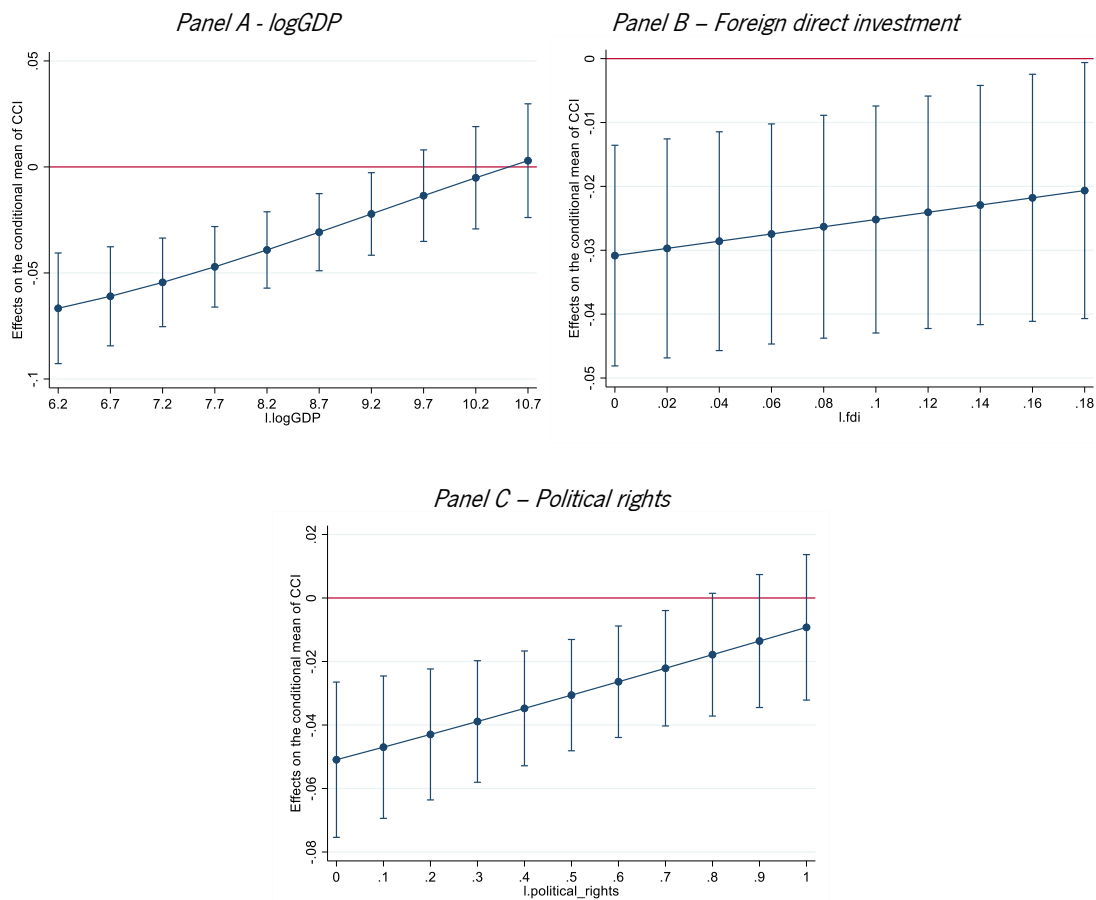


Figure 3. Average marginal effects of the OSI on the conditional mean of the CCI for different levels of GDP, foreign direct investment, and political rights<sup>48</sup>

Panel A of Figure 3 shows the average marginal effect of the *OSI* on the conditional mean of the *CCI* for different levels of the GDP *per capita*. The graph indicates that the impact of e-participation on corruption decreases with increases in GDP *per capita*. For a GDP *per capita* higher than roughly 9,897 USD (logGDP = 9.2), e-government is no longer statistically significant. Panel B presents the average marginal effects of the *OSI* on the conditional mean of the *CCI* for different levels of foreign direct investment flows. The magnitude of the *OSI* coefficient also tends to decrease in absolute terms as *fdi* increases, but the relationship is statistically significant for the entire distribution of *fdi* values. Panel C shows the average marginal effects of the *OSI* on the conditional mean of the *CCI* for different levels of political rights. Once again, the plot reveals a negative relationship, and, analogously to Panel

<sup>48</sup> 95% confidence intervals. All models were estimated by fractional probit with robust standard errors and included year and country dummy variables.



A, above a certain level (roughly 0.75 on a 0 to 1 scale) of political rights, the relationship between the *OSI* and the *CCI* is no longer statistically significant.<sup>49</sup>

Overall, we corroborate **H6**, suggesting that the effectiveness of information technologies as anti-corruption tools varies according to the political and socioeconomic contexts. E-government is less effective in countries with higher GDP per capita and political rights. A plausible interpretation of these results is that in the most developed countries, i.e., countries with higher GDP per capita and higher political rights, e-government development does not play a major role in reducing corrupt activities, as corruption is already low.

### 3.5.4. Robustness tests

This subsection provides an overview of the robustness tests implemented throughout the analysis.<sup>50</sup> Regarding the results reported for the general indexes of corruption and e-government (Table 11), the first robustness test used the degree of openness of the economy (*openness*) as a proxy for the exposure to external markets and investors rather than foreign direct investment (*fdi*). The former was not statistically significant, and its inclusion did not change the main results. We also estimated regressions that included the Freedom of the Press Index (*pressfree*) and the Ease of Starting a Business Index (*easestartbus*) as additional control variables. These variables were statistically significant in some regressions, suggesting that lower levels of bureaucracy and more freedom of the press may contribute to decreasing corruption, but their inclusion leaves the e-government-related results largely unchanged. As previously mentioned, including these variables leads to a loss of observations and, including *pressfree*, weakens the performance of the regressions in the sensitivity tests explained in a few paragraphs below. Therefore, they were not included in the tables with the main results.

As a third robustness test, we estimated cross-section regressions that included additional control variables with low or no variation within countries, which could not be included in regressions with country-fixed effects. These variables are the share of Catholic, Islamic, and Protestant populations, the colonial origins of the countries, and continent dummy variables. Furthermore, we estimated these regressions using the five-year average of the corruption variable as the dependent

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<sup>49</sup> Using the *EPart* as the e-government proxy instead of the *OSI* leads to similar results to those reported on panels A and C, with the difference that the *EPart* is statistically significant until slightly lower GDP per capita and political rights values (roughly 8.7 and 0.55, respectively). When it comes to the effects of *EPart* along the distribution of the *fdi*, the coefficient also decreases along the distribution but is only statistically significant until values slightly below 50% of FDI inflows as a percentage of GDP.

<sup>50</sup> All results mentioned in this subsection will be made available by the authors upon request.

variable, following Brunetti & Weder (2003). In both cases, the negative and statistically significant results for the *OSI* and *EPart* were confirmed. The estimated coefficients (in absolute value) exhibited greater magnitudes than those in the panel results.

We also conducted robustness tests to further examine the effects of the different e-government dimensions on corruption and the impact of e-government on various types of corruption. Firstly, we estimated all regressions using *openness* instead of *fdi* as an explanatory variable. Secondly, we added *pressfree* to the set of control variables. Thirdly, we included the religion-related variables as additional control variables in the regressions without fixed effects. The results reported in Tables 12 and 13 were confirmed.

To address concerns regarding omitted variable bias issues, we implemented the test methods proposed by Oster (2019) and Diegert *et al.* (2023), following the procedure outlined by Diegert *et al.* (2023).<sup>51</sup> Table 15 provides the results for the regressions reported in Tables 11 and 13, where the e-government indicators were statistically significant. Panel A displays the estimated coefficients for the e-government proxy obtained from the linear probability estimations necessary for conducting the tests. All models included country and year fixed effects, and used *logGDP*, *fdi*, and *political\_rights* as the controls, as specified in Tables 11 and 13. Panels B and C show the breakdown points for the tests of Oster (2019) and Diegert *et al.* (2023), respectively. The breakdown points indicate the degree of selection on unobservable factors relative to observable factors required to overturn the baseline finding. Oster (2019) suggests equal selection as a benchmark ( $|\delta| > 1$ ), while Diegert *et al.* (2023) propose a cutoff of 0.5 in their parameter ( $\overline{r_x} > 0.5$ ) for determining robustness. As shown in Table 15, the result for legislative corruption is the only one that does not meet the 0.5 cutoff in the Diegert *et al.* (2023) test. Hence, excluding this exception, the finding reported in Tables 11 and 13 are unlikely to be driven by omitted variable bias. However, the estimation results presented in Table 12 do not satisfy the tests. For the sake of brevity, we did not include the results of the tests in Table 15. Nonetheless, it is crucial to emphasise that the results of Table 12 should be interpreted with caution and should be revisited once more data becomes available.

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<sup>51</sup> We used the Stata package *regsensitivity*.

Table 15. Regression sensitivity analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	General corruption		V-Dem indices for various types of corruption					
Dep. var.	CCI	PCI	PSCI	PST	ECI	ExecBCE	ILC	IJC
<i>Panel A: Baseline results</i>								
I.OSI	-0.028***							
	(0.009)							
I.EPart		-0.030***	-0.023**	-0.015**	-0.030**	-0.025***	-0.022***	-0.017***
		(0.011)	(0.011)	(0.007)	(0.015)	(0.009)	(0.006)	(0.006)
Observ.	1,798	1,642	1,644	1,644	1,644	1,644	1,605	1,642
R <sup>2</sup>	0.969	0.970	0.961	0.962	0.941	0.947	0.962	0.971
<i>Panel B: Sensitivity analysis assuming exogenous controls (Oster, 2019)</i>								
$\delta$	10.41	3.38	5.00	30.08	-57.33	-41.95	-23.60	2.61
<i>Panel C: Sensitivity analysis assuming endogenous controls (Diegert et al., 2023)</i>								
$\bar{r}_x$ (x100)	73.6	72.2	65.1	65.6	80.3	68.5	29.4	71.7

*Notes.* All models were estimated by linear probability estimation with robust standard errors and included year and country dummy variables. Comparison controls: *logGDP*, *fdi*, and *political\_rights*. Standard errors in parenthesis. Statistical significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Columns 1 and 2 present sensitivity analysis estimates for the regressions shown in columns 1 and 3 of Table 4. The remaining columns present estimates of the different types of corruption (Table 13).

To test the robustness of the findings regarding the impact of e-government at different levels of the conditional distribution of corruption, we estimated quantile regressions with the jackknife bias correction proposed by Dhaene & Jochmans (2015),<sup>52</sup> along with bootstrap standard errors. The main difference was that, when using the jackknife correction, the coefficient associated with the *OSI* was revealed to be marginally significant for quantile 0.25.<sup>53</sup> Lastly, we also estimated quantile regressions using the approach proposed by Canay (2011).<sup>54</sup> Under this approach, the coefficients for most of the regressors, including the *OSI* and *EPart* variables, tended to be larger than the ones reported in Tables 11 and 14, which corresponded to fractional probit regressions with fixed effects and quantile regressions using the Machado and Silva (2019) approach, respectively.

<sup>52</sup> As a rule of thumb, Machado & Silva (2019) suggest using this correction whenever the ratio between the number of individuals and the number of periods is greater than 10.

<sup>53</sup> Regarding the coefficients of the *EPart*, with the jackknife bias correction method, the results generally align with those obtained using the previous procedure. However, it is worth noting, as mentioned in the previous section, that the coefficient is statistically significant for quantile 0.75.

<sup>54</sup> As explained in section 3.4., under this approach, the fixed effects act only as a location shift. Bootstrap standard errors were used in the estimations.

### **3.6. Conclusions**

Corruption is a global and major problem that reduces trust in government and imposes severe negative consequences on society. Therefore, successful anti-corruption policies are crucial worldwide, requiring knowledge about the phenomenon and concerted action by the various groups in society, including the government, the private sector, citizens, and civil society organisations. This paper focuses on the effects of government technological progress in curbing corruption.

Previous studies on the relationship between e-government and corruption (Andersen, 2009; Elbahnasawy, 2014; Zhao & Xu, 2015) mainly focused on aggregate and average effects. We contribute to the debate by investigating which e-governments domains are more successful in restraining corruption, which types of corrupt activities are more impacted by e-government, and whether the economic and political context influence the ability of technological innovations in government to curb corruption.

Our analysis suggests that electronic government can be used to deter corruption. This result is not surprising given that e-government innovations can reduce the discretionary power of public officials and, therefore, the opportunities for corruptive exchanges. Furthermore, electronic government tools facilitate the provision of information by governments to citizens, which fosters transparency and promotes scrutiny, prevention, and detection of corrupt behaviour.

Our results also suggest that certain e-government features, such as the development of highly comprehensive online services that eliminate the need for in-person interactions between citizens and civil servants and electronic participation tools, are particularly relevant in deterring corruption. These findings are valuable for policymakers and suggest that implementing fully online services that reduce or eliminate the opportunities for corruptive exchanges should be a priority. They also indicate that promoting e-participation by providing citizens with information about government activities and opportunities for consultation and deliberation can increase the success of anti-corruption reforms.

Furthermore, when analysing at which level of government activities corruption occurs and its different forms, we found evidence that e-government can help mitigate public sector theft, corrupt legislature activities, executive bribery and corrupt exchanges, but not judicial corruption. This suggests that the effectiveness of e-government in reducing corruption varies depending on the type of corruption, highlighting the importance of policymakers being aware of prevalent forms of corruption in their country when considering e-government development as a strategy rather than relying on a one-size-fits-all solution.

Another contribution of this paper is to assess the capacity of e-government to restrain corruption in different contexts. Empirical results indicate that e-government is a more relevant anti-corruption tool for countries that face high levels of corruption and are not in the upper extremes of the GDP per capita, political rights, and foreign direct investment distributions. Hence, our results suggest that the most considerable potential for introducing e-government services is in countries where corruption is a severe problem. In these environments, technological innovations such as those that reduce the discretionary powers of public officials, foster public disclosure of assets and incomes of candidates running for public office, facilitate information on parliamentary votes, draft legislation and parliamentary debates, and increase procurement and fiscal transparency have a larger potential to reduce corrupt activities.

However, we believe e-government innovations will likely have limited effects if not accompanied by broader reforms that foster good governance, trust and accountability in government, transparency, competition and deregulation, political rights, and media freedom. Therefore, policymakers should consider implementing a comprehensive and coordinated approach incorporating e-government innovations as part of broader reforms to address corruption.

