



Contents lists available at ScienceDirect

Government Information Quarterly

journal homepage: www.elsevier.com/locate/govinf

Measuring public procurement transparency with an index: Exploring the role of e-GP systems and institutions

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ARTICLE INFO

Keywords:

Transparency
Public procurement
Institutions
Information technology

ABSTRACT

The high expenditure on public procurement by governments makes it imperative to enhance transparency across the procurement cycle with technology-driven initiatives, such as e-procurement systems. This paper develops the Public Procurement Transparency Index and evaluates the impact of institutional reforms and membership of the World Trade Organisation Government Procurement Agreement on transparency. We use the Technology-Organisation-Environment and Balanced e-Participation Index frameworks to analyse transparency in procurement. The Public Procurement Transparency Index uses generalised least squares technique to develop the country-level transparency score. Findings indicate that e-government procurement systems promote transparency, especially in countries with robust institutional frameworks. Further, with fractional probit regression techniques we find institutional quality and infrastructure are key determinants of transparency in public procurement. The results also highlight the importance of information technology and institutional reforms as a means to enhance transparency and accountability in public procurement and offers valuable implications for policymakers.

1. Introduction

Public procurement expenditure accounts for nearly 10–20% of total gross domestic product (GDP) for high-income countries, and this can be as much as 30% in the case of developing countries (Djankov et al., 2017; Knack et al., 2019; World Bank, 2016). Given the high proportion of expenditure there is need to enhance transparency across the entire public procurement cycle, which includes planning, tender, award, contract management and implementation (OECD, 2016). In public procurement, governments are increasingly using e-government procurement (e-GP) systems as a tool to ensure effective use of public funds, reduce fraud and corruption, as well as increase competition among suppliers (Adam et al., 2020; Ghossein et al., 2018; Knack et al. 2019). e-GP systems provide information in open and machine-readable formats that enhances transparency in procurement processes which fosters governments' accountability. At the international level, there are several initiatives to enhance transparency which, among others, include the World Trade Organisation (WTO)-Government Procurement Agreement (GPA) plurilateral agreement. The WTO agreement mandates the use of

information and communication technologies (ICT) (e.g., the Internet) and e-GP systems for transparent exchange of information (World Trade Organization (WTO), 2012). Providing access to information and enabling stakeholder participation in the procurement cycle is largely linked to the level of information access allowed and involves political decisions (Ackerman & Sandoval-Ballesteros, 2006; Duguay et al., 2023) which explains why not all countries may have opted for WTO-GPA membership.

Research highlights the role of IT (information technology) infrastructure and the link between digital proficiency, and citizens' ability to interpret and process information in promoting transparency, accountability and citizen participation (see Bertot et al., 2010; Chen et al., 2019; Kabanov, 2022). But digitalisation does not necessarily increase transparency and accountability while reducing corruption (OECD, 2016; Pyman & Heywood, 2021; Schapper, 2008; Seong & Lee, 2004; Ware et al., 2007). In public procurement, e-GP has been proven to ensure accountability and transparency by using integrated e-procurement solutions which increase competition (Ruiz Rivadeneira et al., 2023; World Trade Organization (WTO), 2023). However, with

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<https://doi.org/10.1016/j.giq.2024.101952>

Received 11 September 2023; Received in revised form 5 June 2024; Accepted 9 June 2024

Available online 2 July 2024

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increasing integration of IT in governmental processes, the scholarly debate has evolved from questioning what makes policy-making transparent and how to employ transparency as an instrument for effective policy making (Eppel, 2012; Brunswicker et al., 2019; Matheus, Janssen, & Maheshwari, 2020). Attempts have been made to assess transparency in public procurement. Examples include the OECD's (2020a) procurement transparency indices but to the best of our knowledge there is no e-procurement index (i.e. when procurement is conducted using e-GP systems) and how the use of e-GP tools and systems translate into higher transparency. Research shows that an e-procurement transparency index contributes to higher accountability and public trust (Mungiu-Pippidi, 2023) and that having a standardized measure that holds governments and procurement agencies accountable is important. Such tool would also foster fair competition among suppliers, build public trust in government institutions, and serve as a basis for evaluating and improving procurement practices (OECD, 2020). Our paper fills this gap and investigates whether e-GP tools and systems play a role in fostering transparency by examining the link between transparency and institutional reform. This paper firstly, develops procurement-specific measure on country transparency using the Technology-Organisation-Environment (TOE) (Tornatzky & Fleischer, 1990) lens and Balanced e-Participation Index (BEPI) (Pirannejada et al., 2019) framework to offer a comprehensive insight into the dynamics driving transparency in procurement. Secondly, we evaluate the impact of institutional reforms (particularly those related to democracy, government effectiveness, regulatory quality, and contract integrity) on transparency in public procurement. This draws on the broader debate relating to the quality of institutions (Kaufmann, Kraay and Mastruzzi, 2010; Fukuyama, 2013; Rothstein, 2014; Khorana et al., 2014) and examines the impact of WTO-GPA membership, which requires institutional reforms. A related question explored is the role of IT developments (namely e-GP systems) in enabling effective institutions and its relationship with transparency. Data for the Transparency Index is drawn from publicly available sources, namely the World Bank, Organisation for Economic Cooperation and Development (OECD, 2017, 2019a, 2021) and European Research for Anti-Corruption and State-Building (ERCAS). This is complemented by country level data, which is retrieved from individual countries' e-procurement portals. Using a multi-staged sampling process and generalised least squares (GLS) technique, we analyse the transparency score of 133 countries from a total of 218 countries. We draw on institutional variables data from the World Bank Worldwide Governance Indicators (WGI) and employ a fractional probit technique to assess the impact of a country's WTO-GPA membership on transparency in public procurement.

The paper makes two important contributions. Firstly, we develop procurement-specific transparency measure (termed PPT-Index), which analyses whether e-GP tools lead to higher transparency from a policy perspective. Given the high value of public procurement and the general lack of transparency in the process, the unique contribution of the PPT-Index is its ability to foster transparency within the entire e-procurement lifecycle. We develop this index to support governments in assessing the openness, clarity, and the flow of information at each stage of the procurement process. The empirical analysis draws on publicly data which is complemented by country level data to provide policy makers an insight into public procurement related measure for their country. We complement the transparency measurement of the e-procurement cycle with data from bid challenge decisions (complaint mechanism), e-signature facility adoption, and access to public information (e-reports, e-statistics, legal gazette, and public official declarations). This also enhances the accountability of the public officials in the procurement processes. Thus, the uniqueness of this paper lies in providing a standardized transparency measure across the entire e-procurement cycle. It also highlights the role e-GP tools play in fostering accountability among governments and public procurement agencies. Second, the paper delves into what role a country's institutional framework plays in ensuring transparency which is essential to increase participation in doing

business with the public sector. For this, we analyse how country-level institutional indicators, which are a part of any country's wider institutions and digital skillset, contribute to transparency in e-public procurement. The research uses data to not only fill a critical gap in existing literature but also highlights the potential of e-GP tools as a means to catalyze competition among suppliers, instill public trust in government institutions, and establish a foundation for transparent procurement practices. Thus, the PPT-Index aims to support governments to meet the policy objectives of transparency and accountability that contribute directly to greater public trust.

The main findings and policy implications are as follows. First, the PPT-Index provides unbiased and evidence-based insights to support informed policymaking in government procurement by emphasising that public procurement practices which foster transparency can progress beyond the abstract notion of 'good' behaviour. Our results confirm that e-GP systems provide access to information on the procurement ecosystem and support transparency in government policymaking. What is evident is that transparency varies across countries with higher transparency in developed countries, especially the WTO-GPA members. Second, we find a direct relationship between transparency and institutional quality (Islam, 2006; Jiménez et al., 2022) and infrastructure (Relly & Sabharwal, 2009) which supports the case for e-GP reforms (Islam, 2003, 2006). Further, the institutional quality of a country matters, i.e., countries with higher government effectiveness, regulatory quality, contract integrity and democratic form of governments, are more likely to have higher transparency in public procurement. The e-GP systems, complemented with digital infrastructure and skills, which provide better access to information support citizens' interaction with the government via web-forms and automated data processing, which in turn promotes transparency and accountability (Correa et al., 2019).

The structure of the paper is as follows: Section two introduces the relevant literature and develops the hypotheses and the theoretical framework. Section three presents the public procurement transparency index and highlights data sources, sampling technique and research methodology. Section four examines the link between country's institutional framework and transparency, discusses the econometric approach, descriptive statistics, and main findings. Section five discusses policy implications. Section six concludes and Section seven highlights direction for future research.

2. Literature, hypothesis development and conceptual framework

2.1. Literature overview and background

The use of e-procurement (also termed e-government procurement or e-GP) has grown in recent years. This form of procurement uses digital technology in procuring and inviting tender for public works, identify potential suppliers of goods and services, to interact with suppliers, to purchase supplies and services in e-marketplaces, as well as for the transfer of payments (Min & Galle, 2003; Standing et al., 2006); and the reduction of delays in the competition of new infrastructure projects by minimising the informational asymmetries, fraud and other prohibited practises in public procurement projects (). Experience from developing countries shows that e-governance can improve transparency which leads to, among others, corruption control and poverty reduction (Bhuiyan, 2011). Along these lines, the decision to adopt e-government tools also influence the success of new reforms. For instance, the use of software for auctions increases the demand from citizens and firms as well as generates need for higher skills of workers (human capital) to manage new technologies (Aladwani, 2016; Lakka et al., 2013). According to the current research (Janssen et al., 2022; Hujran et al., 2023; Madan & Ashok, 2023), the use of emerging technologies (such as Artificial Intelligence) in innovative procurement improves information flow, support human decisions and allow the acquisition of new hardware and software for different procurement

Table 1
Literature review on e-procurement.

Relevant literature	Focus
Heilbrunn (2004); Seong and Lee (2004); Ware et al. (2007); Hardy and Williams (2008); Schapper (2008); Kim et al. (2009); Pani and Kar (2011); Kim and Lee (2012); Elbahnasawy (2014); Knack et al., 2019; Becker (2018); Schopf (2019); Mélon and Spruk (2020)	Control of corruption, accountability, administrative simplification, integrity transaction costs, policy effectiveness and transparency in procurement process
Relly and Sabharwal (2009); Bertot et al. (2010); Margetts (2011); Gupta and Narain (2012); Cucciniello and Nasi (2014); Jiménez et al. (2022)	Telecommunication, ICT barriers, access to information, free press, social media, digital literacy skills
Larbi, 2007; Ware et al., 2007; Searson and Johnson (2010); Varney (2011); Harrison and Sayogo (2014); Khorana et al., 2015; Lewis-Faupel, Neggers, Olken, and Pande (2016); Chen et al., 2022; Jiménez et al., 2022; Mungiu-Pippidi (2023); Duguay, Rauter, and Samuels (2023)	Legal framework, exchange of complex information, disclosure of public officials, legal repository, norms and regulations

Source: Author's compilation.

stages. In this manner, the use of such technologies not only promotes information transparency, but also enhances accountability, citizen participation and trust in e-government services.

The literature overwhelmingly concurs that the use of e-GP systems increase efficiency through higher competition, transparency, accountability (see for example, Becker, 2018; Henriksen & Mahnke, 2005; Khorana & Kerr, 2021).¹ e-GP tools facilitate an efficient public sector management and lower contract enforcement costs (Gunasekaran & Ngai, 2008; Shim & Eom, 2008). From the bidding entities perspective, e-GP systems facilitates access to a wide pool of vendors and streamlines procurement processes that control spending (Bendoly & Schoenherr, 2005; Moon, 2005), increase entities monitoring capacity through e-auctions (Essig & Arnold, 2001; Fish et al., 2015; Rai et al., 2006) and enables the government to work with 'good' (efficient) suppliers whilst decreasing the failure risk of publicly funded projects (Klabi et al., 2018; Vinogradov et al., 2014). In addition, e-GP allows contracting authorities to aggregate demand across departments, reduces inventory costs and overheads (Croom, 2000; Wyld, 2002; Kameshwaran et al., 2007). Thus, the use of e-GP reduces information asymmetry between business with two interlinked effects: first, e-GP systems foster competition and supplier participation in an open market; second, allows procuring agencies to procure quality goods and services at lower prices. The overall efficiency of the e-procurement system, however, depends on the ease of access to information, and processes and procedures (procurement plan, award, etc.) to facilitate wider inclusion of firms in the contracting activity (Pani & Kar, 2011). Table 1 summarises the current state of discussion.

2.2. Hypotheses development

2.2.1. Transparency in public procurement

Transparency has been viewed from several perspectives, such as the release of government information on key economic indicators (Islam, 2006; Roberts, 2006); citizens ability to craft (human capital skills) and demand better and more information (Williams, 2009); openness of government, i.e., the diffusion of information in the public domain (open meetings, decisions). Others focus on citizen monitoring and decision marking (Meijer, 2015; Meijer et al., 2012); public accountability

support (Lourenço, 2015); governance institutions, regulations and credibility (Armstrong, 2005; Ciborra, 2005; Grigorescu, 2003; Otenyo & Lind, 2004; Stasavage, 2003). Yet others highlight the legal environment and documents, laws and/or regulations published (Beblavý et al., 2022) as well as the administrative capacity to implement and monitor policy accumulation to reduce administrative overload (Lourenço, 2023).