For future research, we recommend further exploration of the most effective e-government dimensions in deterring corruption, as well as the heterogeneity of the effects of e-government on different types of corruption. The analysis of these topics is currently limited by data availability regarding the years and countries covered. Therefore, revisiting these issues when more data becomes available could be a fruitful research endeavour. Additionally, it would be worthwhile to investigate which e-participation tools and dimensions are most effective in deterring corruption.

## 4. Internet and Online Governmental Services Use Divides<sup>55</sup>

### 4.1. Introduction

Internet access among households reached 53.6% worldwide in 2017, according to the International Telecommunication Union (ITU). Even in developing countries, where the gaps are wider (Hilbert, 2016), Information and Communication Technology (ICT) proliferation seems to entail several benefits, such as more freedom of expression (Shirazi *et al.*, 2009) or more commitment to democratic governance (Nisbet *et al.*, 2012). Among the ICT developments, the fast development of online governmental services is a global trend (UNDESA, 2016). The promotion of stronger institutions through more transparency and accountability in the public sector and the engagement of citizens on public matters, has been used to justify several investments in these services (Estevez & Janowski, 2013).

However, the quick development of the digital society also raises some concerns. The digital divide is amongst them, particularly in developing countries, where income is lower and income inequality is higher (Fuchs, 2009). On this regard, Oman has been described as facing numerous challenges, such as infrastructural weakness and citizens' lack of knowledge (Al-Mamari *et al.*, 2013). Targeting ICT and Electronic Government (e-gov) development, the Omani government launched the Digital Oman Strategy, which has been running for more than a decade (Mansour, 2012). However, ITU and UNDESA data reveal that internet access and e-gov development in Oman are still low when compared to the remaining Gulf Cooperation Council (GCC) countries.

Several papers explored the determinants of ICT and online governmental services use. However, the literature is thinner when we look at studies based on large scale surveys and microdata from developing countries. Based on a dataset of 21,546 Omani individuals, we investigate the main determinants of internet and online governmental services use, as well as the leading causes of internet exclusion. In a society where men and women have traditionally distinct roles, we also explore

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gender differences in both the internet and online governmental services use determinants. Policy implications are extracted from the results.

## **4.2. Literature Review**

The digital divide was found to be mostly income-determined in early studies (e.g. Hoffman & Novak, 1998) and differences in ICT use and use purposes are still reflecting many of the existing inequalities in society (Haight *et al.* 2014). However, as access to basic telecommunications started to widespread, other factors emerged as key determinants of the use of ICT (Barnidge *et al.* 2019). Differences in educational levels reverberate in the use of computers (Shelley *et al.*, 2004). The area of residence also influences ICT use, with evidence suggesting a gap between suburban and other areas of residence (Warren, 2007). Additionally, several studies point out that the elders are more likely to be out of the web (e.g. Loges & Jung, 2001; Livingstone & Helsper, 2007).

Gender's role on explaining the digital divides in the developing world is still a topic of debate. Some studies classify gender as an important variable in explaining the digital divides (Mumporeze & Prieler, 2017), finding men more likely to use ICT than women (Alozie & Akpan-Obong, 2017; Gray *et al.*, 2017). The exclusion from technology education, social norms favouring men, limited free time and institutional constraints are amongst the potential explanations for such findings (Antonio & Tuffley, 2014). However, other studies find mixed evidence (Rashid, 2016) or even classify gender as a confounding variable (Hilbert, 2011). According to Hilbert (2011), gender differences in the access and use of ICT are just a reflex of differences in employment, education and income, and woman are inclusively more likely to be ICT users once those differences are considered.

The worldwide proliferation of online governmental services has also motivated research regarding their use. Early studies on US individuals (e.g. Thomas & Streib, 2003), found that income, education level, age and race are factors that influence the use of electronic government (e-gov) services, with civic-mindedness being later added by Dimitrova & Chen (2006). Most recently, Reddick and Anthopoulos (2014) concluded that female, older and lower-income individuals are less likely to be e-gov users, while Liu *et al.* (2014) found that young males living far from a village centre are more expected to be mobile government adopters. At last, some studies argue that a grey digital divide exists when it comes to the use of online governmental services (Choudrie *et al.*, 2013; Friemel, 2016).

To the best of our knowledge, the previous studies concerning digital divides on the specific context of Oman or other GCC countries were based on small samples, and only a few of them exist

(e.g., Sharma, 2015; Rodrigues *et al.*, 2016). In this paper, we attempt to provide a better understanding of the divides in the region by studying a large sample of Omani individuals.

### 4.3. Context

The Sultanate of Oman is a member of the GCC, being the second largest country in this region in terms of area. An absolute monarchy and a unitary state, Oman comprises eleven governorates, each one subdivided into several provinces. The Governorate of Muscat comprises 32% of the total population and the capital city, Muscat. Table 16 provides comparative data for Oman and the remaining GCC countries in 2016.

Table 16. Oman and the other GCC countries – data for 2016

	Oman	Bahrain	Kuwait	Qatar	Saudi Arabia	United Arab Emirates
GDP per capita (current US\$)	14,903	22,629	27,368	59,044	19,982	38,518
Population (total in millions)	4.425	1.425	4.053	2.570	32.276	9.270
Fixed-broadband subscriptions (per 100 people)	6.4	16.3	2.5	9.9	10.2	14.0
Mobile-broadband subscriptions (per 100 people)	93.9	147.3	227.9	117.4	90.0	243.4
Internet users (% of the population)	76.9	95.0	78.4	94.3	74.9	90.6
E-Government Development Index	0.685	0.812	0.739	0.713	0.712	0.830

Notes: The data regarding the GDP *per capita*, population, fixed-broadband subscriptions and internet users comes from the World Bank Development Indicators. The data for the mobile-broadband subscription comes from the International Telecommunications Union statistics. The data for the E-Government Development Index comes from UNDESA.

Being the third most populous country of the region, Oman is the GCC country with the lowest GDP per capita. It is also one of the countries performing poorer in terms of internet usage, connectivity and e-gov development. In a region that is largely dependent on mobile connectivity, the rate of mobile broadband subscription, as well as the percentage of internet users in Oman, is the second lowest in the GCC. Oman was also ranked last among the GCC countries in terms of digital government development.



#### 4.4. Data and descriptive statistics

The data used in this research results from the *Access to, and Use of, ICT by Households and Individuals* survey in Oman. This survey was implemented by the National Center for Statistics and Information via face-to-face interviews at the respondents' homes, from April to August 2016, as a part of the *Comprehensive Households Survey*. Designed by ITU standards, it aimed to assess two main features: the ICT access at the household level and the use of ICT by individuals.

The sample was randomly selected according to the framework of the General Census of the Population, Housing and Establishments. A two-stage stratification method was adopted. Each of the eleven Omani governorates was split into urban and rural localities, and within them, each locality was further divided into several Enumeration Areas (EA). In the first stage, the EAs from each governorate were randomly selected using a probability proportional to size method. In the second stage, within each EA, about 20 households were randomly selected with equal probability. Each household member aged 15 or more was interviewed to provide data on ICT usage. The final sample consists of 21,546 individuals and 5,224 households. Since 5,351 households were initially selected, partial interviews were not counted as responses, and there were no cases of unknown eligibility reported, the household-level response rate, calculated via the American Association for Public Opinion Research formula was approximately 97.6% (see Response Rate 1 at pp. 61 of The American Association for Public Opinion Research, 2016).

Based on the survey's answers, we constructed two binary variables that are used as dependent variables. The internet use-related variable (*internet\_use*) results from the answer to the question "Have you used the internet from any location in the last three months?". The online governmental services use variable (*gov\_services\_use*), results from the selection of at least one of the answers "Getting information from general government organizations", "Interacting with general government organizations", and "Getting services from a government organization or public authority via mobile application", when asked about the undertaken online activities. Both variables assume the value of 1 when the individual was identified as a user, and 0 otherwise.

Table 17 presents the sample composition and descriptive statistics. It reveals that approximately 72.5% of the respondents had used the internet during the three months before answering the questionnaire. In terms of online governmental services use, 3.1% of the individuals reported to use them. A gender gap exists since the proportion of males using the internet and online governmental services is higher than the proportion of females. 80.7% of the interviewed households

revealed to have internet access. Regarding the type of internet, *Mobile broadband via handset* is the most popular among Omani households (68.8%), followed by *Broadband ADSL* (16.8%).

Table 17. Descriptive Statistics

<b>Variable</b>	<b>Category</b>	<b>Full Sample (%)</b>	<b>Males (%)</b>	<b>Females (%)</b>
<i>Individual level indicators (% of individuals)</i>				
Gender	Male	54.6	-	-
	Female	45.4	-	-
Age Group	15-29	43.6	42.8	44.5
	30-44	33.9	34.6	33.0
	45-59	14.1	14.3	13.9
	60+	8.5	8.4	8.7
Education	Less than primary	38.1	38.0	38.2
	Primary	6.7	7.4	5.9
	Lower Secondary	9.4	10.3	8.3
	Upper secondary or post-secondary non-tertiary	37.2	36.2	38.5
	Tertiary	8.6	8.1	9.2
Locality	Urban	66.9	66.4	67.5
	Rural	33.1	33.6	32.5
Nationality	Omani	78.3	72.4	85.4
	Non-Omani	21.7	27.6	14.6
Employment Status	Employed	46.4	68.3	19.9
	Full-Time Student	18.8	15.8	22.5
	Domestic Worker	21.4	0.1	46.9
	Other	13.5	15.8	10.8
Head of Household	Head of Household	24.3	58.4	3.3
	Another role	75.8	41.6	96.7
Internet Users	Users	72.5	73.7	71.0
	Non-users	27.5	26.3	29.0
Online Governmental Services	Users	3.1	3.8	2.4
	Non-users	96.9	96.3	97.7

<i>Household level indicators (% of households)</i>				
Internet Access	Access	80.7	-	-
	No Access	19.3	-	-
Type of Internet Access	Narrowband analogue modem	3.0	-	-
	Other narrowband	1.9	-	-
	Broadband ADSL	16.8	-	-
	Other fixed broadband	5.0	-	-
	Mobile broadband via handset	68.8	-	-
	Mobile broadband via card	0.8	-	-

Additionally, the survey asked, “According to the answer for not using the internet, what are the reasons?”. The possible answers were illiteracy, the high price of the service, the lack of basic ICT skills, security or privacy concerns, having nowhere to access it, social or cultural reasons, having no need, not knowing what the internet is, not being allowed to use the internet, the lack of local content, the necessity for special equipment or other reason. Table 18 reveals the descriptive statistics regarding the reasons for not using the internet.

Table 18. Reasons for not using the Internet (percentage of the non-internet users)

<b>Reason</b>	<b>All non-users (%)</b>	<b>Females (%)</b>	<b>Males (%)</b>
No need	53.1	43.7	61.8
Lack of basic ICT skills	35.7	29.4	41.4
Illiteracy	34.9	46.2	24.5
Price of the service	7.3	3.9	10.4
Not knowing what the internet is	6.2	5.6	6.6
Nowhere to access	2.6	1.8	3.3
Not allowed to use	2.6	3.5	1.7
Other	1.7	1.6	1.7
Security/ Privacy concerns	0.8	0.5	1.0
Social or cultural reasons	0.6	0.7	0.6
Need of special equipment	0.4	0.3	0.5
Lack of local content	0.2	0.1	0.2

The lack of necessity or basic ICT skills, together with illiteracy, emerge as the most frequent self-reported reasons. The price (7.3%), lack of knowledge about what the internet is (6.2%), having nowhere to access it (2.6%) and not having permission to use it (2.6%) were the subsequent most frequently selected reasons for not using the internet. In contrast, security and privacy concerns, social or cultural reasons, the lack of local content and the need for special equipment were the least selected answers. Illiteracy was the most selected answer among females (46.2%) and not being allowed to use the internet is also more usual among females. Illiteracy is more common among senior females, while not being allowed among younger ones (descriptive statistics for different age groups can be provided by the authors upon request). Among males, it was no need (61.8%) the most selected answer.

#### 4.5. Methodology

We use multilevel binary choice models to study the determinants of the internet and online government services use. The use of a multilevel model is justified by the existence of dependencies in the data that result from the sampling strategy. Our baseline models are represented by equation (3):

$$Y_{ij} = \beta_0 + \beta_1 \cdot Male_{ij} + \beta_2 \cdot Age_{ij} + \beta_3 \cdot Age_{ij}^2 + \beta_4 \cdot Locality_{ij} + \beta_5 \cdot Nationality_{ij} + \beta_6 \cdot HeadHousehold_{ij} + \rho \cdot Education'_{ij} + \Theta \cdot EmploymentStatus'_{ij} + \phi \cdot Governorate_{ij} + u_j + e_{ij} \quad (3)$$

where  $Y_{ij}$  represents the dependent variable, which can be *internet\_use*, *gov\_services\_use* or one of the main self-reported reasons for not using the internet: illiteracy (*illiteracy*), price of the service (*price*), lack of basic ICT skills (*ICT skills*), nowhere to access (*no access*), lack of necessity (*no need*), not knowing what the internet is (*not know*) and not being allowed to use (*not allowed*).

Regarding the independent variables,  $Male_{ij}$  is a dummy variable that equals 1 if an individual of a given household is male and 0 if female. While previous studies assume a linear relationship between age and technology use (e.g. Reddick and Anthopoulos, 2014; Alozie and Akpan-Obong, 2017; Gray *et al.*, 2017), we assume a quadratic one, represented by  $Age_{ij}$  and  $Age_{ij}^2$ . This hypothesis emerges from observing that the percentage of internet and online governmental services

users increases until a certain age and decreases afterwards, as Figure 4 illustrates. This suggests that a concave function is suitable to describe the relationship between usage and age.

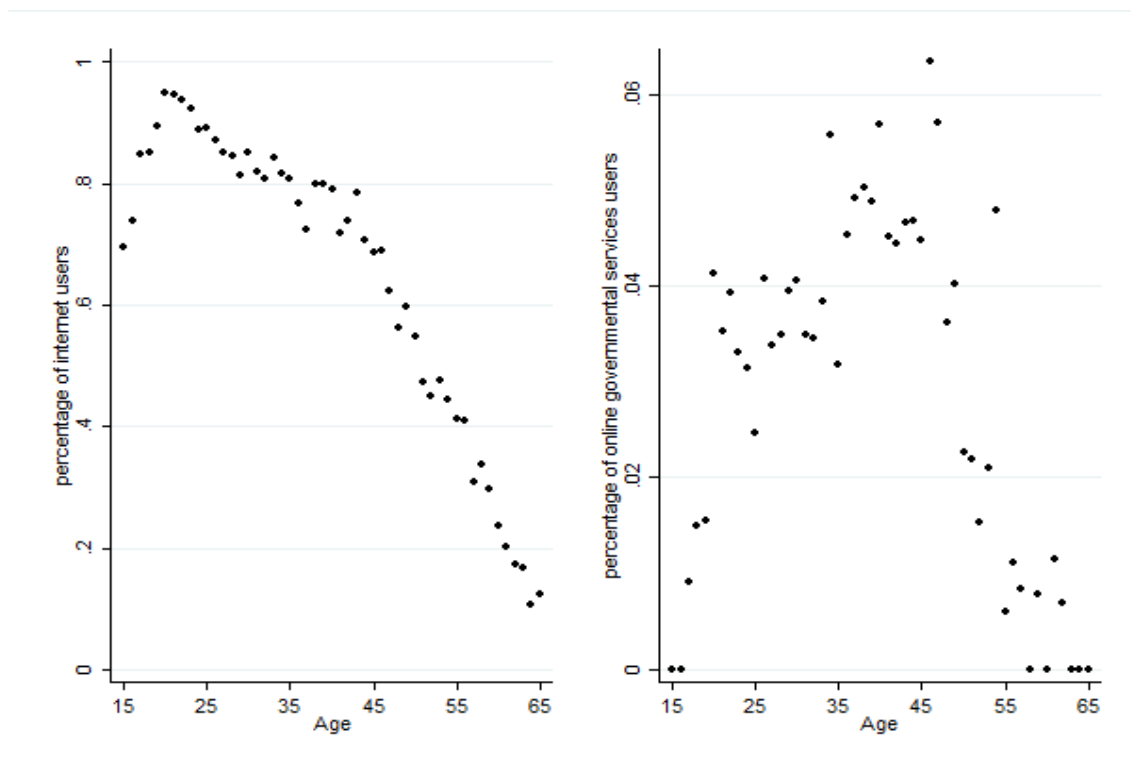


Figure 4. Percentage of internet users (right graph) and percentage of online governmental services users (left graph) by age<sup>56</sup>

$Locality_{ij}$  is a dummy variable that is equal to 1 if an individual  $i$  from household  $j$  lives in an urban area and 0 if he lives in a rural area, while  $Nationality_{ij}$  is a dummy variable that is equal to 1 if the individual is Omani and 0 otherwise.  $HeadHousehold_{ij}$  equals 1 if the individual is identified as the head of household  $j$  and 0 otherwise.  $Education'_{ij}$ ,  $EmploymentStatus'_{ij}$  and  $Governorate'_{ij}$  represent vectors of dummy variables related, respectively, with the education level, employment status and governorate of residence.

Concerning education, the International Classification of Education is followed. Four dummy variables are considered accordingly: *Primary*, *Lower Secondary*, *Upper Secondary* and *Tertiary*, being less than primary education the base category. Concerning the employment status, three dummies are

<sup>56</sup> This Figure is an online supplement to the Martins and Al-Shekailli (2021) article.

used: *Employment*, *Student* and *Domestic*, being *Other* individuals such as the retired, the disabled and the unemployed the base category.  $Governorate'_{ij}$  is composed by ten dummy variables, following the eleven Omani governorates. Finally,  $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \rho, \Theta$  and  $\Phi$  represent the parameters and the vectors of parameters to be estimated, while  $u_j$  and  $e_{ij}$  stand for the random part of the model.

As the dependent variables are binary, we choose the Probit model over the ordinary least squares. In particular, given the above-mentioned data dependencies, two-level random intercept Probit models are used. As the Probit coefficients do not have a direct interpretation, we estimate the marginal effects at the means for each regressor. Variance Inflated Factors (VIF) are calculated to verify that there are no problems of multicollinearity. Since males and females have different traditional roles in the Omani society (e.g. see Table 17, less than 1% of the males in the sample are domestic workers and 58.4% of them are heads of household, while 46.9% of the females are domestic workers and only 3.3% of them are heads of household), Chow tests (Chow, 1960) are performed to evaluate structural differences on the use determinants between them. Accordingly, extensions of the model including interactions between *Male* and other explanatory variables are estimated.

## 4.6. Results

### 4.6.1. Internet and Online Governmental Services Use

Following equation (3), the use of the internet and online government services determinants were estimated. Table 19 presents the results. Column (1) shows the results for the general model with *internet\_use* as the dependent variable. In column (2) *gov\_services\_use* is the dependent variable. To implement Chow tests, auxiliary linear models using subsamples of females and males were estimated. For both dependent variables, they pointed to the existence of significant differences. Therefore, we proceeded by estimating models that included interactions between *Male* and other independent variables. In column (3) we report the results for the model with interactions between *Male* and the set of *Education* dummies, with *internet\_use* as the dependent variable. In column (4) we present the results for the model with interactions between *Male* and *Nationality*. Among the considered interaction terms, these were the only cases in which significant results at the 5% level were obtained (the authors will provide the results for the models with other interaction terms upon request).

Table 19. Internet and Online Governmental Services Use: marginal effects at means

Dependent variable:	(1) <i>internet_use</i>	(2) <i>gov_services_use</i>	(3) <i>internet_use</i>	(4) <i>internet_use</i>
Male	0.079*** (0.009)	-0.0002 (0.001)	0.070*** (0.010)	0.077*** (0.009)
Age	0.013*** (0.002)	0.001*** (0.0003)	0.013*** (0.002)	0.013*** (0.002)
Age2	-0.0003*** (0.0003)	-0.00001*** (0.000004)	-0.0003*** (0.00002)	-0.0003*** (0.00002)
Primary	0.218*** (0.014)	0.005*** (0.002)	0.218*** (0.014)	0.220*** (0.014)
Lower Secondary	0.256*** (0.013)	0.007*** (0.002)	0.254*** (0.013)	0.256*** (0.013)
Upper Secondary	0.392*** (0.009)	0.018*** (0.002)	0.389*** (0.009)	0.393*** (0.009)
Tertiary	0.449*** (0.008)	0.051*** (0.007)	0.448*** (0.008)	0.451*** (0.008)
Locality	0.085*** (0.009)	-0.0002 (0.001)	0.086*** (0.009)	0.086*** (0.009)
Employee	0.123*** (0.014)	0.005*** (0.001)	0.130*** (0.014)	0.122*** (0.014)
Student	0.137*** (0.017)	0.011*** (0.003)	0.141*** (0.017)	0.132*** (0.017)
Domestic	0.110*** (0.015)	-0.004*** (0.001)	0.108*** (0.015)	0.103*** (0.015)
Nationality	0.241*** (0.011)	0.015*** (0.002)	0.246*** (0.011)	0.295*** (0.015)
Head Household	0.043*** (0.009)	0.004*** (0.001)	0.043*** (0.009)	0.041*** (0.009)
Male. Primary			-0.382*** (0.111)	
Male. Lower Secondary			0.003 (0.118)	
Male. Upper Secondary			-0.275*** (0.080)	
Male. Tertiary			-0.044 (0.233)	
Male. Nationality				-0.160** (0.081)
Observations	21,546	21,546	21,546	21,546
Groups	5,224	5,224	5,224	5,224
Log-pseudolikelihood	-6431.456	-2029.938	-6421.338	-6429.313

Notes: Multilevel probit regressions included a constant and governorate dummies; robust standard errors in parenthesis;

Multilevel probit coefficient reported for the interaction terms; Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

The results reveal that *Male* is a relevant explanatory variable for the internet but not for the use of online governmental services. Estimates from column (1) indicate that, when all the explanatory variables are equal to their mean, males are approximately 7.9% more likely to use the internet than females. Contrarily, although the descriptive statistics reveal that more males are using online governmental services than females (see Table 17), estimates in column (2) show that *Male* is not a relevant explanatory variable. This implies that the verified gender divide for online governmental services is reflecting other differences between females and males, such as the higher propensity for females to be domestic workers. Lastly, the interaction terms estimated in the models of columns (3) and (4) suggest that the increase in the likelihood of using the internet by obtaining educational degrees (particularly at the primary and upper secondary levels) and by being Omani is higher for females, since the statistically significant interaction terms are negatively signed.

The concavity hypothesis regarding age is corroborated, both for the internet and the online governmental services case. The estimates from column (1) reveal that the likelihood of using the internet increases until approximately 22 years and starts decreasing after that. In the use of online governmental services case, the maximum point of the polynomial function is different, at the age of approximately 50 years, indicating that only at a later phase of life the use probability starts declining.

The higher the education level, the higher the likelihood of using the internet and online governmental services. Individuals with tertiary education are, on average, 44.9% more likely to use the internet and 5.1% more likely to use online governmental services than the ones who have not completed primary education.

Employment status also reveals to influence the probability of using the internet. Students, employed individuals and domestic workers are, by this order of magnitude, more likely to use the internet than the group of *Other* individuals, who include retired, unemployed and disabled people. Employed individuals and students are also more likely to use online governmental services than the group of *Other* individuals. However, domestic workers were found to be even less likely to use online governmental services than the group of the retired, unemployed or disabled.

The results also indicate that individuals living in urban areas are more likely to use the internet than individuals living in rural areas, but the same effect was not found for the probability of using online governmental services. Finally, Omani and heads of households were found to be more likely to use both the internet and online governmental services than, respectively, non-Omani and individuals who declare to have another role in the household, such as spouse, son, daughter, father or mother.



#### 4.6.2. Reasons for not Using the Internet

To study which individual characteristics explain the selection of the most frequent self-reported reasons for not using the internet, multilevel Probit models and marginal effects at means are estimated. These models follow equation (3), with two exceptions: *Age*<sup>2</sup> is used only when it is revealed to be statistically significant; the education and employment status categories are adjusted to avoid the loss of observations whenever necessary. Table 20 presents the results.

In the model of column (1), a dummy variable that is equal to 1 if the individual has less than primary education and 0 otherwise (*Less than Primary*) is used, instead of several education dummies since there are no individuals with more than primary education indicating illiteracy as a reason for not using the internet. In the same model, on the categories for the employment status variable, the students were reallocated to the base category, since there are no students indicating illiteracy as a reason for not using the internet. In model (6) the categorical variable for education was modified, by merging the upper secondary and the tertiary categories, since there are no individuals with tertiary education indicating the lack of knowledge about what the internet is as a reason for not using it.

Regarding gender differences, results indicate that females are, on average, more likely than males to report illiteracy and not being allowed as reasons for not using the internet. By their turn, males are more likely to mention price, the lack of ICT skills, no access, and no need.

Younger individuals are more propense to indicate price, no access, no need or not being allowed to use the internet. Concerning education, several results came up. They reveal that the highest the education level, the higher the probability of not using the internet by reasons than not a knowledge or skill-related barrier. While individuals with less than primary education reveal to be more likely to indicate illiteracy as a reason for not using the internet, individuals with at least primary education are found to be more likely to indicate no need or price. The latter are also less likely to indicate the lack of ICT skills, as a reason for not using the internet.

When it comes to the employment status, when compared to the retired, disabled or unemployed, the employed are more likely to be non-users due to no access. By their turn, students indicate with higher probability no access, no need or not being allowed and with smaller probability the lack of ICT skills and no knowledge about what internet is. At last, domestic workers are found more likely to mention price, no access, and no need and less likely to indicate illiteracy, as well as not being allowed, than the retired, disabled or unemployed.

Table 20. Reasons for not using the internet: marginal effects at means

Dependent variable:	(1) illiteracy	(2) price	(3) ICT skills	(4) no access	(5) no need	(6) no knowledge	(7) not allowed
Male	-0.189*** (0.020)	0.025*** (0.007)	0.083*** (0.020)	0.005* (0.003)	0.141*** (0.021)	-0.001 (0.007)	-0.027*** (0.009)
Age	0.015*** (0.002)	-0.0005*** (0.0002)	0.011*** (0.003)	-0.0003*** (0.0001)	-0.002*** (0.001)	0.002** (0.001)	-0.001*** (0.0001)
Age2	-0.0001*** (0.00002)		-0.0001*** (0.00003)			-0.00002* (0.00001)	
Less than Primary	0.745*** (0.058)						
Primary		0.022*** (0.010)	0.024 (0.026)	-0.003 (0.005)	0.222*** (0.025)	-0.002 (0.009)	-0.005 (0.004)
Lower Secondary		0.013 (0.010)	-0.087** (0.036)	0.008** (0.004)	0.118*** (0.037)	-0.023 (0.012)	-0.051** (0.021)
Upper Secondary		0.018*** (0.009)	-0.106*** (0.025)	0.011** (0.005)	0.202*** (0.029)		0.001 (0.009)
Tertiary		-0.004 (0.019)	-0.228*** (0.053)	0.027 (0.023)	0.267** (0.099)		0.019 (0.029)
Upper Secondary or Tertiary						-0.032*** (0.005)	
Locality	-0.040*** (0.015)	0.012** (0.006)	-0.016 (0.018)	-0.020*** (0.006)	0.005 (0.019)	0.008 (0.006)	0.003 (0.005)
Employee	-0.001 (0.023)	0.004 (0.006)	0.007 (0.025)	0.007** (0.003)	0.031 (0.025)	-0.010 (0.010)	0.003 (0.005)
Student		0.016 (0.013)	-0.216*** (0.028)	0.011** (0.006)	0.207*** (0.038)	-0.038** (0.010)	0.169*** (0.022)
Domestic	-0.059*** (0.019)	0.023*** (0.009)	0.034 (0.024)	0.006** (0.003)	0.142*** (0.023)	-0.008 (0.009)	-0.028** (0.007)
Nationality	0.110*** (0.023)	-0.042*** (0.007)	-0.074*** (0.023)	-0.001 (0.004)	-0.203*** (0.026)	-0.003 (0.009)	0.007 (0.006)
Head Household	-0.039** (0.016)	0.002 (0.004)	0.043*** (0.016)	0.001 (0.002)	0.056*** (0.018)	-0.004 (0.006)	-0.004 (0.003)
Observations	5,933	5,933	5,933	5,933	5,933	5,933	5,933
Groups	3,165	3,165	3,165	3,165	3,165	3,165	3,165
Log-pseudolikelihood	-2456.652	-1110.489	-3014.679	-379.738	-3181.224	-1101.623	3081.141

Notes: Multilevel probit regressions included a constant and governorate dummies; robust standard errors in parenthesis; Statistical significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1; Column (7) reports the results of a linear mixed effects regression, since the multilevel probit estimator was unable to fit the full model

Differences are also found by nationality and role in the household. Omani people are more propense to be non-users due to illiteracy, while non-Omani due to price, lack of ICT skills or no need. Individuals that are not heads of household are more likely to report illiteracy, while heads of household are more likely to indicate the lack of ICT skills and no need as relevant explanations for not using the web.