From the perspective of public procurement, transparency is based on the belief that democratic governance and efficient markets are enhanced when information is freely available, and administrative agencies have a degree of autonomy, or independence from political interference (Wolfe, 2013). The underlying premise is that transparency can be fostered through national policies, strategy, action plans, dedicated programmes and co-ordination mechanisms that ensure coherence across government departments (horizontally) and different levels of government (national, regional, local) (vertically). In this regard, Lourenço (2023) suggest that a macro perspective of transparency must consider the initial stages of the policy process, agenda-setting and policy formulation. Transparency in public procurement is measured with benchmarks, such as the European Commission's Public Procurement Scoreboard, Open Contracting Partnership, commentaries on the state of regulatory (Public Procurement Act) legal framework in countries (Adam et al., 2020; Correa et al., 2019; World Bank, 2013). However, studies concur that while benchmarking can effectively track and monitor open government initiatives, lack of standardized measures of the progress over time and/or government self-assessment (intentionally or unintentionally) of countries that rank high are attempts to maintain its position rather than improving data provision (Bannister, 2007; Lnenicka et al., 2022; Lnenicka et al., 2024). The WTO-GPA also requires member countries to comply with data reporting requirements, use electronic tools and publish procurement notices to provide equal treatment to domestic and foreign suppliers (Evenett & Hoekman, 2003, 2005; Linarelli, 2003). These create a level playing field for all suppliers so that commitments to create institutions, processes, and decisions are made accessible to the public which allows monitoring, reviewing and commenting on processes and decisions by stakeholders. Enhancing transparency in government procurement features prominently on good governance agenda (Carothers & Gramont, 2011; Križić, 2021). Achieving this agenda necessitates the establishment of 'sound' institutions and implementing measures to facilitate institutional reforms (Khorana et al., 2014; Trepte, 2005; United Nations, 2011).

To foster transparency, countries use e-procurement portals and provide information on procurement lifecycle and frameworks in the public domain, this is linked with the quality of institutions of a country. Institutional reforms can kickstart change, but the 'real' benefits of reform can be reaped by countries only when political bosses recognise the importance of reforms and back them (Szepesi, 2004). There are diverse perspectives on what the quality of institutions means (Fukuyama, 2013; Rothstein, 2014). Kaufmann et al. (2010) offers a broad definition including the modes of access to power, the exercise of power as well as the content of policies. Khorana et al. (2014, p. 122) state "[...] the critical success factors for effective institutional reform are political commitment, the ability to craft an appropriate reform agenda and eventual compliance with rules." The benefits of institutional reform accrue only if the institutions are effective and there is a 'fit' between specific innovations (in this case procurement legislation and e-procurement) and broader institutional environment (Levy & Spiller, 1994). However, the benefits of institutional reform accrue only if the settings are appropriate to kick-start the institutional reform process backed by political leaders' commitment to and willingness to use their weight to support reforms (Khorana et al., 2014, p. 122). Alt and Lowry (1994) argue that democracy increases transparency. In line with the above, we argue that democratic institutions and effective institutions, i.e., functioning e-GP system in a country, support higher transparency which in turn facilitates internal policy coordination accountability in procurement. This leads to the following hypothesis:

¹ Other relevant studies include Cho and Choi (2005); Lenk (2006); Hardy and Williams (2008); Pathak, et al. (2008); Kim et al. (2009); Pathak et al. (2009); Bhuiyan (2011); Varney (2011).

H1. WTO-GPA membership fosters transparency in public procurement.

2.2.2. Link between institutions (i.e., WTO-GPA membership, e-GP) and transparency

Literature highlights the importance of well-functioning institutional frameworks for efficient economic outcomes (North, 1990; Fatas & Mihov, 2013). The implementation of an effective e-GP system enables contracting entities to strengthen competition, transparency, accountability and lowers corruption (see Hardy & Williams, 2008; Kim et al., 2009; Elbahnasawy, 2014; Khorana & Kerr, 2021).

E-procurement systems are, however, linked with the country context which is based on a country's ability to use technology, infrastructure and human capital, and institutions (Heeks, 2005; OECD, 2019; Schapper, 2008). Whitley (1999) argues that e-GP and e-government are components of wider country-level institutional configurations and that e-GP systems cannot be viewed in isolation given these form part of wider institutional arrangements. The implementation of e-GP portals creates an effective institutional framework (Mélou & Spruk, 2020) and e-GP systems foster transparency (Hall & Soskice, 2001). (Fazekas, Lukács, & Tóth, 2015, p. 2) highlight the link between institutional quality and transparency and caution the complexity of the relationship. Studies argue that the political context, technology and wider governance increase citizens readiness to participate in government activities promotes transparency (Jiménez et al., 2022; Pirannejad et al., 2019). Studies confirm that the plurilateral WTO-GPA provides the institutional framework to release procurement related information (Shingal, 2011; Kono & Rickard, 2014; Kutlina-Dimitrova & Lakatos, 2016), and this requires (i) public disclosure of rules; (ii) publication of procurement opportunities; (iii) prior determination and publication of what is to be procured and how submissions are to be considered; (iv) conducting procurement according to prescribed rules and procedures; and (v) how to monitor compliance with rules (World Trade Organization (WTO), 2012). Given that WTO membership requires member countries to have functioning e-procurement portals and creates strong institutional frameworks, the next hypothesis states:

H2. WTO-GPA membership and high institutional quality promote transparency in procurement.

2.2.3. Role of IT in transparency

An institutional framework that prioritises integrity, transparency, and accountability (Fan et al., 2021; Harrison & Sayogo, 2014; Schopf, 2019) requires human capital and technology (Islam, 2003, 2006; Jiménez et al., 2022; Rely & Sabharwal, 2009). Institutional quality must be accompanied by technology and education for effective digital governance (Kim, 2007). To access and utilise the Internet, individuals must have technical skills to use computers, read, comprehend, have ability to search for, use, interpret, and evaluate information (Mossberger et al., 2003, p. 6). The requisite human capital ensures procurement digitisation supports administrative simplification (Jiménez et al., 2022) which contributes to policy effectiveness in the procurement lifecycle, i.e. awards, notifications, bid-challenge recourse, complaint mechanism, e-signature of contracts (Molander, 2014; OECD, 2019a; OECD, 2019b; OECD, 2019c).

The use of e-GP portals relies on Internet speed (Bertot et al., 2010; Meijer, 2013). Studies report that access to telecommunication networks (internet speed, mobile connections) facilitate adoption e-portals, citizens' access to public information (Shapiro, 1999) and improve dissemination of government information while bridging the digital divide in developing countries (International Telecommunication Union (ITU), 2011; Williams et al., 2011). Thus, the digital infrastructure, digital skillset of bidders, entities and citizens are required for an efficient e-GP system (Jiménez et al., 2022). Further, timely access to

information coupled with political willingness ensures institutional quality and efficient resource allocation (Williams, 2009; Williams, 2015). This leads to:

H3. : Information technology and WTO-GPA membership impacts transparency in procurement.

2.3. Conceptual framework

The paper draws on two frameworks, namely TOE and BEPI frameworks. TOE considers the interlinkages between technology, organisational factors, and the external environment. Developed by Tornatzky and Fleischer (1990) the TOE framework assesses the adoption of technological innovations, such as IT (Srivastava & Teo, 2010), enterprise resource planning (Haddara & Elragal, 2013; Zhu et al., 2010), and open systems (Chau & Tam, 1997; Wang & Lo, 2016). BEPI (Pirannejad et al., 2019). The BEPI framework evaluates the e-participation initiatives by adding two extensions (namely Human Development Index and Digital Infrastructure) from the society- and government-led initiatives perspectives. This takes into account governmental (top-down) and societal (bottom-up) aspects of e-participation initiatives into account, by focussing on the process of citizen empowerment for engaging in the processes of policy and political decision-making. This dual focus allows for a detailed analysis of procurement processes and highlight areas where citizen engagement and empowerment can be enhanced to improve overall governance effectiveness and inclusivity. Applying BEPI and TOE frameworks to public procurement allows for an in-depth examination of how institutional changes (government-led initiatives) shape procurement policies, and the overall policy formation and uptake of initiatives (society-led) and policy formation in public procurement.

To our knowledge, the TOE and BEPI frameworks have not been used to study the impact of e-GP adoption on transparency. In the context of public procurement, technology refers to the tools and systems used for procurement activities, i.e., e-GP systems, organisational factors include the structure and capabilities of the procurement organisations and officials in a country. The external environment includes factors such as existing market conditions, regulatory requirements, and supplier relationships. By applying the TOE framework, governments can analyse how e-GP impacts overall procurement efficiency, how the organisational structure (which includes e-portals) influence procurement effectiveness, and how external factors (i.e., WTO-GPA membership) shape the overall procurement landscape. Integrating BEPI with TOE provides a structured approach to understand how political, social (suppliers) and technological dimensions together with institutions shape the national public procurement landscape. These enrich the depth and breadth of analysis and provide a robust foundation for analyzing transparency in procurement. An integrated approach enhances the depth and breadth of analysis, and provides a robust foundation to analyse transparency, efficiency, and effectiveness in public procurement.

Fig. 1 presents the conceptual framework which demonstrates the relationship between institutional framework, political willingness, the role of IT infrastructure and literacy in public procurement. we propose that the WTO-GPA encourages countries to use of e-procurement systems which increase efficiency and transparency in public procurement.

We argue that transparency fosters digital citizen empowerment by granting access to government information. Through e-GP portals, which are a part of the broader institutional framework (namely government effectiveness, regulatory environment, contract integrity and democracy), citizens can monitor government actions, contribute to decision-making processes, and hold officials accountable. This is in line with existing literature (Khorana et al., 2014; Fazekas et al., 2015; Pirannejad et al., 2019; Mélou & Spruk, 2020). Trust between governments and citizens is strengthened through transparent communication,

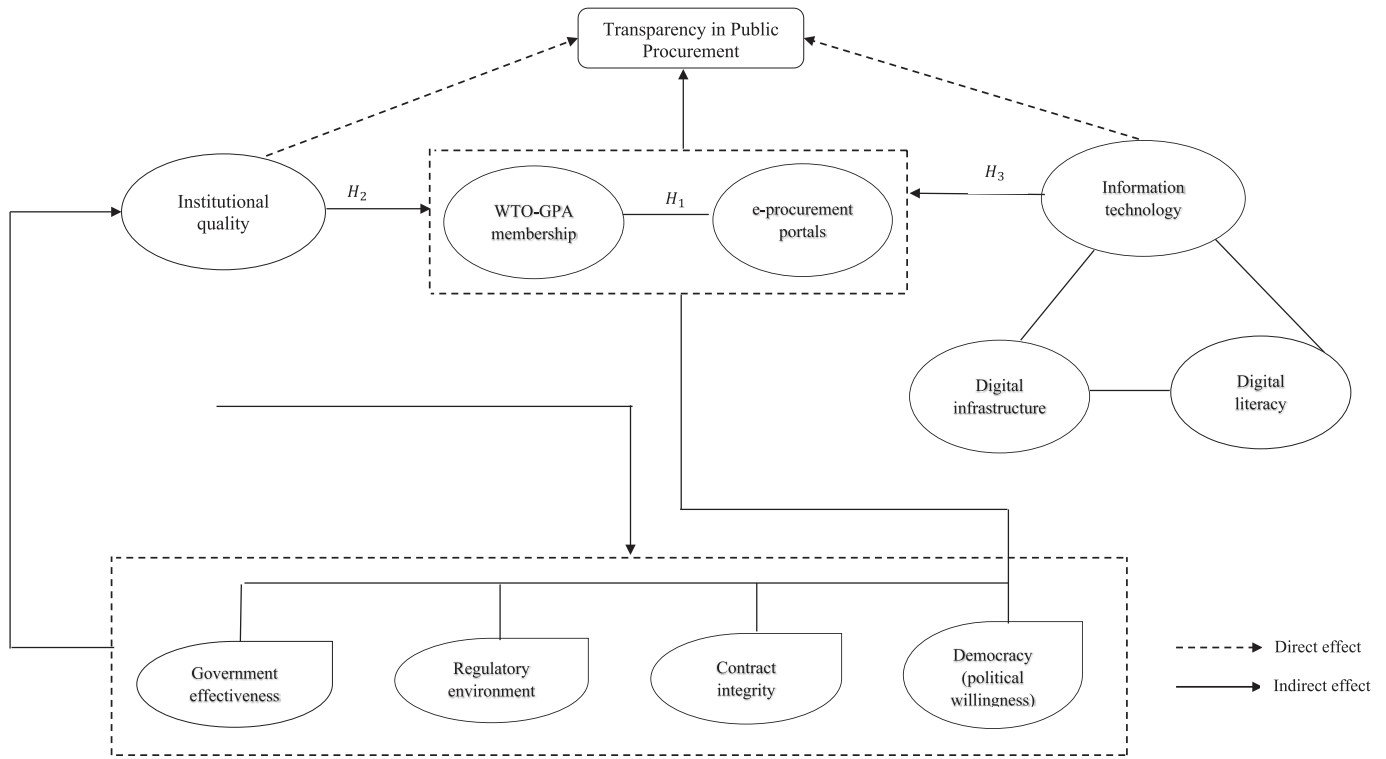


Fig. 1. Conceptual framework. Source: Authors elaboration.

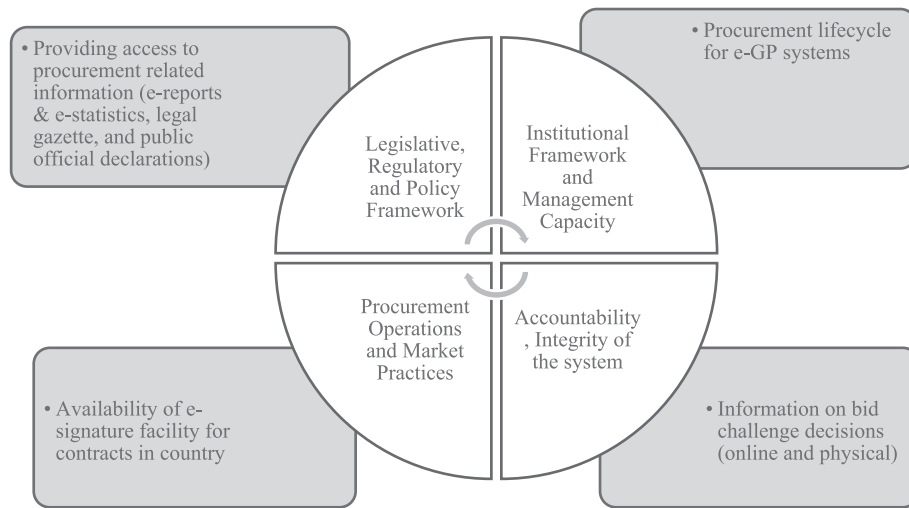


Fig. 2. Institutional Framework and Management Capacity in Procurement. Source: Authors elaboration adapted from MAPS, OECD (2018).

while digital literacy and skills development programs empower citizens to effectively navigate the digital landscape. We posit that political willingness triggers institutional reforms and leads to WTO-GPA membership which in turn fosters transparency (Drabek & Bacchetta, 2004; Alee & Scalera, 2012; Khorana et al., 2014; Choudhury, 2019). The benefits of quality institutions can be harnessed in functioning democracies, where the importance of good institutions is recognised by political leaders. Within this ecosystem, IT plays an important role given the success of e-procurement systems depend on the digital infrastructure and the level of digital literacy of suppliers in the country. It is, thus, a combination of good quality institutions backed by IT infrastructure and digital literacy foster transparency in public procurement.