#### **4.7. Conclusions**

This paper analyses the determinants of the internet and online governmental services use. The results raise serious concerns regarding the digital divide in Oman: the internet is still not used by more than 25% of the sampled individuals, and online governmental services have a quite low use. Education, age, employment status, nationality, the area of residence and the role in the household are important factors for explaining the digital divide, while no need, lack of basic ICT skills and illiteracy are the most frequent explanations for not using the internet.

Gender differences were highlighted in the analysis. The results reveal that males are more likely to use the internet than females, but not online governmental services. Therefore, our results for internet use are in line with the works of Alozie & Akpan-Obong (2017) and Gray *et al.* (2017), who find gender an important predictor of internet use. In contrast, the results for online governmental services follow the idea that gender may act as a confounding variable as in Hilbert (2011). Illiteracy is the main self-report reason for not using the internet among females, while among males, it is no need. This reflects the fact that adult female literacy rate in Oman is amongst the lowest in the GCC (Web Worldwide data). As highlighted by Antonio & Tuffley (2014), social norms are amongst the sources of gender divides. In this study, females were found more likely to indicate not being allowed as a reason for not using the internet and the traditional role of women as domestic workers also reveals to be a source of inequalities between females and males, particularly in the online governmental services use case.

Several signs of progress and innovations towards higher internet access and e-gov development exist. However, if countries like Bahrain and the United Arab Emirates are displaying large progresses in terms of connectivity and internet use, several efforts still must be made to increase usage and connectivity and diminish digital inequalities in the region, particularly in Oman. The results suggest that investing in education and promoting participation in the labour market are effective ways of doing so, especially in a country where close to half of the females are domestic workers. Another

concern should be the gap between Omani and non-Omani, which can be motivated for economic reasons, but also by cultural or language barriers. Finally, more efforts could be made to improve the connectivity in rural areas. Having the lowest regional scores in terms of internet usage and high-speed connectivity, Oman, Kuwait and Saudi Arabia should be particularly keen on conducting these types of investments.

A final note to stress some pitfalls of our research. As a part of the *Comprehensive Households Survey*, the *Access to, and Use of, ICT by Households and Individuals*, is part of a lengthy questionnaire, which answering to is a heavy task for the respondents. Additionally, the survey does not collect variables related to income and individual psychological characteristics, which the literature identifies as relevant for explaining internet and online governmental services usage. Forthcoming editions of the survey should consider taking those variables into account. Finally, our conclusions are based on a sample of a single country, and the findings must be read within the context of the region and the country. In particular, generalizing these results for the developed world should be avoided, and even the generalization for other developing countries should be preceded by a comparative analysis of those countries with Oman.

## 5. Cost Overruns and Delays in Public Procurement

### 5.1. Introduction

Public procurement is a critical aspect of the public sector, playing a vital role in ensuring that the public sector receives quality goods and services at a reasonable cost. It involves the acquisition of goods, services, and works from external sources, ensuring that government agencies have the resources they need to carry out their operations. Therefore, it directly affects public spending and the GDP, accounting for up to 14% of the GDP in the European Union member states (European Commission, 2016) and 15% worldwide (World Bank, 2021). It is also fundamental for the efficiency and transparency of the public sector, as procurement mechanisms are claimed to affect growth and development, corruption, the quality of public service delivery, citizen participation, engagement, and trust (World Bank, 2021). Public procurement also plays a role in achieving broader policy objectives, such as supporting the local economies or social and environmental goals, by specifying requirements or social clauses in the contracts (e.g., Peck & Cabras, 2011; Testa *et al.*, 2012; Nijaki & Worrel, 2012; Mélon, 2020; Gyori, 2022; Manta *et al.*, 2022).

Contract execution is an essential aspect of public procurement for the efficiency and effectiveness of the public sector. A proper contract execution ensures that the terms of an agreement are fulfilled and that the vendor is held accountable for the goods and services provided, which is especially materially relevant in the case of large contracts and projects, such as the ones usually involved in the construction of public infrastructure. It also helps to prevent disputes and delays, which can significantly impact the delivery of public services. However, contract execution elements have been less researched than other procurement outcomes, such as contract prices and awarding.

Over the most recent decades, the digitalisation of public procurement procedures has been widely discussed in this field. The technological developments and the transition towards electronic procurement systems have been demonstrated to be capable of improving procurement performance and efficiency (e.g., Quesada *et al.*, 2010; Vaidya & Campbell, 2016) and increasing the transparency and accountability of the procurement process, ultimately leading to less corruption (e.g., Neupane *et*

*et al.*, 2012; Neupane *et al.*, 2014; Puspita & Gultom, 2022). The Portuguese case has been discussed in the literature as an excellent example in Europe concerning procurement procedures, namely by its use of ICT (Ferreira & Amaral, 2016). However, quantitative studies using econometric methods regarding public procurement outcomes and contract execution using Portuguese data are scarce.<sup>57</sup> The analysis of Camões and Cerejeira (2020), which studies political spillovers in contract awarding using data from *base.gov*, constitutes an exception.<sup>58</sup> In this analysis, we intend to provide a better understanding of the Portuguese public procurement landscape by econometrically studying which types of procedures, contracts, contractors, and vendors' characteristics lead to better execution outcomes.

Therefore, this article aims to contribute to the discussion on the determinants of procurement outcomes by studying procedural and contractual characteristics that influence cost overruns and delays using data from Portuguese public procurement. The article is structured as follows. Section 5.2. reviews the literature on public contract execution and public procurement outcomes. Section 5.3. briefly describes the Portuguese public procurement context and previous studies using data from Portugal. Section 5.4. describes the data. Section 5.5. presents the empirical methodology. Section 5.6. describes the results. Section 5.7. discusses the results and concludes.

## **5.2. Literature Review**

Factors affecting different procurement outcomes, such as contract prices, awarding, and execution, have been studied over the last two decades from several angles by focusing on different elements of procurement, like awarding procedures, contractor discretion, oversight, corruption, reputation, auction design, or other characteristics, namely the impact of electronic procedures.

Contract prices were the focus of several studies. Raventos & Zolessi (2009) analysed the Chilean public health sector, Soudek & Skuhrovec (2013) the Czech electricity and gas markets, Onur *et al.* (2012) the Turkish government auctions, and Pavel and Sičáková-Beblavá (2013) building and information technology sector contracts in Slovak cities. They concluded that contract prices tend to be lower when awarding procedures are open, auctions are electronic, the number of bidders is higher, and there is openness to foreign bids. They were also shown to depend on the type of contractor, with

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<sup>57</sup> The impacts of public electronic procurement in the Portuguese context were analyzed by Costa *et al.* (2013), Ferreira *et al.* (2014) and Ferreira & Amaral (2016) through the implementation of surveys, namely to public authorities.

<sup>58</sup> One of this study's main conclusions is that Portuguese municipalities are more likely to award contracts to firms that previously won contracts in municipalities with the same political colours.

central governments paying higher prices than semi-autonomous governmental agencies (Bandiera *et al.*, 2009).

Factors influencing contract awarding and how they relate to capture and political connections have also been the subject of many studies. Discretion in vendor selection can affect contract awarding (Albano *et al.*, 2008; Coviello & Gagliarduci, 2017; Coviello *et al.*, 2018a). It can lead to more contracts being awarded repeatedly to the same vendors, a higher share of contracts and larger contracts being awarded to politically connected firms (Baltrunaite *et al.*, 2021; Boland & Godsell, 2021), to the manipulation of procurement values (Palguta & Pertold, 2017) and efficiency losses and gains for high-skilled and low-skilled public buyers, respectively (Buccioli *et al.*, 2020). Under less restrictive procurement processes, firms' donations to political parties can also induce favouritism in procurement allocation (Titl & Geys, 2019).<sup>59</sup> Additionally, a study of Italian data has shown that in contracts from local governments, more time in office by the mayors leads to collusion between the local government and some favoured local bidders, worsening procurement outcomes concerning prices (Coviello & Gagliarduci, 2017).

As abovementioned, corruption, manipulation, reputation, and auction design were also studied in the context of procurement outcomes, with estimates based on Tirole's (1986) model suggesting that the losses from capture on procurement represent between 4.14 and 9.93 per cent of the world procurement spending (Auriol, 2006). Corruption at the municipal level was shown to amplify the impact of a project's complexity on the probability of procuring the project with a negotiated procedure. At the same time, complexity also leads to longer delays in the execution and a higher likelihood of awarding local firms (Baldi *et al.*, 2016). Evidence from the Indian software industry also suggests that reputation affects procurement outcomes, with less reputable firms being less likely to obtain contracts and more likely to pay higher shares of overruns (Banerjee & Duflo, 2000).

When targeting reducing corruption risks in procurement, horizontal transparency, i.e., providing information to all parties involved in the bidding process, has been revealed to be an effective strategy (Bauhr *et al.*, 2019). Larger contracts, higher GDP *per capita*, and trade-to-GDP ratio in the host country were also revealed to be associated with a higher likelihood of cross-border awarding of contracts (Kutlina-Dimitrova & Lakatos, 2016), while regulatory protection to incumbents and barriers to foreign direct investment was shown to have the opposite effect. However, when analysing procurement practices, laws, and outcomes, Bosio *et al.* (2022) show that stricter laws correlate with improved procurement outcomes only in countries with low public sector capacity, while administrative

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<sup>59</sup> Favoritism to politically connected firms may result in worse procurement outcomes, namely higher prices (Baranek & Titl, 2020).

hurdles and corruption appear to play minimal roles in explaining competition for government procurement contracts (Kang & Miller, 2022). Risk management and assessment strategies also reveal shortcomings as an anti-corruption strategy in public procurement (Diaz *et al.*, 2022).

Regarding auction design, it was shown that restricted auctions could generate savings in the context of small contracts, not increasing corruption and favouritism (Chever *et al.*, 2017), while studies using data from the Californian Department of Transports (Lewis & Bajari, 2011; Bajari *et al.*, 2014) concluded that scoring auctions could improve the pace of contract execution while renegotiating contracts can generate costs that account from 7.5 to 14 per cent of the winning bid value. Electronic auctions are also perceived as more capable of making tenderers' truth-telling the dominant strategy, which may ensure that contracts are assigned to the most competitive providers more often, ensuring the best value for money, improving transparency, and potentially reducing costs related to the handling and evaluation of bids, communication, and industrial and business espionage (Soudry, 2004).

Other studies have also explored the effect of electronic procedures on procurement outcomes.<sup>60</sup> Using a difference-in-difference strategy, Lewis-Faupel *et al.* (2016) compared procurement outcomes related to public works in provinces and states of India and Indonesia before and after they transitioned to fully electronic procurement, concluding that the introduction of electronic procedures led to fewer delays in the execution of contracts and a broader distribution of winning bids, while Singer *et al.* (2009) estimated that electronic procedures lead to a decrease of nearly 3% in procurement costs to the Chilean state in 2006 and 2007. Electronic procurement has also been shown to be associated with perceptions of improved compliance with contracts, reduced search costs and prices, a smaller number of suppliers (Croom & Brandon-Jones, 2005; Croom & Brandon-Jones, 2007), procurement efficiency (Vaidya & Campbell, 2016), increased transparency and accountability (Neupane *et al.*, 2012; Neupane *et al.*, 2014) and benefits in terms of information sharing, partner relationships, and supply chain integration (Chang *et al.*, 2013).

Lastly, a few articles addressed contract execution outcomes, such as delays, cost overruns, and renegotiations. Using data from US federal procurement, Decarolis *et al.* (2020) concluded that time delays, cost overruns, and the occurrence of renegotiations are affected by bureaucratic competence. Competition was shown to have a negative or neglectable effect (mainly for delays) on these outcomes (Calvo *et al.*, 2019), while project complexity was shown to lead to longer delays in execution (Baldi *et al.*, 2016). Court inefficiency has also been revealed to be a factor that can

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<sup>60</sup> See Schoenherr & Tummala (2007) for an early survey on literature regarding electronic procurement.



negatively influence procurement outcomes (Coviello *et al.*, 2018b). The discussion on the effects of discretion on procurement outcomes also extends to contract execution. If, on the one hand, as previously mentioned, discretion increases the probability that the same firms are awarded contracts repeatedly by the same public entities, on the other hand, that bias in awarding does not appear to deteriorate contract execution (Coviello *et al.*, 2018a). The present study aims to enrich the discussion and knowledge of procurement execution outcomes.

### **5.3. Public Procurement in Portugal**

The Portuguese Public Contracts Code (PCC) was introduced in 2008, making certified electronic procurement platforms and authentication processes that use qualified digital signatures compulsory.<sup>61</sup> Public procurement has become fully electronic since November 2009 for any open, restricted, or negotiated process, making Portugal one of the pioneers in this matter.

The public procurement rules specified on the PCC apply to all public administration, the central government, local and regional governments, public institutes, foundations, and associations. Associations of which one or more public entities are part are also subject to the PCC, depending on some conditions.<sup>62</sup> The PCC is also applicable to the central, regional, and local government's corporate sector whenever the firms act outside the principles of the market and free competition and to private entities operating in the sectors of water, energy, transportation, and postal services, whenever those entities have special or exclusive rights, including monopolies.

The PCC contemplates direct awarding, public tenders, restricted tenders, negotiation procedures, and competitive dialogues and applies to contracts of public works, the concession of public works, the concession of public services, the purchase of services, and the rental or acquisition of movable assets. Direct awarding is a non-competitive procedure in which the contractor invites a vendor to submit a proposal. This procedure can currently be applied in public works below 30,000 euros, purchases of services and rental or acquisitions of movable assets below 20,000 euros, and contracts below 50,000 euros for other contracts. The three thresholds are higher if the contractor does a previous consultation with at least three potential vendors, until 150,000, 75,000, and 100,000

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<sup>61</sup> The PCC was established by decree-law number 18/2008, at *Diário da República* number 20/2008.

<sup>62</sup> Namely, being mostly financed by one or more of these entities, being subject to their managerial control, or having an administrative or executive body in which they have a majority.

euros, respectively.<sup>63</sup> Additionally, in cases of imperative urgency, when there is only one supplier or provider, or when a previous competition has become deserted, the PCC allows the direct awarding of contracts of any value. The public tender is a competitive procedure published in *Diário da República*<sup>64</sup>, in which the bidders can submit proposals without technical or financial assessment or prerequisites. The legislation also encompasses the possibility of urgent public tenders, according to Article 155 of the PCC. These are also published in *Diário da República* but have a shorter deadline for bids and different thresholds for the maximum value of the contracts depending on their type. Restricted tenders are also competitive procedures published in *Diário da República* but have two phases: qualification, which assesses if the bidders fill the prerequisites defined by the contractor; and adjudication, in which the proposals are submitted. The negotiation procedures are similar to the restricted tenders but allow the qualified bidders to improve their proposals through a negotiation phase. Lastly, competitive dialogue is a procedure used when the contractors do not know how to address their needs and can engage in a dialogue with a few qualified bidders before establishing the terms of reference.

Seven platforms operate in the Portuguese market. They must support, among others, functions such as the receipt of offers and applications, the opening of tenders and applications, the provision of information to competitors, the evaluation of proposals, the characterisation of the procedure, the publication of the process, the receipt of requests for clarification, the dispatch of answers to clarification and rectification of the parts of the procedure, and the availability of parts of the procedure to be consulted (Ferreira & Amaral, 2016). The information concerning all contracts made by public entities is then aggregated and made publicly available on the platform *base.gov*, under the responsibility of the *Instituto dos Mercados Públicos do Imobiliário e da Construção*. This portal centralises the most important information relative to all contracts, pre-contractual procedures, and announcements of pre-contractual procedures, except for direct awarding procedures, for which only the contractual information is mandatory, and it is not required to make previous announcements.

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<sup>63</sup> These thresholds were established by law-decree 111-B/2017 of August 31<sup>st</sup>, 2017. When the PCC was introduced, the thresholds described here as applicable for procedures with previous consultation (i.e., 150,000, 75,000, and 100,000 euros) were the ones applicable to all direct awarding procedures, and those are the thresholds that apply during most of the sample period.

<sup>64</sup> *Diário da República* is the official gazette of Portugal.

## 5.4. Data

This paper uses data retrieved from *base.gov*, the platform that aggregates the information concerning all contracts made by Portuguese public entities, as explained in the previous section. The complete dataset covers the contracts published in the *base.gov* platform from August 2008 to March 2018.

The database includes a description of each contract, the names of the contractor and vendor involved in the contract and the competitors, the type of contract, the type of contractual procedure, the object of the contract, the awarding cost and the final cost associated with a contract, the local of execution, the dates of publication of the contract on the platform and of celebration of the contract, the contractual deadline, the closing date, and other required legal details regarding the contract<sup>65</sup>.

As the aim is to study the execution of the contracts, the dependent variables of the models are related to cost overruns and delays in the execution<sup>66</sup>. Therefore, two main variables are studied:

- *costoverrun* is a ratio of the difference between the final cost and the awarding cost over the awarding cost associated with a contract.
- *delay* is a ratio of the difference in the effective work length (i.e., the difference, measured in days, between the effective closing date and the beginning of the contract) and the contractual work length (i.e., the difference between the contractual deadline, measured in days, and the beginning of the contract) over the contractual work length.

Given the pronounced skewness of the distribution of these variables, which have a very high proportion of values equal to 0, two-part models will be used in the empirical analysis (more details in section 5.5.). To estimate those models, two other variables were created:

- *costoverrun\_dummy* is a dummy variable equal to 1 if *costoverrun* is higher than 0 and equal to 0 otherwise.
- *delay\_dummy* is a dummy variable equal to 1 if *delay* is higher than 0 and equal to 0 otherwise.

The analysis explores the influence of procedural, contractual, contractor and vendor entity characteristics on the execution of the contracts. The dummy variable *incumbency* is equal to 1 if the vendor of a given contract was already awarded by the contractor of that contract during our sample period; *logprice* measures the logged contractual price (which is measured in current euros); *competitors* indicates the number of bidders (other than the vendor) in the contract awarding

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<sup>65</sup> For example, the document's ID, the contract's legal grounding, or justifications for changes in the execution time and cost overruns.

<sup>66</sup> Cost overruns and delays were already used in previous studies to measure contract performance (e.g., Coviello *et al.*, 2018 a); Calvo *et al.*, 2019).

procedure; *location*' is a vector of dummy variables that identify the municipality in which the contract was executed<sup>67</sup>; *multilocation* is a dummy variable that is equal to 1 if the contract execution involved more than one municipality; and *year*' is a vector of dummy variables that identify the year in which the contract was awarded.

The *typeofcontract* is a set of dummy variables that classify the type of contract into one of seven types: purchase of services, acquisition of movable assets, rental of movable assets, public works, concession of public works, concession of public services, and others. The *typeofcontractor* is a set of dummy variables that identify the type of contracting authority as belonging to one of the following eight categories: local government, regional government, central government, municipally owned enterprises, state-owned enterprises, public institutes, foundations, and others.<sup>68</sup> The classification of each contractor was based on keywords that are present in the contractor's name in the database. Auxiliary dummy variables were created for each keyword considered based on whether that keyword was on the contractor's name. The dummy variables considered in the *typeofcontractor* set were then created based on the auxiliary dummy variables.<sup>69</sup>

Table 21 shows the summary statistics for the abovementioned variables. Outliers were not included in the analysis. Given the skewness of their distributions and the very high proportion of zeros, a distribution with only the positive values of the dependent variables was considered for the purpose of identifying outliers. Values above the percentile 95 of those distributions were considered outliers.<sup>70</sup>

The table shows that delays are more frequent than cost overruns in Portuguese public procurement, as they occur in approximately 46% of the observed contracts, while cost overruns occur in approximately 4% of the contracts. Purchase of services and acquisition of movable assets are the most common types of contracts. At the same time, local governments, state-owned enterprises, and public institutes are the contractors who award more contracts.

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<sup>67</sup> Portugal has and 308 municipalities, 278 in the mainland and 30 in the two autonomous regions.

<sup>68</sup> Examples of the contractors in the "others" include independent administrative entities, public associations, charities, the military and security forces.

<sup>69</sup> For example, to create the dummy variable for local government, some of the auxiliary dummy variables used were based on whether the keywords "câmara municipal", "junta de freguesia", "associação de municípios" or "administração local" was in the contractor's name, while for public institutes, the acronym "i.p." (or variations of it) is, in most of the cases, present in the contractor's name in the database.

<sup>70</sup> The threshold values for an observation to be considered an outlier were 88.75% for *costoverrun* and 26% for *delay*. An alternative to the percentile 95 would be to consider the  $Q3 + 1.5 \times \text{Interquartile range}$  rule, leading to lower thresholds and a higher loss of observations.

Table 21. Summary Statistics

	<b>Mean</b>	<b>Std Dev</b>	<b>n</b>	<b>min</b>	<b>max</b>	
<i>costoverrun</i>	0.063	1.738	313,483	0	88.750	
<i>delay</i>	1.282	3.371	275,660	0	26.000	
<i>costoverrun_dummy</i>	0.041	0.198	313,483	0	1	
<i>delay_dummy</i>	0.464	0.499	275,660	0	1	
<i>incumbency</i>	0.656	0.475	813,814	0	1	
<i>competitors</i>	0.505	1.818	813,814	0	70	
<i>logprice</i>	8.985	2.020	811,133	-4.605	18.721	
<i>multilocation</i>	0.037	0.190	762,898	0	1	
<i>public_tender</i>	0.059	0.236	821,141	0	1	
	<b>Mean</b>	<b>Std Dev</b>	<b>n</b>	<b>min</b>	<b>max</b>	<b>Frequency</b>
<i>Type of Contract</i>						
<i>purchase of services</i>	0.431	0.495	756,800	0	1	325,632
<i>acquisition of movable assets</i>	0.413	0.492	756,800	0	1	312,723
<i>rental of movable assets</i>	0.008	0.090	756,800	0	1	6,150
<i>public works</i>	0.134	0.341	756,800	0	1	101,731
<i>concession of public works</i>	0.002	0.040	756,800	0	1	1,232
<i>concession of public services</i>	0.001	0.036	756,800	0	1	1,002
<i>others</i>	0.011	0.104	756,800	0	1	8,330
<i>typeofcontractor</i>						
<i>local government</i>	0.335	0.472	813,814	0	1	273,025
<i>regional government</i>	0.016	0.125	813,814	0	1	12,920
<i>central government</i>	0.042	0.200	813,814	0	1	33,870
<i>municipally-owned enterprise</i>	0.045	0.207	813,814	0	1	36,530
<i>state-owned enterprise</i>	0.200	0.400	813,814	0	1	162,480
<i>public institute</i>	0.172	0.172	813,814	0	1	140,266
<i>foundation</i>	0.020	0.139	813,814	0	1	16,092
<i>other</i>	0.170	0.376	813,814	0	1	138,631

Notes: The number of observations for each variable varies based on missing data on the original data source, the portal *base.gov*.

## 5.5. Methodology

As previously mentioned, we study both cost overruns and delays in the execution of contracts. Given the skewness of our dependent variables<sup>71</sup>, two-part models will be used to estimate the regressions. As Boulton & Williford (2018) discussed in detail, simple linear regressions and other common methods are based on assumptions that fail to be satisfied in skewed data and address questions of interest when modelling semicontinuous outcomes. Amongst other common approaches to deal with skewed continuous data, such as variable transformations or the Tobit model, the two-part model is considered the most appropriate to deal with skewed continuous data that contains true zeros (e.g., Min & Agresti, 2002; Eisenberg *et al.*, 2015; Boulton & Williford, 2018)<sup>72</sup>.

Two-part models consist of breaking the regressions into two, assuming that the observations have two distinct data-generation processes: the process that determines if an individual has a zero or a nonzero outcome and the process that determines the value for an individual in the case that it differs from 0 (Olsen & Schafer, 2001; Neelon *et al.*, 2016). The first part estimates a model to determine which factors may explain whether the variable equals 0 or not. The second part estimates a model using only the nonzero observations of the dependent variables to determine the factors that may explain the size of the cost overruns and delays.

The baseline version of the first-part models is represented by equations (4) and (5):

$$\begin{aligned} \text{costoverrun\_dummy}_i = & \beta_0 + \beta_1 \text{incumbency}_i + \beta_2 \text{competitors}_i + \beta_3 \log \text{price}_i + \\ & \theta \cdot \text{typeofcontract}'_i + \phi \cdot \text{typeofcontractor}'_i + \lambda \cdot \text{location}'_i + \uparrow \cdot \text{year}'_i + \varepsilon_i \quad (4) \end{aligned}$$

$$\begin{aligned} \text{delay\_dummy}_i = & \beta_0 + \beta_1 \text{incumbency}_i + \beta_2 \text{competitors}_i + \beta_3 \log \text{price}_i + \theta \cdot \text{typeofcontract}'_i + \\ & \phi \cdot \text{typeofcontractor}'_i + \lambda \cdot \text{location}'_i + \uparrow \cdot \text{year}'_i + \varepsilon_i \quad (5) \end{aligned}$$

where  $i$  represents the contract, *costoverrun\_dummy*, and *delay\_dummy* are the dependent variables. *incumbency*, *competitors*, *logprice*, *typeofcontract'*, *typeofcontractor'*, *location'*, and *year'* are the

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<sup>71</sup> As seen in Table 21, *costoverrun* has a proportion of approximately 96% of values equal to 0, and *delay* has a proportion of approximately 54% of values equal to 0.

<sup>72</sup> The Tobit model is more appropriate for censored outcomes.

explanatory variables or vectors of explanatory variables of the model, as explained in the previous section.  $\beta_0, \beta_1, \beta_2, \beta_3, \theta, \phi, \lambda,$  and  $\tau$  are the coefficients and vectors of coefficients to be estimated. Lastly,  $\varepsilon$  is the error term. These models are estimated using logit, and the average marginal effects are reported in the results section. As there is no information prior to the beginning of the dataset relative to which vendors and contracts had celebrated contracts in the past, it is possible that in the first periods of the dataset, there are incumbent vendors who were not identified as such due to the absence of prior information. Therefore, the regressions were estimated without including the contracts from 2008 and 2009 to minimise that potential limitation.

The second-part models can be represented by equations (6) and (7). The nonzero values distribution of both dependent variables exhibits positive skewness, so the logarithmic transformation is applied in these regressions. Figure 5 presents histograms of the distributions.

$$\log\text{costoverrun}_i = \beta_0 + \beta_1\text{incumbency}_i + \beta_2\text{competitors}_i + \beta_3\log\text{price}_i + \theta.\text{typeofcontract}'_i + \phi.\text{typeofcontractor}'_i + \lambda.\text{location}'_i + \tau.\text{year}'_i + \varepsilon_i \text{ if } \text{costoverrun\_dummy}_i > 0 \quad (6)$$

$$\log\text{delay}_i = \beta_0 + \beta_1\text{incumbency}_i + \beta_2\text{competitors}_i + \beta_3\log\text{price}_i + \theta.\text{typeofcontract}'_i + \phi.\text{typeofcontractor}'_i + \lambda.\text{location}'_i + \tau.\text{year}'_i + \varepsilon_i \text{ if } \text{delay\_dummy}_i > 0 \quad (7)$$

where conditions  $\text{costoverrun\_dummy} > 0$  and  $\text{delay\_dummy} > 0$  specify that these models will only include the observations of contracts with cost overruns or delays, respectively. The second part regressions are estimated by ordinary least squares.