3. Public procurement transparency index

3.1. Overview

We develop procurement-specific transparency measure, termed PPT-Index, which is a composite index that presents a single score value of transparency. The rationale for developing the index is its usefulness as policy tool to hold governments accountable, to promote competition, and reduce corruption. At present there is a lack of comprehensive e-procurement transparency index, which this paper develops by providing a measurable score for countries. This tool allows procuring agencies and suppliers to monitor fairness and integrity in procurement

processes for a particular year. The strength of the Index is its ability to assign individual weights to the different components to provide policymakers at a glance representation of transparency in procurement for effective decision making. The PPT-I enables bidders, stakeholders and citizens to engage with public procurement information from anywhere in the world without going through excessive bureaucratic procedures. According to Lnenicka et al. (2024), access to public data support government transparency actions, creates new opportunities, increases citizen trust in government and reduces information inequalities. Within this context, the PPT-I grants access to government information and aims to “increase the foundation for a well-governed public procurement system”, public trust and good governance (OECD, 2018).

The PPT-Index consists of four variables, namely e-GP lifecycle; information on bid challenge decisions; availability of e-signatures for contracts; access to procurement related information (e-reports & e-statistics, legal gazette, and public official declarations). The components of the Index draw on the Methodology for Assessing Procurement Systems (MAPS), developed by the World Bank and the Organisation for Economic Cooperation and Development (OECD),² which evaluates how countries' procurement systems work in four main categories, namely Legislative, Regulatory and Policy Framework; Institutional Framework and Management Capacity; Procurement Operations and Market Practices; and Accountability, Integrity and Transparency of the Public Procurement System. Fig. 2 lists variables from OECD MAPS to estimate transparency in e-procurement.

Drawing on Pirannejad et al. (2019), we use BEPI, and assume that e-procurement is a subset of e-participation which allows public (suppliers in this case) to access procurement related information through e-GP systems. The rationale to use BEPI is its ability to emphasise the importance of information flows for higher suppliers e-participation in the government marketplace. BEPI highlights the importance of allowing free access to information for all stakeholders. We hypothesise that free public procurement information is crucial for domestic and foreign suppliers, civil society and the general public. Enabling visibility of the procurement process, from the beginning to the end of the procurement cycle will enhance transparency and accountability. For this reason, we establish the link between the BEPI and e-GP given both share the goal of fostering transparency, efficiency and engagement in government processes through digital technology. In this regard, studies also show that this reduces public funds mismanagement, corruption and increase competition among suppliers to ensure better value for taxpayers' money (Ghossein et al., 2018; Knack et al. 2019).

3.2. Data sources and sampling

Data sources: Fig. 3 presents the modalities to select countries and data sources used for the PPT-Index.

Sampling: Fig. 4 reports the inclusion criteria and the multi-stage sampling methods used to develop the PPT-Index.

Following a staged sampling approach, we collect information on 218 countries in stage 1. Stage 2 excludes 15 countries with missing information, and the sample is reduced to 203 countries. Stage 3 checks data from the (OECD, 2017 2019, OECD, 2021). Stage 4 uses secondary data from the European Research for Anti-Corruption and State-Building (ERCAS) published in 2022, this has 129 countries. Finally, stage 5 manually gathers missing data from individual country portals. The final dataset includes 133 countries. Table A.1 presents the final list of countries included for analysis in the sample.³ Annex A presents the full

² MAPS is an OECD tool that aims to “increase the foundation for a well-governed public procurement system”, Details of the methodology can be accessed at <https://www.oecd.org/gov/public-procurement/methodology-assessing-procurement/>

³ Overall, 85 countries were removed from the original sample due to lack of data for all variables.

list of the countries with links to relevant data sources. Table 2 presents sub indicators and the inclusion criteria of the variables used to develop the PPT-Index.

3.3. Methodology

The PPT-Index is estimated with the following equation:

$$\text{PPT-I} = \text{GP}_{\text{Cycle}} \omega_1 + \text{e-signature} \omega_2 + \text{bid-challenge} \omega_3 + \text{e-public information} \omega_4 \quad (1)$$

where:

ω are inverse-covariance weights estimated with the generalised least squares (GLS) technique to create a composite index⁴ on transparency in procurement. This was developed by Schwab et al. (2020). This approach does not assume nor impose weighting schemes, thus, weights for each dimension are influenced by the correlation within each subcomponent(s).⁵ Unlike other⁶ weighting techniques, the GLS method is flexible because it assigns lower weights to indicators with missing values and/or high correlated indicators that do not add “new” information to the index. In this way, the summary index reduces measurement errors from the estimation process.

To ensure accuracy, we conduct the correlation of the e-GP cycle with the index components which include e-signature, bid-challenge, e-reports & statistics.⁷ This means if the correlation between sub-components is high, the GLS assigns a lower weight to variables which is likely to affect the distribution of other sub-indicators of the index. A tetrachoric factor analysis is employed and a new component, namely “e-public information” which contains e-reports, e-statistics, legal gazette, and disclosure of public officials is created to reduce noise between the variables. Kolenikov and Angeles (2004, 2009) show that the conversion of categorical (ordinal) into indicator (binary) variables can modify the orientation of the axes and introduce spurious correlations. We perform an oblique rotation, wherein factors are moderately intra-

⁴ Several weighting methods are used to construct a composite index such as the equal weights method, this is used for ethics, open budget, public integrity, corruption and transparency (Bandura, 2008; Mungiu-Pippidi, 2023; Mungiu-Pippidi & Dadaşov, 2016; OECD, 2008). Partially non-compensatory technique of geometric aggregation i.e. square root of the product between each dimension, has been used by OECD (2008). Lidén (2015) and Kabanov (2022) employ the refined e-participation index to consider democracies and citizen engagement in public policymaking. The best-worst approach uses a structured pairwise comparison method to account for varying importance of items in an aggregate index (Rezaei, 2015; 2016; Pirannejad et al., 2019). Finally, the unobserved components model (UCM) aggregates multiple sources of data into a single composite index, e.g. WGI indicators, assumes that the error within each source is uncorrelated across other sources and the variance across respondents remains the same (Kaufmann et al., 2006; Kaufmann et al., 2010; Williams, 2015).

⁵ Some empirical issues are worth stressing. First, if components are highly correlated weights can be zero or negative. Second, information on individual variables is likely to be cross reported, in which case the GLS would increase random errors of variables which are correlated with other components (Schwab et al., 2020).

⁶ Equal weights and non-compensatory schemes have strong assumptions and neglect the individual value of each component and/or possible interactions mechanisms which is a strong and normative assumption and possible interactions between components. UCM extracts common factors from different sources but assumes that weights are proportional to the reliability of each source. This means that each source is uncorrelated across countries., Hence, we use the summary index approach to calculate weights with the GLS procedure (Anderson, 2008; Schwab et al., 2020) which accommodates to the data generating process without imposing equal weights, minimizes standard errors of uncorrelated variables and also handles indicators with missing data.

⁷ For procurement reports and statistics, a significant and positive correlation (0.729) is documented whereas the other variables, namely e-signature and bid-challenge exhibit a positive but moderate correlation.

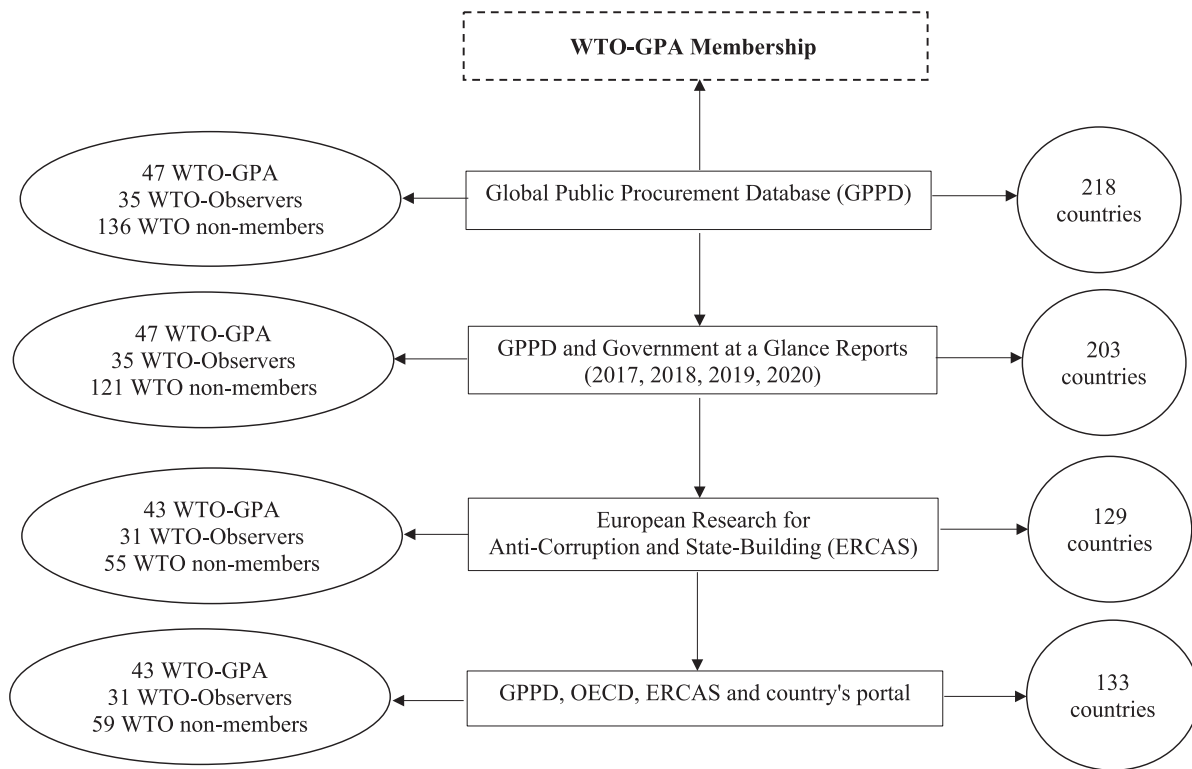


Fig. 3. Data sources.
Source: Authors compilation.

correlated compared to orthogonal rotations, to preserve the norms of the loading matrix rows (Clarkson & Jennrich, 1988). The components with an eigenvalue higher than 1 are retained.⁸ Thus, a single factor contains information from the three sub-indicators on e-public information dimension, which excludes potential spurious correlation. This new variable is normalized to fit the range from 0 to 1.⁹ Finally, to facilitate transparency comparison between countries the PPT-Index is rescaled¹⁰ with values between 0 and 1, where 0 is “completely opaque” and 1 “fully transparent”. a score of 1.¹¹ Fig. 5 presents the weights of the PPT-Index and Table A.2 (Panel B) reports the Cronbach's alpha of the dimensions of transparency in public procurement. Results indicate that the PPT-I is internally consistent with an average Cronbach alpha of 75% which is acceptable.

Fig. 5 shows e-GP cycle contributes 39% on average to transparency, followed by bid-challenge (29%) and e-signatures (22%). E-public information has a smaller share, only 10%.

The results are fitted into Eq. (1) as below:

⁸ Table A2 (panel a) reports the factor loadings. The retained factor namely “e-public information” is standardized and rescaled from 0 to 1.

⁹ A similar procedure was also applied by Pirannejad et al. (2019) and Kabanov (2022).

¹⁰ It is worth mentioning that the PPT-Index is continuous variable whilst all sub indicators with the exception of the e-public information index are binary variables (0 or 1). This differentiation is necessary because all normalisation methods which are invariant to the interval scale, are also invariant on the ratio scale (OECD, 2008, p. 85).

¹¹ This means that countries that countries with the lowest score across four dimensions of procurement (e.g. Namibia -2.8) are assigned a score of 0. Conversely, countries with robust e-procurement systems (e.g. United Kingdom 1.17).

$$\begin{aligned}
 \text{PPT} - \text{I} = & \text{GP Cycle } \omega_{(0.389)} + \text{e} - \text{Signature } \omega_{(0.290)} \\
 & + \text{bid} - \text{challenge } \omega_{(0.219)} + \text{e} - \text{public information } \omega_{(0.103)}
 \end{aligned}
 \tag{2a}$$

The estimated weights show that the e-GP cycle and bid-challenge recourse constitute 68% of the PPT-Index which highlights the importance of procurement information dissemination before the contract is awarded. This is to reduce the risk of corruption and increase transparency (Bauhr et al., 2020; Knack et al., 2019) and public scrutiny of procurement officials from investigative journalists (Chen & Neshkova, 2020), government watchdogs and regulators through more competitive and monitoring procedures (Duguay et al., 2023).

3.4. Stylized facts

Table 3 presents a snapshot of transparency from the PPT-Index in public procurement by region.