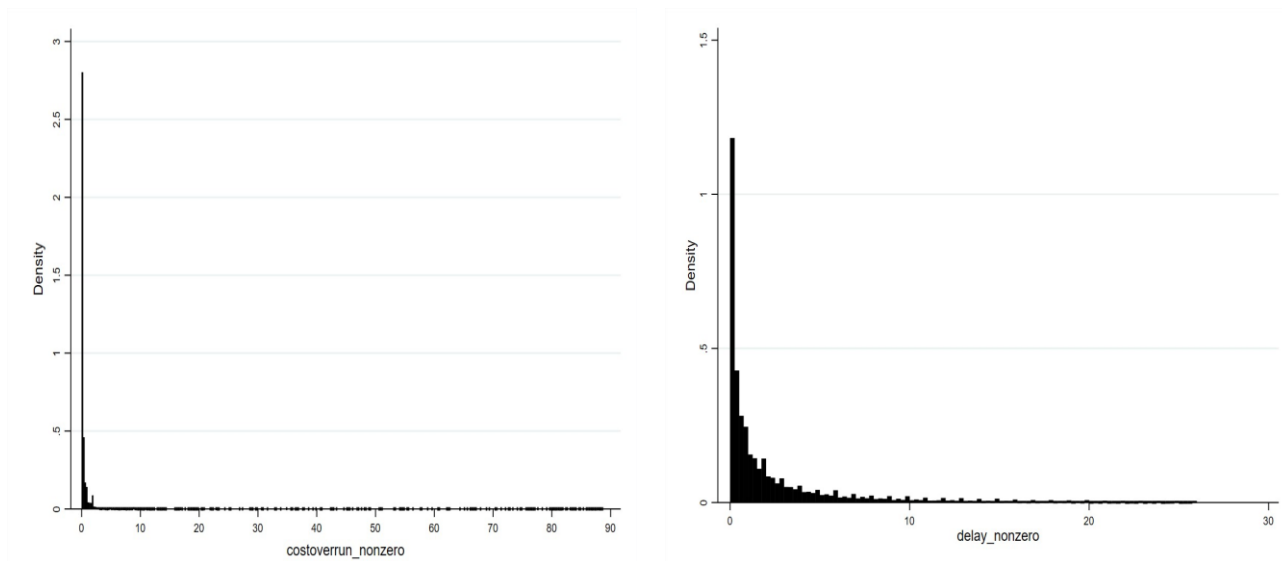


Figure 5. Distribution of the nonzero part of the dependent variables

This study also analyses samples of only direct awarding or public tenders, Portugal's two most common awarding procedures, representing nearly 95% of the sample. As there are apparent differences between the two procedures, namely concerning their regulatory frameworks, the role of competition and the bidding process, it is relevant to understand if factors such as vendor's incumbency or the presence of competitors have different impacts on the contract execution depending on the awarding procedure followed. When analysing public tenders, some regressions also include the dummy variable *urgenttender*. This variable equals 1 if a public tender was urgent, following Article 155 of the PCC.<sup>73</sup> Table 22 shows the average values of the main variables used in this analysis in contracts awarded by direct awarding and through a public tender. It is possible to observe that both cost overruns and delays are more frequent on public tenders. Public tenders also exhibit higher average contractual prices, more competitors in the bidding process, and more contracts executed in multiple locations. This points to a higher complexity in the contracts awarded by public tender. Purchases of services are relatively more frequent in direct awarding contracts. At the same time, acquisitions and rentals of movable assets and public works represent a higher share of the total number of contracts in public tenders. Lastly, on direct awarding, the central government and public institutes are contractors that are relatively more frequent in direct awarding when compared to public tenders. In contrast, contracts of local governments, state-owned enterprises and foundations represent a higher share of the total number of contracts in public tenders.

<sup>73</sup> The portal base.gov does not directly report if a public tender was done through an urgent procedure. Therefore, this variable was constructed based on whether article 155 of the PCC was mentioned in the basis of the contract.



Table 22. Summary statistics by awarding procedure

	<i>Direct Awarding</i>			<i>Public Tender</i>				
	<b>Mean</b>	<b>Std Dev</b>	<b>n</b>	<b>Mean</b>	<b>Std Dev</b>	<b>n</b>		
<i>costoverrun</i>	0.059	1.685	281,168	0.114	2.460	16,120		
<i>delay</i>	1.352	3.491	245,001	1.104	2.435	14,951		
<i>costoverrun_dummy</i>	0.038	0.191	281,168	0.098	0.297	16,120		
<i>delay_dummy</i>	0.465	0.499	245,011	0.634	0.482	14,951		
<i>incumbency</i>	0.647	0.478	723,608	0.648	0.478	48,293		
<i>logprice</i>	8.884	1.890	721,598	10.973	2.150	47,721		
<i>competitors</i>	0.324	1.035	723,608	3.031	5.381	48,293		
<i>multilocation</i>	0.030	0.172	672,692	0.086	0.280	48,293		
	<b>Mean</b>	<b>Std Dev</b>	<b>n</b>	<b>Frequency</b>	<b>Mean</b>	<b>Std Dev</b>	<b>n</b>	<b>Frequency</b>
<i>typeofcontract</i>								
<i>purchase of services</i>	0.456	0.498	666,594	304,144	0.287	0.452	48,293	13,840
<i>acquisition of movable assets</i>	0.390	0.488	666,594	260,256	0.420	0.494	48,293	20,279
<i>rental of movable assets</i>	0.007	0.082	666,594	4,489	0.023	0.149	48,293	1,092
<i>public works</i>	0.132	0.339	666,594	88,040	0.256	0.436	48,293	12,344
<i>concession of public works</i>	0.002	0.042	666,594	1,204	0.001	0.023	48,293	25
<i>concession of public services</i>	0.001	0.034	666,594	751	0.005	0.071	48,293	243
<i>others</i>	0.012	0.107	666,594	7,710	0.010	0.098	48,293	470
<i>typeofcontractor</i>								
<i>local government</i>	0.347	0.476	723,608	250,810	0.410	0.492	48,293	19,818
<i>regional government</i>	0.016	0.126	723,608	11,645	0.017	0.131	48,293	841
<i>central government</i>	0.043	0.204	723,608	31,324	0.016	0.125	48,293	767
<i>municipally-owned enterprise</i>	0.045	0.207	723,608	32,604	0.045	0.206	48,293	2,150
<i>state-owned enterprise</i>	0.179	0.383	723,608	129,334	0.226	0.418	48,293	10,900
<i>public institute</i>	0.173	0.378	723,608	124,916	0.132	0.339	48,293	6,387
<i>foundation</i>	0.020	0.140	723,608	14,473	0.031	0.172	48,293	1,481
<i>other</i>	0.178	0.382	723,608	128,504	0.123	0.329	48,293	5,949

## 5.6. Results

This section presents and comments on the results and is divided into two. Section 5.6.1. presents the first- and second-part results for cost overruns, first for the whole sample and subsamples of contracts awarded by direct awarding and public tenders. Section 5.6.2. does the same for delays. Robustness tests, described below, were implemented in both subsections.

### 5.6.1. Results for cost overruns

Table 23 presents the marginal effects of the first part of estimations for cost overruns. Columns (1) and (2) report the results for the entire sample. In column (1), a more parsimonious model, following equation (4), is presented. In column (2), the *multilocation* and *publictender* dummy variables are added to the model as further controls for contract execution complexity and type of procedure. Columns (3) and (4) do the same for the contracts awarded by direct awarding, except adding the *publictender* dummy, and columns (5) and (6) for the contracts awarded through a public tender. In column (6), the *urgenttender* dummy variable is added to the model.

The results reveal that incumbency, price and competition are all factors that affect the likelihood of a cost overrun to occur. When contractors and vendors have celebrated contracts between themselves in the past, cost overruns are, on average, more likely to occur. However, that effect is only observable in contracts awarded by direct awarding, in which vendor discretion is higher. On those, contracts awarded to incumbent vendors are found to be associated with a 0.2% higher probability of cost overruns. No statistically significant relationship exists between vendor incumbency and cost overruns on contracts awarded through public tenders. Contracts with higher prices are found to be more likely to generate cost overruns in contracts awarded by both types of procedures. Competition is found to be associated with different outcomes depending on the type of procedure. On contracts awarded by direct awarding, additional bidders are revealed to be associated with a 0.5% higher likelihood of cost overruns. This result might capture the effect of contract complexity, as in direct awarding, the average number of additional bidders is 0.324, and 83.4% of the contracts are awarded without additional bidders, and contracts in which there are additional bidders have, on average, higher contractual prices. In contrast, more competitive bidding processes are revealed to have no effect on cost overruns on contracts awarded by public tender.

Table 23. First part regressions for cost overruns – marginal effects

dep variable: <i>costoverrun_dummy</i>	All		Direct Awarding		Public Tender	
	(1)	(2)	(3)	(4)	(5)	(6)
incumbency	0.00218*** (0.000801)	0.00186** (0.000801)	0.00196** (0.000821)	0.00193** (0.000821)	0.00168 (0.00483)	0.00118 (0.00484)
logprice	0.00588*** (0.000251)	0.00473*** (0.000248)	0.00347*** (0.000262)	0.00342*** (0.000261)	0.00871*** (0.00183)	0.00867*** (0.00183)
nr_competitors	0.00276*** (0.000136)	0.00200*** (0.000146)	0.00532*** (0.000214)	0.00533*** (0.000214)	-0.000685 (0.000458)	-0.000653 (0.000459)
<i>multilocation</i>		0.00579*** (0.00193)		0.00673*** (0.00211)		0.0283*** (0.00987)
<i>publictender</i>		0.0214*** (0.00141)				
urgenttender						0.0269* (0.0154)
<i>Type of Contract (purchase of services is the base category):</i>						
acquisition of movable assets	-0.00447*** (0.000799)	-0.00486*** (0.000803)	-0.00395*** (0.000829)	-0.00377*** (0.000829)	-0.0586*** (0.00556)	-0.0581*** (0.00551)
public works	0.0201*** (0.00131)	0.0196*** (0.00131)	0.00893*** (0.00132)	0.00918*** (0.00132)	0.0989*** (0.00915)	0.104*** (0.00928)
concession of public works	-0.00499 (0.00924)	-0.00296 (0.00982)	-0.00273 (0.00956)	-0.00255 (0.00958)	-	-
concession of public services	0.000327 (0.00958)	0.000783 (0.00970)	-0.00135 (0.00959)	-0.00137 (0.00955)	0.00214 (0.0642)	0.000663 (0.0617)
rental of movable assets	-0.000633 (0.00419)	-0.00248 (0.00403)	0.00261 (0.00488)	0.00265 (0.00488)	-0.0185 (0.0177)	-0.0180 (0.0177)
others	0.0206*** (0.00554)	0.0188*** (0.00543)	0.0214*** (0.00593)	0.0215*** (0.00593)	-0.00410 (0.0246)	-0.00489 (0.0242)
<i>Type of Contractor (local government is the base category):</i>						
regional government	0.00974*** (0.00337)	0.00885*** (0.00330)	0.00818** (0.00350)	0.00725** (0.00341)	0.0219 (0.0206)	0.0188 (0.0202)
central government	-0.0144*** (0.00157)	-0.0146*** (0.00157)	-0.0134*** (0.00150)	-0.0136*** (0.00149)	-0.0280 (0.0242)	-0.0301 (0.0238)
municipally-owned enterprise	0.00678*** (0.00142)	0.00711*** (0.00144)	0.00747*** (0.00147)	0.00741*** (0.00148)	-0.00574 (0.0103)	-0.00762 (0.0104)
state-owned enterprise	0.0265*** (0.00142)	0.0256*** (0.00141)	0.0261*** (0.00147)	0.0254*** (0.00147)	0.0415*** (0.00854)	0.0356*** (0.00855)
public institute	0.000798 (0.00107)	-0.000216 (0.00106)	0.000130 (0.00107)	-0.000179 (0.00107)	0.00596 (0.00945)	0.000623 (0.00941)
foundation	0.0223*** (0.00334)	0.0197*** (0.00324)	0.0275*** (0.00372)	0.0273*** (0.00372)	0.0194 (0.0190)	0.0173 (0.0190)
other	0.0431*** (0.00130)	0.0438*** (0.00131)	0.0412*** (0.00129)	0.0410*** (0.00129)	0.0139 (0.00937)	0.0128 (0.00945)
Observations	282,928	282,928	251,727	251,727	14,421	14,421
Pseudo R2	0.0673	0.0698	0.0645	0.0646	0.192	0.194
Log-likelihood	-44627	-44506	-37881	-37876	-3709	-3703
AIC	89632	89394	76132	76124	7726	7718
SIC	91627	91409	78063	78065	8893	8900

Notes: All regressions were estimated by Logit and included municipality and year dummy variables; robust standard errors in parenthesis; significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1; the coefficient for concession of public works is not reported in the models for public tenders due to lack of observations

Another variable that proxies contract complexity is *multilocation*. The results reveal that when a contract is executed in more than one municipality, cost overruns are 0.7% more likely to occur on direct awarding contracts and 2.8% more likely in contracts awarded by public tenders. The column (2) model also shows that contracts awarded by public tenders are 2.1% more likely to have cost overruns than those awarded by other types of procedures. The results of column (6) reveal that urgent public tenders are 2.7% more likely to generate cost overruns when compared to regular public tenders.

Concerning the type of contract, the main results obtained for the entire sample hold for both direct awarding and public tenders: cost overruns are more likely to occur in public works when compared to the base category, purchase of services, and less likely in acquisitions of movable assets. Lastly, concerning the type of contractor, contracts in which the contractor is a state-owned enterprise are more likely to generate cost overruns when compared to the base category, local government. Direct awarding contracts in which the contractor is from the central government are less likely to experience cost overruns. The opposite happens for direct awarding contracts in which the contractor is a regional government, municipally-owned enterprises, and public foundations.

Table 24 presents the results of the second part's regressions for cost overruns. The outline of the Table is similar to the one in Table 23. The first two columns report the results for the whole sample, following what is described in equation (6). Columns (3) and (4) present the results for the subsample of contracts awarded by direct awarding, and columns (5) and (6) for the contracts awarded through a public tender.

The results reveal that incumbency has, in general, no impact on the magnitude of cost overruns and a marginally statistically significant impact in the case of contracts awarded by public tender. Higher contract prices, despite being associated with a higher probability of cost overruns, have not been revealed to be associated with cost overruns of a higher magnitude. More competitors in the bidding process are associated with cost overruns of higher magnitude in contracts awarded by direct awarding but do not affect contracts awarded by public tenders, reinforcing the result of the first part model and the potential role of contract complexity as a determinant of execution outcomes. Contracts executed in multiple municipalities were revealed to be associated with cost overruns of higher magnitude, but the coefficient is only statistically significant for contracts awarded by direct awarding. Public tenders are also associated with cost overruns of higher magnitude when compared with other types of procedures.