The global score base of the PPT-Index is 0.705.¹² We observe that North America and European countries rank first with an average transparency of 0.955 and 0.906 while Sub-Saharan Africa is at the bottom of the list with 0.528. In the case of South America, transparency scores are also lower (0.577) compared to Asia (0.752). For instance, within countries transparency scores range from 0.748 up to 1 for North America (USA, Canada, Mexico), Europe, Latin America (Chile, Peru) and East Asia and Pacific (Korea, Australia, Japan, Singapore, New Zealand). Exceptions include China, Malaysia, Mongolia, Philippines, and Timor-Leste, where the scores are between 0.600, Cambodia and Myanmar with a score close to zero (0.037). Similar scores are observed for Sub-Saharan African countries (0.563), Middle East and North Africa

¹² The average global transparency sub-score estimated by Mungiu-Pippidi, 2023 is 0.697 but this is based on procurement awards and notifications and does not include the full procurement cycle.

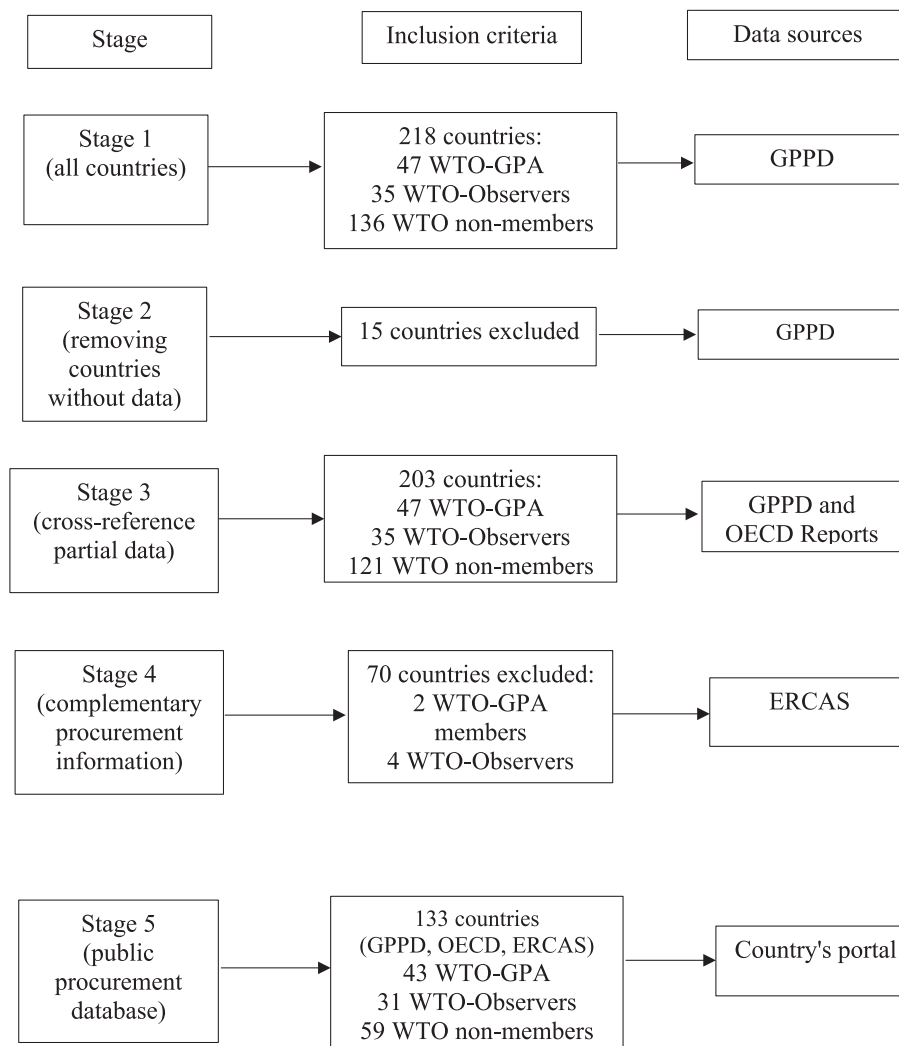


Fig. 4. Inclusion criteria for PPT-Index.

Source: Authors compilation.

(0.578), Latin America (0.609) and Central America with the exception of Belize and Barbados which show lack of transparency in procurement. Exceptions include Peru and Chile (0.793, 0.748) in Latin America. In sub-Saharan Africa these include Rwanda (0.748), Cameroon, Ethiopia, Zambia (0.711); Malta, Jordan, Qatar (Middle East and North Africa) where procurement transparency ranges from 0.600 to 0.955.

Fig. 6 shows the average transparency score by WTO-GPA membership, WTO-GPA Observers and WTO-GPA non-members.

Transparency levels exhibit heterogeneity across countries and regions. The results show that the WTO-GPA parties report a higher transparency in procurement (0.969). For Observer countries the transparency score is 0.676. For non-GPA members, the score is 0.528, which is 83.5% lower than WTO-GPA members. The explanation for varying levels of transparency is due to difference in the level of information provided by governments and also because some countries are WTO-GPA members and other are not. This follows from the binding commitment of WTO-GPA countries to disclose public procurement information throughout the entire lifecycle. However, the quantity of information disclosed may be influenced by factors such as e-portals maintenance, institutional quality, and digital infrastructure networks, leading to varying levels of transparency across countries. Transparency in procurement is further complicated by the political nature of government decisions and institutional factors. The WTO-GPA mandates for signatories to disseminate procurement data translates into benefits for

businesses seeking to participate in international procurement by providing greater access to information, thereby increasing competition and fairness. However, it poses a challenge for governments with limited digital infrastructure or weaker institutions, as they may struggle to meet these transparency requirements. Consequently, we suggest that while WTO-GPA membership provides a necessary condition for enhancing transparency, it may not be sufficient without the above-mentioned conditions.

Fig. 7 displays the correlation for transparency by WTO-GPA and non-WTO-GPA members.

We observe that legal mechanisms, public information dissemination, e-signature technologies and e-GP cycle differ by WTO-GPA membership. For WTO-GPA signatory countries the correlation is positive and highly significant; for WTO-GPA non-members the effect is negative and statistically significant at the 1% level. The positive correlation for GPA countries indicates that compliance with WTO GPA rules directly correlates with higher transparency levels. Further, legally binding measures on sharing procurement information through e-portals are a driver for higher transparency in WTO-GPA member countries. The explanation for higher score for GPA members is that member countries are obliged by the WTO-GPA to adopt transparency provisions and e-GP systems, which we test in Section 4.

Table 2
Inclusion Criteria.

Dimension	Subcomponent	Inclusion Criteria	Inclusion Code
e-GP cycle	e-publishing	e-procurement platform publishes procurement plans of procurement entities	A score of 1 is assigned if this feature is available in a country
	Online documents	e-platforms allow bidders to download tender documents.	A score of 1 is assigned if this feature is available in a country
	Awards	e-platforms publishes contract award decisions	A score of 1 is assigned if this feature is available in a country
Bid challenge/Complaint mechanism	Bid challenge	Unsuccessful bidders can challenge contract award decisions through the country's portal.	A score of 1 is assigned if this feature is available in a country
e-signature	e-signature	The country provides advanced e-signature and other authentication technologies in procurement contracts	A score of 1 is assigned if this feature is available in a country
Public information on e-procurement	Online reports	Government regularly publishes and provides access to online reports on procurement contracts	A score of 1 is assigned if this feature is available in a country
	Online statistics	Government regularly publishes and allows access to online statistics on procurement contracts	A score of 1 is assigned if this feature is available in a country
	Legal gazette	The country provides information on procurement regulations (and changes) through the official legal gazette	A score of 1 is assigned if this feature is available in a country
	Conflict of interest	The country provides information on disclosure of public officials	A score of 1 is assigned if this feature is available in a country

Note: For exclusion criteria a score of 0 is assigned if the country does not provide information on the subcomponents.

Source: Authors compilation.

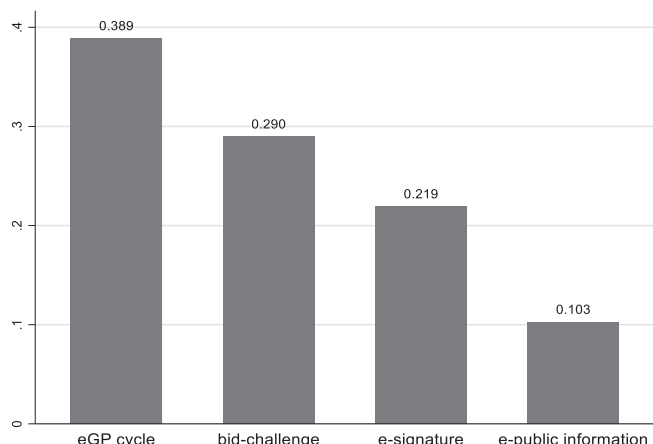


Fig. 5. Public Procurement Transparency Index (PPT-Index) - weight of the components.

(Source: Authors elaboration based on GPPD, OECD and country e-portals.)

Table 3
Transparency in procurement by region.

Region	PPT-I (average score)	Number of countries
North America	0.955	2
Europe and Central Asia	0.906	46
South Asia	0.752	5
East Asia and Pacific	0.669	15
Middle East and North Africa	0.597	12
Latin America and the Caribbean	0.577	26
Sub-Saharan Africa	0.528	27
World	0.705	133

Source: Authors compilation.

4. Examining the link between institutional framework and information technology

Governments play a critical role in promoting transparency by allowing access to information on the rules, regulations and the overall regulatory framework. When bidders have access to information that is complete and transparent information, they can exploit the procurement possibilities. A strong institutional framework that promotes transparent systems with rules and regulations acts as an incentive to bidders and increases competition in the market, which delivers value for money.

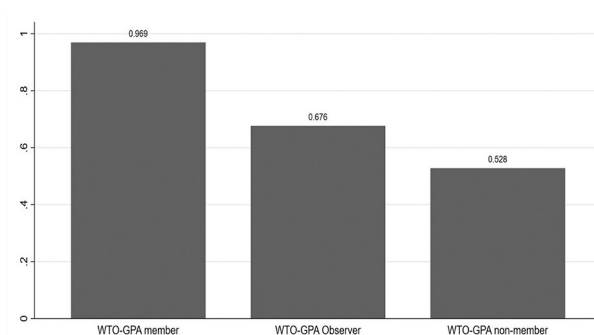


Fig. 6. Average transparency score for WTO-GPA, WTO-Observers and WTO non members.

Source: Authors elaboration.

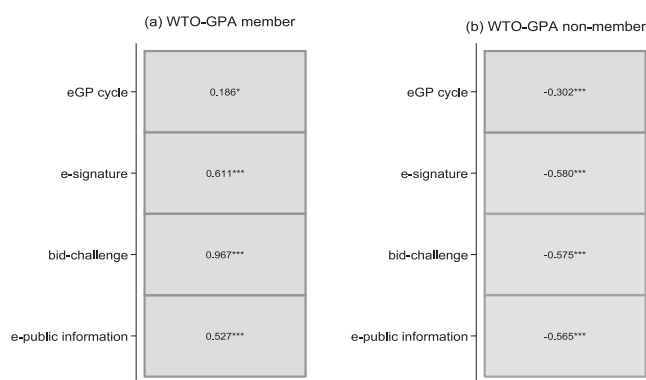


Fig. 7. Correlation of PPT-Index components for WTO-GPA and non-GPA members.

Note: ***, **, * indicate statistical significance at 1, 5 and 10% level, respectively.

Source: Authors compilation.

The underlying reason for providing information is that informing the bidders about the procurement institutional framework ensures efficient resource allocation (Williams, 2009; Williams, 2015; Fan et al., 2021). But quality institutions must be complemented with IT access i.e., digital infrastructure and literacy, to facilitate efficient procurement systems that drive efficiency gains for contracting entities, bidding firms, taxpayers (Jiménez et al., 2022; OECD, 2019b; OECD, 2019c).

Table 4

Description of variables, definition and sources.

Variable	Definition	Data source
PPT-Index	Public procurement transparency index	Own compilation
e-GP	Equal 1 if the country introduced e-GP tools, 0 if not	Government Public Procurement Database (GPPD) and OECD
GPA Observer	Equal 1 if the country signed the GPA agreement, 0 if not	World Trade Organisation (WTO)
Non-member	Equal 1 if the country is a WTO observer, 0 if not	World Trade Organisation (WTO)
OECD	Equal 1 if the country is not a WTO member, 0 if not	World Trade Organisation (WTO)
dem_pol_will	Equal 1 if the country is an OECD member, 0 if not	Organisation for Economic Co-operation and Development (OECD)
inst_effect	Quality of democracy, political interests, accountability human heights and freedom of association (EIU) in 2021	World Governance Indicators (WGI)
reg_envir	Institutional and government effectiveness (EIU) in 2021	World Governance Indicators (WGI)
contract_int	Regulatory environment, compliance and bureaucratic inefficiency (WMO) in 2021	World Governance Indicators (WGI)
i_band_speed	Contract integrity, securing major contracts from risk of bribery (WMO) in 2021	World Governance Indicators (WGI)
int_band_s	International bandwidth per Internet user (bit/s) in 2021	International Telecommunication Union (ITU)
mob_band_s	Fixed broadband subscriptions (per 100 people) in 2021	World Development Indicators (WDI)
access_elec	Mobile cellular subscriptions (per 100 people) in 2021	World Development Indicators (WDI)
digital_lit	Access to electricity (% of population) in 2021	World Development Indicators (WDI)
digital_infra	Ability to use digital technology of all parts of society in 2022	Digital Development Compass (UNPD)
	Digital infrastructure index	Own compilation

Source: Authors compilation.

4.1. Data

Public procurement related data is taken from the World Bank (GPPD) and OECD (2017, 2019a, 2021). Transparency related institutional variables are from World Bank's Worldwide Governance Indicators (WGI) (see Kaufmann et al., 2010; Kaufmann and Kraay, 2023). We consider four WGI sub-variables, namely 'government effectiveness', 'regulatory environment', 'contract integrity' and democracy (proxy for political willingness).¹³ We rationalise that procurement as government activity is linked with public policy effectiveness (Khorana et al., 2014) and contract security which are both related to democracy.¹⁴ Data on internet speed users is from the International Telecomm Union (ITU); while broadband internet, mobile subscriptions and access to electricity is from the WDI (World Bank, 2023). Data on digital literacy (ability to use digital technology of all parts of society) is from the United Nations Development Program (UNDP). Table 4 lists variables, definitions and data sources. Table A.3 outlines the datasets, variables used and data links.

We construct procurement-specific digital infrastructure index using the GLS approach¹⁵ with:

- i) international internet speed users, bits per second
- ii) broadband internet subscriptions, per 100 people
- iii) mobile subscriptions, per 100 people
- iv) access to electricity (percentage of population).

The weights, assigned with the GLS procedure, show that broadband accounts on average 41%, internet speed 33%, mobile subscriptions 16% and access to electricity 11%.

$$D - I = \text{broadband} - \text{subscriptions } \omega_{(0.406)} + \text{internet speed } \omega_{(0.330)} + \text{mobile} - \text{subscriptions } \omega_{(0.156)} + \text{access electricity } \omega_{(0.108)} \tag{2b}$$

¹³ We use the (standardized) estimated parameters from the UCM unlike the aggregate institutional indicators.

¹⁴ As Williams (2011, p.813) states, "the country scores can be used to compare relative governance across countries in time t, but the scores for each country for time t, t + 1, t + 2 etc. are not directly comparable". Hence, given the cross-sectional nature of our study, we use the estimated parameters instead of the aggregated WGI scores.

¹⁵ The digital infrastructure index does not employ factor analysis approach due to low interterm correlations.

4.2. Econometric approach

The dependent variable, PPT-Index, is continuous with a closed bounded domain [0,1]. Given the predicted values of linear models may lie outside the unit-interval, we employ a fractional probit technique, which is in line with Papke and Wooldridge (1996) and Wooldridge (2010). We estimate H1, H2, and H3 with following equations:

H1. WTO-GPA membership, supported by a strong political willingness to reform and complemented by e-GP systems, fosters transparency in public procurement.

$$y_t = \beta_0 + \beta_1 eGP_t + \beta_2 WTOGPA_i + \beta_3 WTOGPA_{OBi} + WTOGPA_i \times \beta_4 dem_t + WTOGPA_{OBi} \times \beta_5 dem_t + \epsilon_i \tag{3}$$

H2. WTO-GPA membership together with e-procurement portals and strong institutional frameworks promotes transparency.

$$y_t = \beta_0 + \beta_1 eGP_t + WTOGPA_i \times \beta_2 instqly_t + WTOGPA_{OBi} \times \beta_3 instqly_t + \epsilon_i \tag{4}$$

H3. Transparency depends on both WTO-GPA membership and the level of information technology (digital infrastructure and digital literacy) available in a country.

$$y_t = \beta_0 + \beta_1 eGP_t + WTOGPA_i \times \beta_2 DI_t + WTOGPA_{OBi} \times \beta_3 DI_t + WTOGPA_i \times \beta_4 dl_t + WTOGPA_{OBi} \times \beta_5 digt_t + eGP_t \times \beta_6 DI_t + eGP_t \times \beta_7 dl_t + \epsilon_i \tag{5}$$

where

- y_t is the transparency index in public procurement (PPT-Index);
- eGP_t is the dummy for active e-GP portals;
- $WTOGPA_i$ is the dummy for WTO-GPA membership;
- $WTOGPA_{OBi}$ is the dummy for WTO-GPA Observer status;
- $WTOGPA_{NONi}$ is the omitted category (non-membership to WTO-GPA);
- dem_t is a measure of democracy (political willingness);
- $instqly_t$ is a vector of institutional indicators, namely government effectiveness, regulatory environment and contract integrity;

DI_t is the digital infrastructure index;

dl_t is the level of digital skills in a country;

Subscript i is reported for dummy variables, t is time which is the latest year of data available and ϵ_i is the error term.

The fractional probit approach provides a consistent estimation, unlike the ordinary least squares (OLS) where the predicted¹⁶ values of linear models “[...] can never be guaranteed to lie in the unit interval” Papke & Wooldridge (1996, p. 620).” We also consider the following methodological issues. First, the empirical analysis uses cross-sectional data. This allows running pooled models. Second, the potential endogeneity of a covariate is addressed with an interaction between the endogenous variable(s) and exogenous binary indicator(s); the standard statistical inference for the interaction terms applies (see Nizalova & Murtazashvili, 2016; Beverelli et al., 2018; Bun & Harrison, 2019). The WTO-GPA and WTO-GPA Observer countries are interacted with institutional quality variables, digital infrastructure, and digital literacy. The interactions show an indirect effect of the WTO-GPA membership and Observer status on transparency through political willingness, institutional quality, information technology. Third, to avoid multicollinearity issues we assess the indirect effects of institutional and digital variables with one indicator at a time.¹⁷

4.3. Descriptive statistics and discussion of results

Table 5 presents the PPT-Index and digital index descriptive statistics by WTO-GPA membership.

WTO-GPA parties have higher PTT-Index and digital infrastructure (0.567) compared to WTO-Observers (0.367). Digital literacy is high for GPA countries (0.904). For instance, from GPA parties, Korea, Switzerland, France, Estonia and the UK have highest access to digital infrastructure (internet speed, mobile connections), 0.647 on average. A similar pattern is observed for digital literacy, which is 0.912 on average, for these countries.

WTO-GPA Observers and GPA non-members have low digital infrastructure and digital literacy, this is likely to affect the e-procurement portal usage. Examples of WTO-GPA Observers with e-procurement portals are Kyrgyz, Georgia and Thailand with digital infrastructure and literacy levels, at 0.406 and 0.833 average, respectively.

For WTO-GPA non-members (e.g. Angola, Lesotho, Zimbabwe), IT infrastructure (internet speed, mobile connections) and digital literacy is lower (0.149 and 0.570) on average. For countries, such as Sierra Leone and Chad, which have no e-procurement portal also have limited access to digital infrastructure (0.070) and digital literacy (0.215). This is not surprising given most WTO-GPA non-member parties are developing countries with limited access IT infrastructure (0.260) and digital literacy capacities (0.600). Table 6 presents the top 20 and bottom 20 countries in the order of ranking.

Results confirm that transparency is lower for countries that do not mandate to comply with GPA commitments. The ranking for all countries in our sample is reported in Table A.4. We observe that the institutional frameworks affect transparency in public procurement. For instance, the WTO-GPA Parties exhibit high institutional quality as evidenced by government effectiveness (0.718), regulatory environment (0.734), contract integrity (0.733) and democracy (0.754). But this is not the case for WTO-GPA non-member parties where the quality of institutions, namely government effectiveness (0.221), regulatory environment (0.460), contract integrity (0.353) and democracy (0.387),

¹⁶ OLS can be augmented with a non-linear function of the independent regressor(s), but these functions must include the predicted values from the linear regression model into the equation. Papke and Wooldridge (1996) provide a detailed explanation of the shortcomings of this procedure.

¹⁷ For instance, the WGI are likely to be highly correlated because of measurement errors from survey sources and the assessment given to each country (Kaufmann et al., 2007).

Table 5
Descriptive statistics.

Panel A: WTO-GPA party	Mean	SD	Min	Max
PPT-Index	0.969	0.037	0.852	1
Democracy (political willingness)	0.754	0.128	0.461	0.956
Government effectiveness	0.718	0.217	0.250	1
Regulatory environment	0.734	0.108	0.500	1
Contract integrity	0.733	0.189	0.333	1
Digital infrastructure	0.567	0.097	0.398	1
Digital literacy	0.904	0.051	0.790	1
Number of countries	43			
Panel B: WTO-GPA Observer status				
PPT-Index	0.676	0.077	0.560	0.793
Democracy (political willingness)	0.454	0.161	0.128	0.740
Government effectiveness	0.415	0.175	0	0.750
Regulatory environment	0.546	0.152	0.250	0.917
Contract integrity	0.409	0.148	0.167	0.833
Digital infrastructure	0.367	0.089	0.151	0.540
Digital literacy	0.765	0.116	0.390	0.920
Number of countries	31			
Panel C: WTO-GPA non-member				
PPT-Index	0.528	0.238	0	1
Democracy (political willingness)	0.387	0.178	0.051	0.849
Government effectiveness	0.221	0.192	0	0.625
Regulatory environment	0.460	0.159	0	0.750
Contract integrity	0.353	0.186	0	0.833
Digital infrastructure	0.260	0.129	0	0.560
Digital literacy	0.600	0.170	0.180	0.900
Number of countries	59			

Source: Authors compilation.

is likely to lead to a lack of transparency. This is because a poorly implemented institutional framework influences a society's incentive system, which in turn affects social interactions and individual's behaviours (North, 1990). Taken together, the results confirm that transparency in procurement is likely to be determined by a country's WTO-GPA commitments, political willingness, institutional frameworks, digital infrastructure and literacy.

Tables A.5 and A.6 present pairwise correlation and multicollinearity analysis. The mean of Value Inflation Factor (VIF) is 4.773 which suggests no multicollinearity below the rule of thumb of 10.

4.4. Discussion

H1. WTO-GPA membership fosters transparency in public procurement.

Table 7 (column I) reports WTO-GPA membership fosters transparency in public procurement. The GPA parties present evidence of higher transparency (1.623) with positive and statistically significant coefficient at the 1% level. The positive and significant relationship between e-GP adoption and transparency (2.391) at the 1% level suggests WTO-GPA parties have institutional frameworks for information on tender notifications, contract awards, and e-quotations. WTO-GPA Observers, with no mandate to comply with GPA requirements, have lower transparency (0.212) but it is highly significant at the 5% level.

Column II reports results when democracy (political willingness) is introduced. For GPA Parties democracy is positive (2.058) and statistically significant at the 1% level, suggesting political willingness to reform leads countries to join WTO-GPA membership which fosters transparency. For WTO-GPA Observers, the impact on transparency is 0.325 and significant at the 5% level suggesting democratic government are likely to publish data which fosters transparency and citizens trust in e-government services. In line with extant literature on e-government initiatives, political commitment, e-participation and new mechanisms to increase transparency (Bisogno et al., 2022; Cinar et al., 2019; Cinar et al., 2021; Moser-Plautz, 2023; Savoldelli et al., 2014). In this case

Table 6
Top and bottom 20 countries with transparency in public procurement.

WTO-GPA member	PPT-I (overall score)
Armenia	1
Bulgaria	1
Croatia	1
Estonia	1
Finland	1
France	1
Greece	1
Israel	1
Italy	1
Korea, Rep.	1
Latvia	1
Lithuania	1
Moldova	1
Portugal	1
Romania	1
Slovak Rep.	1
Spain	1
Switzerland	1
Ukraine	1
United Kingdom	1
WTO-Observer	PPT-I (overall score)
Georgia	0.793
Thailand	0.793
Albania	0.748
Chile	0.748
India	0.748
Indonesia	0.748
Jordan	0.748
Kyrgyz Republic	0.748
North Macedonia	0.748
Russia	0.748
Sri Lanka	0.748
Turkey	0.748
Vietnam	0.748
Cameroon	0.711
Kazakhstan	0.711
Pakistan	0.708
Argentina	0.645
Paraguay	0.645
Dominican Rep.	0.608
Colombia	0.608
WTO non-member	PPT-I (overall score)
South Africa	0.563
Tanzania	0.563
Uganda	0.563
Yemen	0.563
Bolivia	0.560
Iran	0.560
Venezuela	0.560
Grenada	0.523
Lesotho	0.523
St. Lucia	0.523
Zimbabwe	0.523
Algeria	0.037
Cambodia	0.037
Myanmar	0.037
Barbados	0
Belize	0
Chad	0
Lebanon	0
Namibia	0
Sierra Leone	0

Source: Authors compilation.

countries that signed for the GPA are more likely to report high transparency levels in procurement.

H2. WTO-GPA membership and high institutional quality promotes transparency.

Table 7 (columns III-V) shows transparency is impacted indirectly by institutional quality through WTO-GPA membership. The impact of GPA

membership on transparency is evidenced by the coefficients of government effectiveness (2.089), regulatory environment (2.139) and contract integrity (2.058), and all the interaction terms are statistically significant at the 1% level. The GPA parties have active e-procurement portals when complemented with robust institutions foster on average transparency (2.429). For Observer countries, the effect of institutional quality on transparency is modest but statistically significant at the 5% level. Point estimates confirm institutional quality, namely government effectiveness (0.334), regulatory environment (0.358) and contract integrity (0.379), have a moderate impact on transparency.

The is because firstly, the GPA requires providing equal and fair access to procurement information and mandates use of e-GP (World Trade Organization (WTO), 2012). Secondly, institutional quality (government effectiveness, regulatory environment, contract integrity) is influenced by political willingness to reform (Citro et al., 2021; Khorana et al., 2014) and government openness trust in the public sector and its institutions (Schmidhuber et al., 2021). Along these lines, we argue that a combination of effective institutions from WTO-GPA membership enhances information to the bidders on the e-GP life-cycle, bid-challenge, e-signature, e-public information. This improves accountability, increases trust in e-government applications accountability and lowers the transaction cost (Barcevičius et al., 2019; Bauhr & Grimes, 2014; Bosio et al., 2022; Kim & Lee, 2012; Knack et al., 2019).

H3. Information technology and WTO-GPA membership impacts transparency in procurement.

Table 8 (Column I) shows that IT infrastructure is an enabling factor, given WTO-GPA membership mandates countries to use e-GP tools. The digital coefficient for the GPA parties is positive (2.748) and statistically significant at the 1% level whereas for WTO-Observers the effect is 0.488 and significant at the 5% level. Results highlight the importance of adequate digital infrastructure and the dissemination of public information released by governments for transparency (Bisogno et al., 2022; Lathrop & Ruma, 2010; Noveck, 2009; Relly & Sabharwal, 2009; Twizeyimana & Andersson, 2019).