Table 24. Second part regressions for cost overruns

dep variable: <i>logcostoverrun</i>	All		Direct Awarding		Public Tender	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>incumbency</i>	-0.0484 (0.0628)	-0.0525 (0.0626)	-0.0931 (0.0699)	-0.0938 (0.0699)	0.275* (0.160)	0.272* (0.163)
<i>logprice</i>	-0.307*** (0.0166)	-0.355*** (0.0179)	-0.381*** (0.0207)	-0.384*** (0.0208)	-0.345*** (0.0509)	-0.346*** (0.0508)
<i>nr_competitors</i>	0.0416*** (0.00969)	0.0235** (0.00971)	0.0549*** (0.0167)	0.0555*** (0.0167)	0.0117 (0.0132)	0.0120 (0.0132)
<i>multilocation</i>		0.431** (0.171)		0.347* (0.206)		0.0871 (0.393)
<i>publictender</i>		0.750*** (0.102)				
<i>urgenttender</i>						0.298 (0.443)
<i>Type of Contract (purchase of services is the base category):</i>						
<i>acquisition of movable assets</i>	-0.641*** (0.0868)	-0.630*** (0.0866)	-0.700*** (0.0942)	-0.690*** (0.0941)	-0.761* (0.401)	-0.753* (0.404)
<i>public works</i>	-0.836*** (0.0915)	-0.887*** (0.0938)	-0.802*** (0.109)	-0.787*** (0.110)	-1.131*** (0.222)	-1.110*** (0.224)
<i>concession of public works</i>	-3.585** (1.410)	-3.438** (1.405)	-3.381** (1.417)	-3.356** (1.417)	-	-
<i>concession of public services</i>	1.210 (0.990)	1.231 (0.961)	0.871 (1.095)	0.863 (1.085)	2.314*** (0.849)	2.298*** (0.824)
<i>rental of movable assets</i>	-0.0596 (0.373)	-0.112 (0.369)	-0.138 (0.376)	-0.122 (0.376)	0.130 (1.178)	0.153 (1.182)
<i>others</i>	0.272 (0.266)	0.261 (0.262)	0.171 (0.268)	0.184 (0.268)	1.156 (1.123)	1.164 (1.127)
<i>Type of Contractor (local government is the base category):</i>						
<i>regional government</i>	1.334*** (0.282)	1.232*** (0.286)	1.415*** (0.353)	1.323*** (0.358)	0.713 (0.585)	0.716 (0.586)
<i>central government</i>	0.406 (0.336)	0.380 (0.338)	0.330 (0.388)	0.281 (0.388)	1.953*** (0.715)	1.943*** (0.716)
<i>municipally-owned enterprise</i>	0.334** (0.140)	0.390*** (0.140)	0.524*** (0.164)	0.523*** (0.164)	0.484 (0.367)	0.486 (0.358)
<i>state-owned enterprise</i>	1.187*** (0.112)	1.106*** (0.114)	1.139*** (0.132)	1.104*** (0.133)	0.897*** (0.241)	0.884*** (0.278)
<i>public institute</i>	0.389*** (0.131)	0.345*** (0.131)	0.265* (0.151)	0.234 (0.152)	0.654** (0.322)	0.642** (0.322)
<i>foundation</i>	1.017*** (0.192)	1.033*** (0.190)	0.890*** (0.206)	0.866*** (0.206)	1.809*** (0.504)	1.815*** (0.501)
<i>other</i>	0.313*** (0.103)	0.354*** (0.103)	0.327*** (0.116)	0.322*** (0.116)	0.490* (0.292)	0.496* (0.300)
Observations	11,421	11,421	9,513	9,513	1,401	1,401
R2	0.138	0.143	0.149	0.149	0.261	0.261

Notes: All regressions were estimated by Ordinary Least Squares and included municipality and year dummy variables; robust standard errors in parenthesis; significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1; the coefficient for concession of public works is not reported in the models for public tenders due to lack of observations

The results also reveal that when cost overruns occur, they tend to be smaller for acquisitions of movable assets, public works, and concessions of public works when compared to the base category, purchases of services. In contrast, when a public tender awards the contract, cost overruns tend to be higher in concessions of public services. Lastly, contracts in which the contractor is a state-owned enterprise or a foundation are associated with cost overruns of a higher magnitude in both types of procedures. A similar conclusion can be drawn when the contractor is a public institute. In that case, the results are either marginally significant or non-significant for the subsample of direct awarding contracts. Contracts from the regional government and municipally-owned enterprises are associated with higher cost overruns in contracts awarded by direct awarding. Contracts from the central government generate higher magnitude cost overruns when awarded through public tenders. Therefore, in what concerns cost overruns, the overall balance is that regional governments, municipally- and state-owned enterprises, and public foundations tend to generate the worst contractual outcomes compared to the other types of contractors, as their contracts are associated with both higher probabilities and higher magnitudes of cost overruns, in the results for the full sample and in the results for, at least, one of the types of awarding procedures.

Two robustness tests were implemented on both the first and second-part regressions.<sup>74</sup> First, as there was a change in the legislation relative to some of the price thresholds for some types of procedures by the end of August 2017, as described in section 5.3., the regressions were estimated without including the observations of contracts celebrated after that date. Second, the regressions were estimated with a stricter outlier identification rule, in which, as previously mentioned in footnote 70, the threshold for an observation to be considered an outlier was based on the  $Q3 + 1.5 \times \text{interquartile range}$  rule. When implementing the first of the two robustness tests, the results reported in Tables 23 and 24 remained unchanged. In the second of the robustness tests, the main results remained similar, but there were a few exceptions. The main one was that the coefficients associated with *multilocation* were not revealed to be statistically significant. As this robustness test applied a stricter outlier identification rule, one interpretation of the results is that this variable is particularly highly associated with cost overruns of huge magnitude. The other differences found when implementing this robustness test were that the coefficients for acquisition of movable assets and regional government of the first part regression in the subsample of direct awarding contracts (i.e., Table 23, columns (3) and (4)) were not statistically significant.

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<sup>74</sup> The results of all robustness tests will be provided upon request.

### **5.6.2. Results for delays**

This subsection presents the results of the delays in contract execution. It follows a similar structure to the previous subsection. Table 25 presents the marginal effects of the first part estimations for delays. Following the same outline as in the previous two tables, columns (1) and (2) show the results for the entire sample. Following what is described in equation (5), columns (3) and (4) show the results for the contracts awarded by direct awarding, and columns (5) and (6) for the contracts awarded through public tenders.

Table 25 reveals that price similarly influences the likelihood of a delay as it influences the likelihood of a cost overrun. Higher contract prices are associated with higher probabilities of delays. The same happens for additional bidders in the awarding procedure. Concerning vendor incumbency, the results for public tenders are not statistically significant. However, vendor incumbency is associated with a 2.5% lower probability of delays for contracts awarded by direct awarding. Therefore, in contracts awarded by direct awarding, incumbency is associated with a higher likelihood of cost overruns but a lower likelihood of delays.

Contracts executed in more than one municipality are also found to be more likely to lead to delays in both contracts awarded by directed awarding and public tender. Public tenders are approximately 6.4% more likely to be associated with delays than other awarding procedures.

Regarding the type of contract, independently of the type of procedure, delays are found to be more likely in public works when compared to the base category purchase of services. This result is similar to what was reported for cost overruns in Table 23. Additionally, acquisitions of movable assets, concessions of public works and public services and rentals of movable assets are associated with a higher probability of delays when the contract is awarded by direct awarding. Lastly, concerning the type of contract, all types of contractors are less likely to generate delays compared to the base category, local government, when the contract is awarded by direct awarding. When the contract is awarded via public tender, that result holds for state-owned enterprises and public institutes but not for other types of contractors. Therefore, the study finds that the type of contractors that are more likely to generate cost overruns are not the same as those that are more likely to generate delays, as, in general, local government is the most delay-prone contractor type.

Table 25. First part regressions for delays – marginal effects

dep variable: <i>delay_dummy</i>	All		Direct Awarding		Public Tender	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>incumbency</i>	-0.0219*** (0.00203)	-0.0231*** (0.00203)	-0.0253*** (0.00216)	-0.0254*** (0.00216)	0.00989 (0.00807)	0.00865 (0.00807)
<i>logprice</i>	0.0135*** (0.000550)	0.0119*** (0.000557)	0.0105*** (0.000628)	0.0104*** (0.000628)	0.00605*** (0.00211)	0.00627*** (0.00210)
<i>nr_competitors</i>	0.00944*** (0.000620)	0.00739*** (0.000640)	0.00731*** (0.000916)	0.00731*** (0.000916)	0.00529*** (0.000931)	0.00564*** (0.000935)
<i>multilocation</i>		0.0233*** (0.00519)		0.0146** (0.00597)		0.0719*** (0.0140)
<i>publictender</i>		0.0642*** (0.00475)				
<i>urgenttender</i>						0.0206 (0.0207)
<i>Type of Contract (purchase of services is the base category):</i>						
<i>acquisition of movable assets</i>	0.00660*** (0.00212)	0.00500** (0.00212)	0.00836*** (0.00226)	0.00850*** (0.00226)	-0.0434*** (0.0112)	-0.0422*** (0.0112)
<i>public works</i>	0.429*** (0.00430)	0.425*** (0.00439)	0.413*** (0.00490)	0.414*** (0.00490)	0.370*** (0.0101)	0.372*** (0.0101)
<i>concession of public works</i>	0.472*** (0.0337)	0.472*** (0.0332)	0.474*** (0.0321)	0.474*** (0.0321)	-	-
<i>concession of public services</i>	0.0388 (0.0240)	0.0372 (0.0242)	0.0630** (0.0255)	0.0630** (0.0255)	-0.318*** (0.0803)	-0.319*** (0.0803)
<i>rental of movable assets</i>	0.0608*** (0.0105)	0.0545*** (0.0105)	0.0695*** (0.0120)	0.0696*** (0.0120)	-0.00688 (0.0276)	-0.00383 (0.0277)
<i>others</i>	0.0843*** (0.0123)	0.0809*** (0.0123)	0.104*** (0.0128)	0.104*** (0.0128)	-0.240*** (0.0435)	-0.245*** (0.0434)
<i>Type of Contractor (local government is the base category):</i>						
<i>regional government</i>	-0.0696*** (0.00834)	-0.0752*** (0.00838)	-0.0607*** (0.00897)	-0.0634*** (0.00905)	-0.0198 (0.0320)	-0.0365 (0.0324)
<i>central government</i>	-0.0835*** (0.00596)	-0.0848*** (0.00596)	-0.0872*** (0.00628)	-0.0878*** (0.00629)	0.0151 (0.0446)	0.00757 (0.0445)
<i>municipally-owned enterprise</i>	-0.0393*** (0.00475)	-0.0396*** (0.00476)	-0.0556*** (0.00497)	-0.0560*** (0.00497)	0.0107 (0.0209)	0.00696 (0.0210)
<i>state-owned enterprise</i>	-0.152*** (0.00356)	-0.154*** (0.00361)	-0.148*** (0.00381)	-0.149*** (0.00387)	-0.0561*** (0.0138)	-0.0711*** (0.0141)
<i>public institute</i>	-0.130*** (0.00334)	-0.135*** (0.00338)	-0.126*** (0.00362)	-0.127*** (0.00364)	-0.0633*** (0.0134)	-0.0837*** (0.0139)
<i>foundation</i>	-0.0498*** (0.00744)	-0.0560*** (0.00741)	-0.0809*** (0.00801)	-0.0815*** (0.00801)	0.149*** (0.0188)	0.143*** (0.0188)
<i>other</i>	-0.133*** (0.00289)	-0.133*** (0.00290)	-0.139*** (0.00304)	-0.139*** (0.00305)	0.0298** (0.0128)	0.0265** (0.0129)
Observations	249,785	249,785	220,811	220,811	13,547	13,547
Pseudo R2	0.0843	0.0850	0.0683	0.0683	0.193	0.195
Log-likelihood	-157470	-157361	-141719	-141716	-7262	-7247
AIC	315335	315119	283832	283828	14841	14815
SIC	317389	317194	285862	285868	16036	16025

Notes: All regressions were estimated by Logit and included municipality and year dummy variables; robust standard errors in parenthesis; significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1; the coefficient for concession of public works is not reported in the models for public tenders due to lack of observations



Table 26 presents the second part's results for delays, following the model described in equation (7). As in the previous three tables, the first two columns report the results for the whole sample. Columns (3) and (4) present the results for the subsample of contracts awarded by direct awarding, and columns (5) and (6) for the contracts awarded through a public tender.

Table 26. Second part regressions for delays

dep variable: <i>logdelay</i>	All		Direct Awarding		Public Tender	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>incumbency</i>	-0.140*** (0.0127)	-0.132*** (0.0128)	-0.103*** (0.0136)	-0.103*** (0.0136)	-0.199*** (0.0396)	-0.186*** (0.0395)
<i>logprice</i>	-0.147*** (0.00370)	-0.135*** (0.00387)	-0.159*** (0.00427)	-0.158*** (0.00428)	-0.107*** (0.0129)	-0.106*** (0.0126)
<i>nr_competitors</i>	-0.0308*** (0.00267)	-0.0221*** (0.00277)	-0.0730*** (0.00532)	-0.0730*** (0.00532)	-0.00796** (0.00341)	-0.00970*** (0.00337)
<i>multilocation</i>		-0.296*** (0.0340)		-0.0680* (0.0388)		-0.601*** (0.0795)
<i>publictender</i>		-0.249*** (0.0241)				
<i>urgenttender</i>						-0.605*** (0.123)
<i>Type of Contract (purchase of services is the base category):</i>						
acquisition of movable assets	0.298*** (0.0133)	0.305*** (0.0133)	0.362*** (0.0140)	0.362*** (0.0140)	0.712*** (0.0610)	0.708*** (0.0610)
public works	1.494*** (0.0190)	1.517*** (0.0194)	1.400*** (0.0213)	1.398*** (0.0213)	2.229*** (0.0596)	2.182*** (0.0601)
concession of public works	1.661*** (0.143)	1.638*** (0.144)	1.640*** (0.141)	1.640*** (0.141)	-	-
concession of public services	-0.260* (0.134)	-0.265** (0.134)	-0.289** (0.139)	-0.289** (0.139)	1.450** (0.575)	1.479*** (0.565)
rental of movable assets	0.0108 (0.0624)	0.0267 (0.0623)	-0.0519 (0.0688)	-0.0523 (0.0688)	0.874*** (0.195)	0.796*** (0.193)
others	0.450*** (0.0706)	0.460*** (0.0705)	0.467*** (0.0711)	0.466*** (0.0711)	-0.171 (0.327)	-0.155 (0.319)
<i>Type of Contractor (local government is the base category):</i>						
regional government	-0.211*** (0.0522)	-0.177*** (0.0525)	-0.235*** (0.0564)	-0.227*** (0.0566)	0.619*** (0.144)	0.692*** (0.146)
central government	-0.0744** (0.0332)	-0.0586* (0.0333)	-0.0994*** (0.0345)	-0.0968*** (0.0345)	0.472** (0.217)	0.541** (0.223)
municipally-owned enterprise	-0.300*** (0.0270)	-0.294*** (0.0270)	-0.261*** (0.0291)	-0.259*** (0.0291)	-0.414*** (0.0998)	-0.374*** (0.101)
state-owned enterprise	-0.268*** (0.0218)	-0.235*** (0.0220)	-0.194*** (0.0234)	-0.187*** (0.0237)	0.0734 (0.0655)	0.205*** (0.0672)
public institute	-0.453*** (0.0212)	-0.415*** (0.0213)	-0.363*** (0.0224)	-0.358*** (0.0226)	-0.496*** (0.0789)	-0.295*** (0.0803)
foundation	-0.624*** (0.0476)	-0.582*** (0.0473)	-0.457*** (0.0532)	-0.455*** (0.0532)	-1.424*** (0.104)	-1.343*** (0.103)
other	-0.842*** (0.0187)	-0.832*** (0.0187)	-0.860*** (0.0198)	-0.857*** (0.0198)	-0.227*** (0.0691)	-0.230*** (0.0693)
Observations	112,827	112,827	100,154	100,154	8,627	8,627
R2	0.110	0.112	0.112	0.113	0.279	0.288

Notes: All regressions were estimated by Ordinary Least Squares and included municipality and year dummy variables; robust standard errors in parenthesis; significance levels: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1; the coefficient for concession of public works is not reported in the models for public tenders due to lack of observations

The second-part regressions for delays reveal that when a delay occurs, incumbency, price, competition, and multiple execution locations are associated with delays of lower magnitudes, no matter the procedure through which the contract was awarded. Public tenders and urgent tenders were also revealed to be associated with delays of smaller magnitudes, compared with other types of procedures and regular tenders. Regarding the type of contract, all types of contracts are associated with longer delays when compared to purchases of services when contracts are awarded via public tenders (except for the "others" category). In the contracts awarded by direct awarding, a positive and statistically significant coefficient is found for acquisitions of movable assets, public works and concessions of public works, and the coefficient associated with concession of public services is statistically significant and negatively signed. Concerning the type of contractor, when the contract is awarded via direct awarding, the results tend to be aligned with the ones of the first part regressions. Therefore, for contracts awarded by direct awarding, local governments are associated with a higher probability and magnitude of delays. In contracts awarded by public tender, regional and central governments and state-owned enterprises are associated with delays of higher magnitude, while municipally-owned enterprises, public institutes and foundations with delays of lower magnitudes when compared to the base category, local government.