Column II shows the positive effect of the WTO-GPA membership and digital skills on transparency is 1.779 and statistically significant at 1% level, unlike WTO-GPA Observers which is 0.268 and significant at 5% level. The coefficient for the e-GP system is 2.404 on average and highly significant, suggesting that improvements in information technology, such better access to high-speed broadband internet and mobile networks in conjunction with digital literacy capabilities, support higher transparency procurement. Results confirm the importance of skills (e-competences) to use e-government systems and understand the information, e-participation in the decision-making process and government accountability to increase transparency (Chen & Neshkova, 2020; Evans & Yen, 2005; Kearns, 2004; Zheng, 2016).

Columns (III-IV) report the indirect effect of e-GP systems through digital infrastructure and digital literacy on both WTO-GPA and WTO-GPA Observer countries. For WTO-GPA parties, digital infrastructure and literacy skill remain positive (2.125 and 1.393) and highly significant. In comparison, for WTO-GPA Observers, the coefficient is positive (0.291) but statistically insignificant. The same pattern is observed for digital literacy where the coefficient is 0.047 and insignificant. Interestingly, the interaction between e-procurement portals, digital infrastructure and digital literacy is positive and highly significant, suggesting that countries that provide better connectivity services (broadband internet, mobile) with digital literacy increase transparency by 1.581 and 1.435, respectively.

Taken together, the results reinforce the findings that high quality of digital infrastructure and digital literacy of e-procurement portals leads to higher transparency. In line with existing literature (Barcevičius et al., 2019; Bosio et al., 2022; Jiménez et al., 2022; Khorana et al., 2014) when procurement under the GPA rules is complemented with digital infrastructure and literacy skills, citizens' trust in e-portals and overall transparency increases.

Table 7
Transparency in Procurement, WTO-GPA membership and Institutional quality.

Variables \ Model specification	(I)	(II)	(III)	(IV)	(V)
Dependent variable: PPT-Index					
e-GP	2.391*** [0.183]	2.429*** [0.183]	2.450*** [0.183]	2.405*** [0.183]	2.433*** [0.183]
WTO-GPA	1.623*** [0.096]				
WTO-GPA Observer	0.212** [0.066]				
WTO-GPA × Democracy (political willingness)		2.058*** [0.147]			
WTO-GPA Observer × Democracy (political willingness)		0.325** [0.137]			
WTO-GPA × Government effectiveness			2.089*** [0.176]		
WTO-GPA Observer × Government effectiveness			0.334** [0.144]		
WTO-GPA × Regulatory environment				2.139*** [0.149]	
WTO-GPA Observer × Regulatory environment				0.358** [0.116]	
WTO-GPA × Contract integrity					2.058*** [0.176]
WTO-GPA Observer × Contract integrity					0.379** [0.150]
Constant	-2.145*** [0.175]	-2.145*** [0.175]	-2.145*** [0.175]	-2.145*** [0.175]	-2.145*** [0.175]
Pseudo R-squared	0.243	0.239	0.232	0.237	0.230
Log-Likelihood	-61.070	-60.197	-60.780	-61.521	-62.126
Number of countries	133	131	131	133	133

Note: e-GP, WTO-GPA and WTO-GPA Observers are binary variables (0 or 1). Robust standard errors in brackets, ***,**, * indicate statistical significance at 1, 5 and 10% level, respectively.

Source: Authors compilation.

Table 8
Transparency in Procurement, WTO-GPA membership and Information technology.

Variables \ Model specification	(I)	(II)	(III)	(IV)
Dependent variable: PPT-Index				
e-GP	2.412*** [0.183]	2.395*** [0.183]		
WTO-GPA × Digital infrastructure	2.748*** [0.214]		2.125*** [0.394]	
WTO-GPA Observer × Digital infrastructure	0.488** [0.174]		0.291 [0.296]	
WTO-GPA × Digital literacy		1.779*** [0.109]		1.393*** [0.187]
WTO-GPA Observer × Digital literacy		0.268** [0.085]		0.047 [0.150]
e-GP ⁺ × Digital infrastructure			1.581** [0.597]	
e-GP × Digital literacy				1.435*** [0.367]
Constant	-2.145*** [0.175]	-2.145*** [0.175]	-0.267 [0.166]	-0.697*** [0.212]
Pseudo R-squared	0.236	0.241	0.183	0.205
Log-Likelihood	-61.643	-61.178	-65.860	-64.087
Number of countries	133	133	133	133

Note: e-GP, WTO-GPA and WTO-GPA Observers are binary variables (0 or 1). Robust standard errors in brackets, ***,**, * indicate statistical significance at 1, 5 and 10% level, respectively.

Source: Authors compilation.

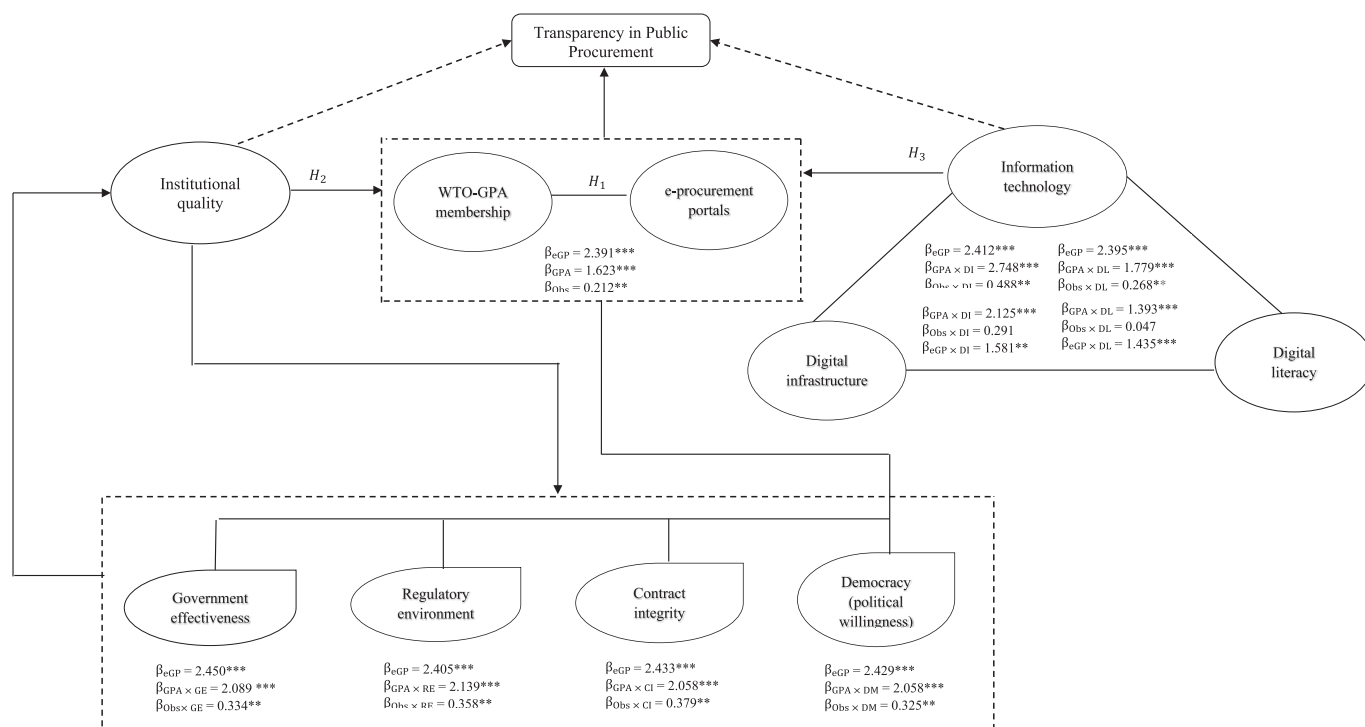
Fig. 8 presents the relationship between institutional framework, political willingness and IT (digital infrastructure and digital literacy). Results confirm political willingness, proxied by democracy, triggers institutional reforms and membership to the WTO-GPA which in turn leads to effective e-procurement portals use. Thus, sound institutions (e. g. contract integrity) and better access to digital infrastructure resources (connectivity and speed of broadband internet, mobile services) and the level of digital literacy of citizens backed by political willingness and IT initiates a virtuous cycle of procurement transparency.

4.5. Robustness checks and sensitivity analysis

To test the robustness, we firstly assess whether results hold for OECD countries. Table 9 (Column I) shows that transparency increases by 1.140 in OECD countries compared to non-OECD countries. The e-GP coefficient is positive (2.555), and statistically significant at the 1% level. In addition, democracy (Column II) increases PPT-Index by 1.516 and institutional variables, namely, government effectiveness (1.559), regulatory environment (1.680) and contract integrity (1.530) are highly significant (columns III-V). These confirm that political leadership and institutional frameworks are important drivers of e-GP system and transparent procurement.

Table 10 (columns I-IV) show that OECD countries have higher IT infrastructure (2.221) which when complemented with digital literacy of suppliers (1.274) fosters transparency in public procurement (columns I-IV).

The use of e-GP by OECD countries increases transparency (2.365) and when countries provide better access to IT infrastructure (internet speed, broadband connectivity mobile access) with high digital literacy transparency increase is 1.829. These findings, are expected as developed countries invest more in infrastructure and hence, have more resources for e-government initiatives which in turn increase e-participation and transparency. However, e-procurement systems



Note: Authors elaboration, ***, **, * indicate statistical significance at 1, 5 and 10 percent level, respectively

Fig. 8. WTO-GPA membership, Institutional quality, Information technology and Transparency in Public Procurement.

Table 9
Transparency in Procurement, OECD membership and Institutional quality.

Variables \ Model specification	(I)	(II)	(III)	(IV)	(V)
Dependent variable: PPT-Index					
e-GP	2.555*** [0.182]	2.563*** [0.182]	2.563*** [0.182]	2.550*** [0.182]	2.560*** [0.182]
OECD	1.140*** [0.146]				
OECD × Democracy (political willingness)		1.516*** [0.171]			
OECD × Government effectiveness			1.559*** [0.162]		
OECD × Regulatory environment				1.680*** [0.158]	
OECD × Contract integrity					1.530*** [0.158]
Constant	-2.145*** [0.175]	-2.145*** [0.175]	-2.145*** [0.175]	-2.145*** [0.175]	-2.145*** [0.175]
Pseudo R-squared	0.185	0.191	0.192	0.191	0.187
Log-Likelihood	-65.738	-63.993	-63.894	-65.217	-65.600
Number of countries	133	131	131	133	133

Note: e-GP and OECD are binary variables (0 or 1). Robust standard errors in brackets, ***, **, * indicate statistical significance at 1, 5 and 10% level, respectively. Source: Authors compilation.

cannot be viewed in isolation. The efficacy of one institution (such as an e-portals) is influenced by the efficacy of related institutions. For instance, e-participation in public policies and accountability increases citizen engagement and trust in government initiatives (Bisogno et al., 2022; Cucciniello & Nasi, 2014; Hall & Soskice, 2001; Pirannejad et al., 2019).

Second, we assign equal weights (25%) to the PPT-Index components. The results in Tables A.7-A10 confirm that transparency remains high in WTO-GPA countries. This is because the WTO-GPA requires ‘sound’ institutions which facilitate institutional reforms that provide, i. e. these provide access to procurement related information (awards, e-notifications, e-quotations). However, this is not the case for the WTO-

GPA Observers that are not mandated to comply with GPA commitments. A lower level of transparency in these countries can be attributed to unwillingness to reform (lack of political leadership) and poor institutional quality. Also, e-GP usage, the indirect effect of WTO-GPA and OECD membership (through institutional indicators, digital infrastructure and digital literacy skills) are considerably lower but yet remain highly significant. An explanation for these results is the weighting estimation scheme method which assigns the same importance to each dimension, and hence, underestimates the use of e-GP. Notwithstanding this, even with equal weight our main results hold.

Table 10
Transparency in Procurement, OECD membership and Information technology.

Variables \ Model specification	(I)	(II)	(III)	(IV)
Dependent variable: PPT-Index				
e-GP	2.549*** [0.181]	2.553*** [0.182]		
OECD × Digital infrastructure			1.390***	
	[0.219]		[0.295]	
OECD × Digital literacy		1.274*** [0.150]		0.851*** [0.177]
e-GP × Digital infrastructure			2.365*** [0.432]	
e-GP × Digital literacy				1.829*** [0.287]
Constant	-2.145*** [0.175]	-2.145*** [0.175]	-0.416*** [0.141]	-0.864*** [0.186]
Pseudo R-squared	0.192	0.187	0.165	0.169
Log-Likelihood	-65.199	-65.600	-67.352	-67.002
Number of countries	133	133	133	133

Note: e-GP and OECD are binary variables (0 or 1). Robust standard errors in brackets, ***,**, * indicate statistical significance at 1, 5 and 10% level, respectively.

Source: Authors compilation.

4.5.1. Sensitivity analysis

We conduct a sensitivity analysis with an enhanced Public Procurement Transparency Index (PPT_e-Index), this includes e-GP cycle; e-signature; e-bid challenge and e-public information. The construct of bid challenge now includes two subcomponents namely, e-bid challenge mechanism and bid-challenge law. We differentiate between e-bid challenge and bid challenge law i.e. the possibility to perform an online recourse of Procurement Entity (PE) decisions and the legal requirement to provide information to unsuccessful bidders. We use the inclusion/exclusion procedure for the qualitative bid challenge law variable bid challenge law. A score of 1 is assigned if the country grants by law the possibility to challenge PE decisions legally. In cases where such information is missing i.e. not provided by governments or Public Procurement Law, a value of 0 is assigned. The inclusion of the sub-dimensions of bid-challenge informs whether excessive bureaucratic procedures disincentivize unsuccessful bidders to file bid-challenge.

We then re-run the PPT-Index with the expanded sub-components and confirm that the transparency index in public procurement is internally consistent and reliable. Fig. 9 displays the weights of Enhanced PPT-Index (PPT_e-I).

Table 11 reports the standardized loading factors and reliability of the index.

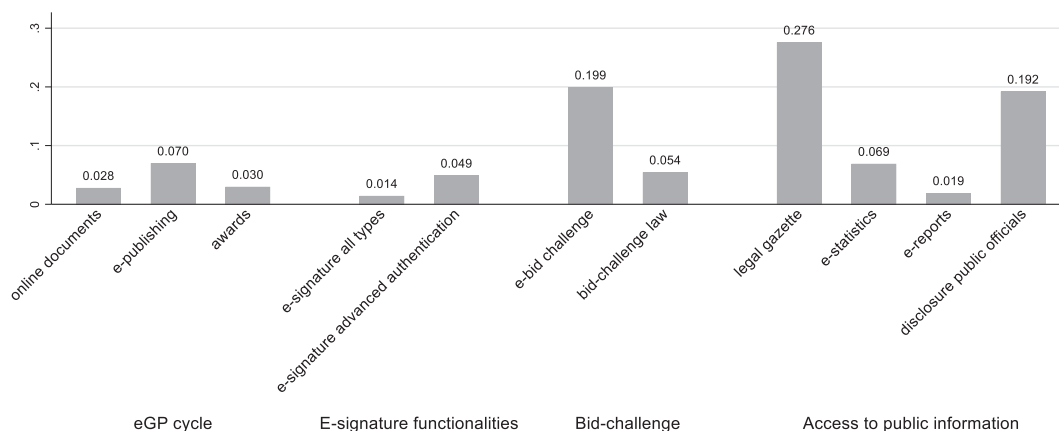


Fig. 9. Public Procurement Transparency Enhanced Index (PPT_e-I) - weight of the components.
Note: Authors compilation.

The factor loadings are above 0.4 which is widely accepted as a measure of stability (Stevens, 2002). An internal reliability analysis is performed to determine the consistency of the PPT_e-I where a Cronbach's α of near here}0.7 indicates high reliability (Peterson, 1994). The Cronbach alpha for three of the four dimensions is above 0.7 with the exception of e-public information (0.57). Given that all items of the construct are binary (0 or 1), we employ the KR-20 test which is a special case of the Cronbach alpha (Crocker & Algina, 2008). The coefficient derived from the KR-20 test is near here} 0.8, which confirms good internal consistency. Finally, Fig. 10 displays the standard errors of the PPT-I and Enhanced PPT-I (PPT_e-I) for WTO-GPA, WTO-Observers and WTO non-member countries.

Results show that the PPT_e-I has low dispersion (0.170) compared to the PPT-I (0.252). However, this is not the case for WTO-GPA parties (0.037 and 0.060) and WTO-Observers (0.077 and 0.164). The lower dispersion of the PPT-I is attributed to the tetrachoric analysis which reduces noise between the variables. For these reasons, we regard the PPT-I as our preferred measure of transparency in public procurement.

Table 11
Constructs, Items, and Standardized Factor Loadings.

Constructs	Items	Factor loadings
E-procurement cycle ($\alpha = 0.71$)	(1) e-publishing	0.42
	(2) contract award	0.56
	(3) online documents	0.70
E-signature functionalities ($\alpha = 0.90$)	(1) e-signature advanced authentication	0.95
	(2) e-signature all types	0.70
Bid-challenge ($\alpha = 0.80$)	(1) e-bid challenge	0.92
	(2) bid challenge law	0.64
Access to public information ($\alpha = 0.57$)	(1) e-reports	0.54
	(2) e-statistics	0.55
	(3) legal gazette	0.52
	(4) disclosure public officials	0.41

[Notes: a) Convergent validity: 8/11 items (72.7%) have a correlation coefficient with the score of their own dimension greater than 0.400. Divergent validity: 4/11 items (36.4%) have a correlation coefficient with the score of their own dimension greater than those computed with other scores. b) The Comparative Fit Index (CFI) and Normal Fit Index (NFI) reported for the validation analysis are 0.937 and 0.912 respectively whereas the (standardized) root mean square residual is 0.068. CFI values higher than 0.90 and SRME lower than 0.08 indicate that the model improves the fit (Byrne, 1994; Fan et al., 1999; Schumacker & Lomax, 2004) Source: Authors compilation].

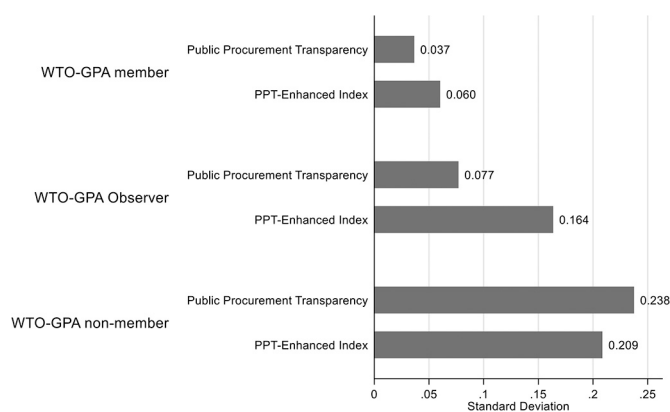


Fig. 10. Public Procurement Transparency (PPT—I) vs PPT-Enhanced Index (PPT_e-I).

Note: Authors compilation.

4.6. Limitations

The study has some limitations. First, the PPT-Index uses cross-sectional data which means that the data allows running pooled models only. This restricts the ability to exploit the panel structure across different years and countries. Second, we use publicly available information such as GPPD, OECD Government at Glance reports and ERCAS which does not draw on surveys and expert opinions from the sample of countries analyzed. In line with Pirannejad et al. (2019), we acknowledge that a country's context (e.g. social factors and political context) could influence the weights of the Index and the release of procurement related information.

5. Policy implications

The governance of public procurement processes, which includes the use of e-GP tools complemented and the institutional framework, plays an important role in achieving and advancing the public policy objectives of higher transparency and accountability. Information on the existing levels of transparency increases participation in procurement and key starting points to assure sustainable and efficient public procurement systems. The findings of our results have two main policy implications. First, clear procurement regulations and a robust institutional framework provides access to laws and regulations, planned procurements, calls for tender, award announcements (domestic and foreign suppliers). Information relating to e-procurement systems (e.g. benchmarks, monitoring results, statistics, etc) promote fair and equitable treatment for potential suppliers, stakeholders and citizens. The findings suggest that the information within the procurement lifecycle (eGP usage; bid challenge mechanisms; use of e-signature for contracts and e-public information) has important implications for information usability, citizen participation and trust in government initiatives that in turn increase transparency. Along these lines, political and institutional leadership (e.g. joining the WTO-GPA) is decisive for the successful implementation of e-GP systems because it enables governments to lock in domestically contested economic reforms (Baccini & Urpelainen, 2015). Thus, the implementation of any e-GP system must be a change management process project and governments must ensure that political willingness is backed by ample information on the benefits of using e-GP to the procuring entities staff. Further, bidders must also be informed of the strategic importance of e-GP.

Second, a robust e-procurement framework system is important, but it is not sufficient to foster transparency. Strong institutions and e-GP portals enhance transparency at all levels of the procurement process, foster competition, and increase accountability of entities and staff. In addition, a coherent framework supporting the uptake of e-portals for

firms is vital to provide additional market access in government procurement. This is in line with the OECD (2016) that states access to public information is the cornerstone of an open and inclusive government to reduce corruption and increase trust among citizens and government. It is important to ensure that the staff in contracting entities and bidders have appropriate skills and knowledge of the processes and functionalities to use e-portals. Governments need to clearly define the vision for what is to be achieved through e-GP which must be backed by strong institutional leadership and political buy-in for reform. For the bidding entities and bidders to fully benefit, investment in digital infrastructure and skills for benefits is necessary. Policy interventions must promote public and private investment to improve the digital infrastructure that ensures connectivity and provides access to high-speed broadband internet and mobile networks. This means that boosting IT infrastructure requires availability, affordability, and high digital skills of citizens/stakeholders to use modern e-portals. In this manner, boosting and building digital skills awareness will require collaborative efforts by public, private and civic organisations. Policy makers must, therefore, focus on developing proactive policies that support the use of simple user-friendly e-portals through a robust digital infrastructure and digital skills will allow all users to leverage technology. These measures must be complemented by strong institutional quality to support competition and accountability in public procurement.

6. Conclusions

Three main findings emerge on transparency in public procurement. First, we develop a unique transparency index on public procurement. The novelty of the PPT-Index is its ability to amplify the flow of information at each stage: (e-GP cycle, mechanism of complains (bid challenge); support the adoption of e-signature of contracts; e-public information) of the entire procurement process which makes it a valuable tool for practitioners, citizens and policymakers in examining transparency, competition, integrity, accountability within the public procurement arena. Second, we find transparency levels are heterogeneous across countries. The WTO-GPA signatories have higher transparency in public procurement compared to non-GPA members. The dissemination of procurement information depends to a large extent on the political decision (democracy) to join the WTO-GPA. The WTO-GPA mandates countries have robust institutions (namely government effectiveness, regulatory environment, contract integrity) which leads to higher transparency in procurement. Better access to procurement related information is also linked with the political decision to join the WTO-GPA which creates an enabling business environment for citizens, stakeholders. Third, the level of IT infrastructure and digital skillsets are key drivers for higher transparency. A country's IT infrastructure (internet speed, connectivity) and digital skills-set of citizens/stakeholders in conjunction efficient functioning of e-GP tools supports higher access of bidders to procurement information. This supports e-participation in government initiatives, increases accountability through the use of modern e-portals and promotes transparency in public procurement.

7. Directions for future research

Future studies should consider using longitudinal data on the PPT-Index variables (namely e-GP lifecycle, bid challenge recourse, e-signature and e-public information) over time. This would mean analyzing longitudinal data. This could include for example contracts and/or surveys to assess whether bid challenge is likely to reduce corruption in public procurement. Another area of research should be examining whether the absence of checks and balances prevent bidders to challenge decisions on procurement entities. Thirdly, future researchers include social and political aspects of open government initiatives (O'Shaughnessy, Schiff, Varshney, Rozell, & Davenport, 2023)

and whether cyber security measures of e-portals improve contract security. Finally, the results are to be treated as associations rather than causal relations. It will also be interesting to explore whether specific initiative in procurement, such as sustainable green public procurement and gender-responsive public procurement are linked with the institutional framework of a country. Lastly, researchers could examine the link between the level of institutional framework and the degree of corruption in public procurement.

CRedit authorship contribution statement

Sangeeta Khorana: Writing – original draft, Methodology, Formal

analysis, Data curation, Conceptualization. **Santiago Caram:** Writing – original draft, Validation, Formal analysis, Data curation. **Nripendra P. Rana:** Writing – review & editing, Supervision, Methodology, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Appendix

Table A1

List of countries.

Panel A: GPA members (43)					
Armenia	Czech, Rep.	Iceland	Luxembourg	Portugal	Ukraine
Australia	Denmark	Ireland	Malta	Romania	United Kingdom
Austria	Estonia	Israel	Moldova	Singapore	United States
Belgium	Finland	Italy	Montenegro	Slovak, Rep.	
Bulgaria	France	Japan	Netherlands	Slovenia	
Canada	Germany	Korea, Rep.	New Zealand	Spain	
Croatia	Greece	Latvia	Norway	Sweden	
Cyprus	Hungary	Lithuania	Poland	Switzerland	
Panel B: Observer status (31)					
Albania	Colombia	India	Mongolia	Russia	Vietnam
Argentina	Costa Rica	Indonesia	North Macedonia	Saudi Arabia	
Brazil	Côte d'Ivoire	Jordan	Pakistan	Sri Lanka	
Cameroon	Dominican, Rep.	Kazakhstan	Panama	Tajikistan	
Chile	Ecuador	Kyrgyz, Rep.	Paraguay	Thailand	
China	Georgia	Malaysia	Philippines	Turkey	
Panel C: WTO-non-members (59)					
Algeria	Burkina Faso	Guatemala	Malawi	Peru	Trinidad & Tobago
Angola	Burundi	Guyana	Mali	Qatar	Tunisia
Azerbaijan	Cambodia	Haiti	Mexico	Rwanda	Uganda
Bangladesh	Chad	Honduras	Morocco	Senegal	Uruguay
Barbados	Congo DRC	Iran	Mozambique	Serbia	Uzbekistan
Belize	Egypt, Arab Rep.	Jamaica	Myanmar	Sierra Leone	Venezuela
Benin	El Salvador	Kenya	Namibia	South Africa	Yemen
Bolivia	Ethiopia	Lebanon	Nepal	St. Lucia	Zambia
Bosnia & Herzg.	Ghana	Lesotho	Nicaragua	Tanzania	Zimbabwe
Botswana	Grenada	Liberia	Nigeria	Timor-Leste	
Panel D: Total number of countries excluded in multi-stage sampling due to non-availability of information in GPPD database (85)					
Afghanistan	Congo, Rep.	Hong Kong	Micronesia	South Sudan	
American Samoa	Cuba	Iraq	Monaco	St. Kitts & Nevis	
Andorra	Curaçao	Isle of Man	Nauru	St. Martin (French part)	
Antigua and Barbuda	Djibouti	Kingdom of Eswatini	New Caledonia	St. Vincent & the Grenadines	
Aruba	Dominica	Kiribati	Niger	Sudan	
Bahamas, The	Equatorial Guinea	Korea, Dem. Rep.	Northern Mariana Isl.	Suriname	
Bahrain	Eritrea	Kosovo	Oman	Syrian Arab Rep.	
Belarus	Faroe Islands	Kuwait	Palau	Taiwan	
Bermuda	Fiji	Lao PDR	Papua New Guinea	Togo	
Bhutan	French Polynesia	Libya	Puerto Rico	Tonga	
British Virgin Islands	Gabon	Liechtenstein	Samoa	Turkmenistan	
Brunei Darussalam	Gambia, The	Macao, China	San Marino	Turks & Caicos Islands	
Cabo Verde	Gibraltar	Madagascar	São Tomé & Príncipe	Tuvalu	
Cayman Islands	Greenland	Maldives	Seychelles	United Arab Emirates	
Central African Rep.	Guam	Marshall Islands	Sint Maarten	Vanuatu	
Channel Islands	Guinea	Mauritania	Solomon Islands	Virgin Islands (U.S.)	
Comoros	Guinea-Bissau	Mauritius	Somalia	West Bank and Gaza	

Source: Authors compilation.