The robustness tests described in the previous subsection were also implemented in the regressions for delays. The results reported in Tables 25 and 26, described in the paragraphs above, were similar to those obtained in the robustness tests. The main differences in the results were related to the non-statistical significance of some coefficients reported as marginally significant in Tables 25 and 26, particularly regarding the type of contract dummies.

## **5.7. Conclusion**

Contract execution is an essential feature of public procurement. However, contract execution outcomes have been less researched than factors affecting contract prices or contract awarding. Using data from *base.gov* for Portuguese public contracts, this research uses two-part models to study the likelihood of cost overruns and delays in contract execution and their magnitude relative to the contracted price and execution duration. The results contribute to discussing how contractual, procedural, contractor and vendor characteristics affect contract execution outcomes.

This study reveals that factors such as vendor incumbency and competition in the bidding process effect on contract execution outcomes might depend on whether a direct awarding or a public

tender awards the contract. Coviello *et al.* (2018 a) claimed that discretion in the awarding process increases the likelihood of incumbent vendors being multiple times but that such bias does not worsen contract outcomes. The results of this analysis partially support the latter. On the one hand, it was found that incumbency is associated with a higher likelihood of cost overruns when the contract is awarded by direct awarding, and overall, public tenders are associated with a higher likelihood of cost overruns and delays than other procedures. On the other hand, the results show that vendor incumbency is associated with better contract execution outcomes concerning delays, especially in direct awarding contracts. This suggests that firms being awarded contracts repeatedly by the same public entity is efficient from an execution speed standpoint, at the expense of being more likely to generate cost overruns, particularly when awarding contracts via direct awarding. Therefore, discretion in the awarding procedure is concerning from the standpoints of winning distribution and the public sector's transparency and integrity (Palguta & Pertold, 2017; Coviello *et al.*, 2018a; Baltrunaite *et al.*, 2021; Boland & Godsell, 2021), but might in some circumstances benefit timely contract execution. Banerjee & Duflo (2000) argued that reputation affects contract outcomes. Reputation is not measured in the context of our study. However, it is potentially related to the incumbency results, as the same contractor might award vendors multiple contracts by building a positive reputation by providing timely contract executions. Though, these results also show that it is also possible that incumbents might abuse contractor's trust on the financial side of contract execution, resulting in more cost overruns.

Competition was shown to have a positive or neglectable effect on delays and overruns in the study by Calvo *et al.* (2019). The findings of this study are not entirely consistent with those. More competitors in the bidding process are shown to be associated with delays of lower magnitude and not to affect cost overruns in contracts awarded through public tenders. However, the same was not valid for the likelihood of delays. In contracts awarded by direct awarding, more competitors in the bidding process are associated with worse contractual execution outcomes regarding the likelihood of cost overruns and delays. As discussed in section 5.6.1., some of these results for competition in the context of direct awarding contracts might be capturing the effect of contract complexity, which has been previously discussed in the literature as capable of affecting execution outcomes (e.g., Baldi *et al.*, 2016). This study does not include a composite complexity indicator like the one used by Baldi *et al.* (2016). However, when considering simpler proxies for complexity, such as the contract starting price or the indication that a contract was executed in multiple municipalities, this study strongly suggests that more complex contracts have a higher likelihood of delays and cost overruns.

This study also finds that urgent public tenders are more likely to lead to cost overruns than regular tenders, suggesting that more oversight and restrictions should be applied to those contracts. Regarding the type of contract, public works are associated with a higher likelihood of cost overruns and delays, and delays of higher magnitudes, and are, overall, the type of contract associated with the worst execution outcomes. State-owned enterprises are more likely to incur cost overruns no matter the type of procedure followed and are also associated with cost overruns of higher magnitude. When contracts are awarded by direct awarding, regional government, municipally-owned enterprises, and foundation contractors are associated with worse outcomes regarding cost overruns. Concerning delays, local government contractors are the ones who, with a few exceptions, tend to be associated with worse execution outcomes no matter the awarding procedure. Those results can be considered when deciding which contracts and types of entities need more oversight on contract execution. The results on public works reinforce once again the relevance of complexity as a relevant driver of the quality of contract execution outcomes, as the execution of those contracts is typically more complex than purchases of services, acquisitions of movable assets, and other types of contracts.

This paper hopes to contribute to the discussion of factors that influence procurement execution outcomes, as the evidence provided here can help policymakers and regulators to be better informed regarding the pros and cons of different procedures and contractual characteristics from the execution outcomes standpoint. Future studies should continue exploring factors affecting contractual execution outcomes by using data from different countries and diving deeper into specific sectors or types of public entities, as different public entities have different organisational and operational dynamics, objectives and time horizons. For example, it could be worth exploring if the quality of contract execution when the contractor is a local government or the central government is affected by the electoral cycles at the local or national level. Future studies can also revisit some of the results presented here, particularly regarding the type of procedure, using a regression discontinuity design methodology, given that some procedures are restricted to contracts below certain threshold values. A final note to stress a limitation of this study. The analysis is based on information retrieved from the portal *base.gov*, relying entirely on the entities that report to and manage the portal in terms of the accuracy and availability of data. This is particularly relevant regarding the information used to construct the dependent variables, which is not available for all the contracts in the database.

## **6. Conclusion**

The essays of this thesis explore the transformative influence of digitalisation on government operations, with a particular focus on its socioeconomic implications. Each article explores a distinct impact or facet of the digital transformation of the public sector and provides empirically grounded insights that contribute to our understanding of the impacts and challenges associated with government transformation. This conclusion starts by overviewing each chapter's main findings and policy recommendations. It then overviews the research limitations and suggests future research directions. It ends with some brief overarching remarks and conclusions.

Chapter 2 studied the role of digital government in alleviating administrative and regulatory burdens across 169 countries from 2004 to 2018. The empirical analysis corroborates the idea present in policy reports and conceptual frameworks that digital government can foster a more business-friendly environment in several areas of business regulations, such as starting a business, dealing with construction permits, getting electricity, registering property, paying taxes, getting credit and protecting minority investors. It also finds that government effectiveness plays a role in facilitating business. Examples of ICT-based reforms that were able to reduce administrative and regulatory burdens are provided in this chapter. However, it is argued that policymakers should not simply try to transfer ICT solutions from one country to another, as these solutions should be preceded by an analysis of a country's needs and more pressing challenges and their administrative, legal, and regulatory contexts.

Chapter 3 studied the role of digital government as a tool for minimising the prevalent problem of corruption. The empirical analysis of data from over 170 countries from 2002 to 2020 suggests that digital government is a deterrent to corrupt activities. The study explores specific digital government domains that are more helpful in deterring corruption and finds that online service completion and electronic participation can be critical elements for this purpose. The empirical analysis also concludes that context matters in the relationship between digital government and corruption, as the effectiveness of digital government as an anti-corruption tool is higher in countries with moderate to high corruption levels and lower economic development. It also finds that not all types of corruption are impacted by

digital government, as the evidence suggests that e-government can mitigate public sector theft, corrupt legislature activities, executive bribery and corrupt exchanges, but not judicial corruption. Therefore, the conclusions of this essay advocate the need for tailored anti-corruption strategies that consider the contextual nuances of the countries, the specific digital government tools to be developed and the types of corruption that are being tackled.

In Chapter 4, the focus changes from the potential positive impacts of digital government in society to digital divides, one of the biggest social challenges of digital transformation. Using individual-level data from the Sultanate of Oman, the analysis focuses on Internet and online governmental services usage. It finds that education, employment status, nationality, age and gender are economic and demographic traits that shape the digital landscape regarding the use of digital tools and services. Some of the recommendations emerging from this research are that, when developing policies to tackle digital divides and digital exclusion, some emphasis must be placed on improving digital literacy and accessibility. The study also identifies that societal norms, especially regarding traditional household roles and gender, can play a role in individual participation in the digital world and the type of usage of the internet.

The essay of Chapter 5 examines execution outcomes in public procurement using data from the Portuguese *base.gov* portal. The study researches the relationship of factors related to contractual, procedural, contractor, and vendor characteristics with cost overruns and delays in the execution of public contracts. The analysis finds that vendor incumbency, contract complexity, the type of contract, contractor and procedure influence execution outcomes. It also separately analyses contracts awarded by public tenders and direct awarding and finds that the impact of some of the previously mentioned factors may vary depending on which procedure was followed. The findings of this chapter can help policymakers to be more aware of which contracts are more prone to cost overruns and delays and may, in consequence, benefit from tighter oversight from regulatory authorities while also allowing them to be better informed on the potential effects on execution outcomes when deliberating changes in legislation. Moreover, this study serves as a practical example of how digital government, in this case through public procurement portals, can promote transparency and provide resources for research.

The following paragraphs will summarise some of the limitations of the analyses implemented and suggest some directions for future research. In Chapter 2, one of the research challenges was the inexistence of prior theoretical economic literature or previous sound empirical studies on the relationship between digital government and administrative and regulatory burdens. Therefore, the study conducted has, to some extent, an exploratory nature. Future studies should formalise the

theoretical relationship between e-government and administrative burden reduction and dive deeper into the empirical analysis of the most critical factors in explaining each area of business regulations.

The study of Chapter 3 explores which e-government domains affect corruption, which types of corruption are more affected by e-government and the circumstances under which e-government is more effective in reducing corruption. This represented a novelty in the literature, but some parts of the analysis faced data constraints. When studying which digital government domains are more helpful in deterring corruption, the study relied on a relatively small subset of data encompassing only the European Union countries since the DESI data was the only one that provided a large enough dataset and with enough granularity for that part of the analysis. Therefore, this topic should be revisited when more years of data, data for more countries or new indicators that break down digital government into different dimensions become available.

One of the contributions of Chapter 4 is to study digital divides with individual-level data in a society where digital government's maturity is lower than in most European countries, and some of the societal norms might exacerbate digital divides. However, the context specificity also raises questions regarding the generalisation of the results. Therefore, future research can revisit similar topics using datasets covering different countries or multiple countries. Moreover, although gender differences are analysed in this research, the analysis is based on a survey that was not designed to target the analysis of differences between genders specifically. Therefore, future research could benefit from a more nuanced exploration of the intricacies of gender divides in digital access and usage and combine quantitative and qualitative methods.

Chapter 5 shares some of the limitations of Chapter 4 concerning the possibility of generalising the results, given that the analysis is focused on a specific country. Therefore, future studies can continue to explore factors affecting contract execution outcomes in public procurement by using datasets from different countries. They can also focus on specific types of contracts, public entities or periods. For example, as already mentioned in section 5.7., it could be interesting to explore if the electoral cycles influence the contract execution outcomes when the contractor is a local government or the central government and to test some of the obtained results using a regression discontinuity design setup. Another possibility is to research if the COVID-19 pandemic influenced execution outcomes, namely in contracts awarded by contractors from the health sector. Lastly, it is important to recall that the study was conducted with data retrieved from *base.gov*, and that the information regarding differences between contract prices and final prices or execution deadlines and actual starting and ending execution dates was only available for some contracts. Therefore, the validity of the findings is

somewhat dependent on the probability of the existence of missing data in each contract not being affected by the presence or absence of cost overruns and delays (i.e., that the reporting of final prices and actual closure dates is not lower when the contractual prices and execution deadlines are not respected).

As an overarching conclusion, these essays portray the multifaceted nature of digital government and digital transformation, with implications for the business environment, corruption, social divides, and procurement processes. A common feature across several of the findings of the essays of this thesis is the contextual dependency of some outcomes. Therefore, this thesis advocates that what is effective in one country may not necessarily translate directly to another and that digital solutions, anti-corruption policies and policies to tackle digital divides should consider the socioeconomic and cultural contexts. Another conclusion is that digital government should not be regarded as an ultimate and one-fits-all remedy for reducing bureaucracy, fighting corruption, and achieving more inclusion, as other factors are also relevant for fulfilling those purposes, and not all digital government solutions might be effective in all contexts. Moreover, while, for example, this thesis shows that digital government can be more effective as an anti-corruption tool in contexts where economic development is not high, those are also the contexts more prone to digital divides. Therefore, policymakers should not look at digitalisation in isolation but adopt a holistic approach that considers technological and non-technological aspects of the reforms and is aware of the benefits and challenges of digitally transforming the public sector.

As the digital landscape continues to evolve, governments should prepare to adapt to the consequential changes in the public sector's operations and anticipate some of the challenges that may arise to continuously find a proper balance between reaping the benefits and addressing some of the potential issues that digital transformation might bring. This implies studying and understanding the limitations and potentialities of emerging technologies, such as artificial intelligence, that are already in play in several governmental organisations and whose embedment in society only tends to grow. In this regard, countries that have higher gaps within the population concerning literacy, digital skills, and internet accessibility should be particularly keen on trying to find adequate approaches to be able to develop and modernise without leaving anyone behind and implement effective strategies to tackle digital divides.



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