Table A2
Measurements Results Public Procurement Transparency (PPT-I).

Panel A: Factor Analysis		
	Loading factor1	Uniqueness
Legal gazette	0.648	0.581
Public official declarations	0.692	0.520
E-procurement reports & statistics	0.610	0.628
Panel B: Internal reliability		
	Average interitem correlation	Cronbach's alpha
e-GP cycle	0.552	0.787
Bid challenge	0.402	0.669
E-signature	0.416	0.681
E-public information	0.357	0.625
Test scale	0.432	0.752

Source: Authors compilation.

Table A3
Database, variables and sources.

Dataset	Variable	Source
World Trade Organisation (WTO)	WTO-GPA countries WTO-Observer countries	https://www.wto.org/english/tratop_e/gproc_e/mem_obs_e.htm
Global Public Procurement Database (GPPD)	e-notification; online documents; awards; e-signature advanced authentication; e-signature other methods; e-reports; e-statistics	https://www.globalpublicprocurementdata.org
European Research Centre for Anticorruption and State-building (ERCAS) (OECD, 2017, OECD, 2019a; OECD, 2019b; OECD, 2019c, OECD, 2021)	legal gazette; disclosure public officials e-notification; online documents; awards; e-signature advanced authentication; e-signature other methods; e-reports; e-statistics	https://zenodo.org/records/7225627 www.corruptionrisk.org/transparency https://doi.org/10.1787/gov_glance-2017-en https://doi.org/10.1787/8ccf5c38-en https://doi.org/10.1787/1c258f55-en https://www.oecd.org/about/members-and-partners/ http://www.govindicators.org
World Governance Indicators (WGI)	Democracy (eiu21va1) in 2021 Government effectiveness (eiu21ge1) in 2021 Regulatory environment (wmo21rq1) in 2021 Contract integrity (wmo21cc1) in 2021	
World Development Indicators (WDI)	Fixed broadband subscriptions (per 100 people), (IT.NET.BBND-P2) in 2021 Mobile cellular subscriptions (per 100 people), (IT.CEL.SETS-P2) in 2021 Access to electricity (% of population), (EG.ELC.ACCS.ZS) in 2021	http://data.worldbank.org/indicator/IT.NET.BBND.P2 http://data.worldbank.org/indicator/IT.CEL.SETS.P2 http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
International Telecommunication Union (ITU) Digital Development Compass Dataset	International bandwidth per Internet user (bit/s) in 2021 Digital literacy skills in 2022	https://datahub.itu.int/data/ http://www.digitaldevelopmentcompass.org https://github.com/undp/digital-development-compass
Bid-challenge	e-bid challenge bid challenge law	Author's based on manual search from e-portals GPPD (Public Procurement Law), https://www.globalpublicprocurementdata.org https://bpp.worldbank.org/content/dam/sites/data/bpp/documents/BID-2023-PPP-Dataset.xlsx

Source: Authors compilation.

Table A4
Public Procurement Transparency (PPT-I) scores of the countries.

Country	PPT-I (overall score)
Albania	0.748
Algeria	0.037
Angola	0.563
Argentina	0.645
Armenia	1
Australia	0.955
Austria	0.955
Azerbaijan	0.748
Bangladesh	0.748
Barbados	0.000
Belgium	0.955
Belize	0.000
Benin	0.563

(continued on next page)

Table A4 (continued)

Country	PPT-I (overall score)
Bolivia	0.560
Bosnia and Herzegovina	0.748
Botswana	0.563
Brazil	0.600
Bulgaria	1
Burkina Faso	0.608
Burundi	0.600
Cambodia	0.037
Cameroon	0.711
Canada	0.955
Chad	0.000
Chile	0.748
China	0.600
Colombia	0.605
Congo (DRC)	0.563
Costa Rica	0.560
Côte d'Ivoire	0.563
Croatia	1
Cyprus	0.917
Czech Republic	0.955
Denmark	0.955
Dominican Republic	0.608
Ecuador	0.600
Egypt, Arab Rep	0.600
El Salvador	0.748
Estonia	1
Ethiopia	0.711
Finland	1
France	1
Georgia	0.793
Germany	0.955
Ghana	0.563
Greece	1
Grenada	0.523
Guatemala	0.600
Guyana	0.563
Haiti	0.563
Honduras	0.600
Hungary	0.955
Iceland	0.955
India	0.748
Indonesia	0.748
Iran	0.560
Ireland	0.955
Israel	1
Italy	1
Jamaica	0.563
Japan	0.955
Jordan	0.748
Kazakhstan	0.711
Kenya	0.600
Korea, Rep.	1
Kyrgyz Republic	0.748
Latvia	1
Lebanon	0.000
Lesotho	0.523
Liberia	0.563
Lithuania	1
Luxembourg	0.955
Malawi	0.563
Malaysia	0.600
Mali	0.600
Malta	0.955
Mexico	1
Moldova	1
Mongolia	0.600
Montenegro	0.852
Morocco	0.748
Mozambique	0.563
Myanmar	0.037
Namibia	0.000
Nepal	0.807
Netherlands	0.955
New Zealand	0.852
Nicaragua	0.600
Nigeria	0.563

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Table A4 (continued)

Country	PPT-I (overall score)
North Macedonia	0.748
Norway	0.955
Pakistan	0.708
Panama	0.600
Paraguay	0.645
Peru	0.793
Philippines	0.600
Poland	0.955
Portugal	1
Qatar	0.748
Romania	1
Russian Federation	0.748
Rwanda	0.748
Saudi Arabia	0.600
Senegal	0.600
Serbia	0.600
Sierra Leone	0.000
Singapore	0.914
Slovak Republic	1
Slovenia	0.955
South Africa	0.563
Spain	1
Sri Lanka	0.748
St. Lucia	0.523
Sweden	0.955
Switzerland	1
Tajikistan	0.600
Tanzania	0.563
Thailand	0.793
Timor-Leste	0.600
Trinidad and Tobago	0.600
Tunisia	0.600
Turkey	0.748
Uganda	0.563
Ukraine	1
United Kingdom	1
United States of America	0.955
Uruguay	0.600
Uzbekistan	0.600
Venezuela	0.560
Vietnam	0.748
Yemen	0.563
Zambia	0.711
Zimbabwe	0.523

Source: Authors compilation.

Table A5

Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) PPT-Index	1									
(2) e-GP	0.653***	1								
(3) WTO-GPA	0.725***	0.166*	1							
(4) WTO-GPA non-member	-0.627***	-0.271***	-0.613***	1						
(5) Democracy (political willingness)	0.538***	0.261***	0.711***	-0.528***	1					
(6) Institutional effectiveness	0.622***	0.265***	0.694***	-0.632***	0.820***	1				
(7) Regulatory environment	0.560***	0.238***	0.637***	-0.551***	0.735***	0.811***	1			
(8) Contract integrity	0.485***	0.149*	0.690***	-0.499***	0.803***	0.825***	0.778***	1		
(9) Digital infrastructure	0.632***	0.248***	0.736***	-0.649***	0.709***	0.779***	0.755***	0.684***	1	
(10) Digital literacy	0.595***	0.289***	0.636***	-0.677***	0.659***	0.725***	0.631***	0.576***	0.844***	1

Note: e-GP, WTO-GPA and WTO-GPA non-member are binary variables (0 or 1). ***, **, * indicate statistical significance at 1, 5 and 10% level, respectively.

Source: Authors compilation.

Table A6

Multicollinearity analysis.

Variables	VIF	Tolerance
PPT-Index	7.070	0.142
e-GP	3.130	0.320
WTO-GPA	7.420	0.135
WTO-GPA Observer	1.680	0.594

(continued on next page)

Table A6 (continued)

Variables	VIF	Tolerance
OECD	3.310	0.302
Democracy (political willingness)	4.500	0.222
Institutional effectiveness	6.590	0.152
Regulatory environment	4.060	0.246
Contract integrity	4.730	0.211
Digital infrastructure	5.710	0.175
Digital literacy	4.300	0.233
Mean	4.773	0.248

Notes: a. e-GP, WTO-GPA, WTO-GPA Observer and OECD are binary variables (0 or 1).

b. VIF values greater than 10 indicate reasons for concern due to collinearity among variables. Tolerance values less than 0.1 indicate collinearity among variables. From our (centred) values we can infer that the majority of variables do not suffer from severe collinearity issues. Another useful rule of thumb to check for the presence of multicollinearity is the condition number of the eigenvalues below 15. In our case, the condition (not reported) is 10.089 which falls within that rule.

Source: Authors compilation.

Table A7

Transparency in Procurement, WTO Membership and Institutional quality.

Variables \ Model specification	(I)	(II)	(III)	(IV)	(V)
Dependent variable: PPT-Index (equal weights)					
e-GP	1.631*** [0.205]	1.696*** [0.205]	1.727*** [0.205]	1.654*** [0.205]	1.700*** [0.205]
WTO-GPA	1.765*** [0.105]				
WTO-GPA Observer	0.307*** [0.086]				
WTO-GPA × Democracy (political willingness)		2.195*** [0.156]			
WTO-GPA Observer × Democracy (political willingness)		0.454** [0.179]			
WTO-GPA × Government effectiveness			2.191*** [0.182]		
WTO-GPA Observer × Government effectiveness			0.469** [0.190]		
WTO-GPA × Regulatory environment				2.304*** [0.163]	
WTO-GPA Observer × Regulatory environment				0.516** [0.152]	
WTO-GPA × Contract integrity					2.179*** [0.185]
WTO-GPA Observer × Contract integrity					0.527** [0.199]
Constant	-1.845*** [0.196]	-1.845*** [0.196]	-1.845*** [0.196]	-1.845*** [0.196]	-1.845*** [0.196]
Pseudo R-squared	0.249	0.238	0.226	0.240	0.227
Log-Likelihood	-67.509	-67.262	-68.271	-68.345	-69.462
Number of countries	133	131	131	133	133

Note: e-GP, WTO-GPA and WTO-GPA Observers are binary variables (0 or 1). Robust standard errors in brackets, ***, **, * indicate statistical significance at 1, 5 and 10% level respectively.

Source: Authors compilation.

Table A8

Transparency in Procurement, WTO Membership and Information technology.

Variables \ Model specification	(I)	(II)	(III)	(IV)
Dependent variable: PPT-Index (equal weights)				
e-GP	1.667*** [0.205]	1.638*** [0.205]		
WTO-GPA × Digital Infrastructure	2.943*** [0.245]		2.455*** [0.368]	
WTO-GPA Observer × Digital infrastructure	0.696** [0.229]		0.527* [0.311]	
WTO-GPA × Digital literacy		1.931*** [0.119]		1.633*** [0.181]
WTO-GPA Observer × Digital literacy		0.388*** [0.110]		0.214 [0.155]

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Table A8 (continued)

Variables \ Model specification	(I)	(II)	(III)	(IV)
Dependent variable: PPT-Index (equal weights)				
e-GP ⁺ × Digital infrastructure			1.184** [0.504]	
e-GP × Digital literacy				1.086** [0.312]
Constant	-1.845*** [0.196]	-1.845*** [0.196]	-0.571*** [0.135]	-0.920*** [0.173]
Pseudo R-squared	0.236	0.247	0.213	0.231
Log-Likelihood	-68.633	-67.712	-70.762	-69.086
Number of countries	133	133	133	133

Note: e-GP, WTO-GPA and WTO-GPA Observers are binary variables (0 or 1). Robust standard errors in brackets, ***, **, * indicate statistical significance at 1, 5 and 10% level respectively.

Source: Authors compilation.

Table A9

Transparency in Procurement, OECD Membership and Institutional quality.

Variables/Model specification	(I)	(II)	(III)	(IV)	(V)
Dependent variable: PPT-Index (equal weights)					
e-GP	1.859*** [0.204]	1.875*** [0.204]	1.876*** [0.204]	1.854*** [0.204]	1.868*** [0.204]
OECD	1.260*** [0.149]				
OECD × Democracy (political willingness)		1.640*** [0.174]			
OECD × Government effectiveness			1.682*** [0.164]		
OECD × Regulatory environment				1.826*** [0.162]	
OECD × Contract integrity					1.654*** [0.161]
Constant	-1.845*** [0.196]	-1.845*** [0.196]	-1.845*** [0.196]	-1.845*** [0.196]	-1.845*** [0.196]
Pseudo R-squared	0.171	0.175	0.177	0.179	0.172
Log-Likelihood	-74.467	-72.794	-72.637	-73.801	-74.442
Number of countries	133	131	131	133	133

Note: e-GP and OECD are binary variables (0 or 1). Robust standard errors in brackets, ***, **, * indicate statistical significance at 1, 5 and 10% level respectively.

Source: Authors compilation.

Table A10

Transparency in Procurement, OECD Membership and Information technology.

Variables \ Model specification	(I)	(II)	(III)	(IV)
Dependent variable: PPT-Index (equal weights)				
e-GP	1.853*** [0.204]	1.857*** [0.204]		
OECD × Digital infrastructure	2.418*** [0.224]		1.543*** [0.296]	
OECD × Digital literacy		1.402*** [0.153]		0.983*** [0.180]
eGP × Digital infrastructure			2.376*** [0.369]	
eGP × Digital literacy				1.759*** [0.258]
Constant	-1.845*** [0.196]	-1.845*** [0.196]	-0.802*** [0.113]	-1.203*** [0.157]
Pseudo R-squared	0.179	0.173	0.188	0.181
Log-Likelihood	-73.760	-74.294	-72.983	-73.615
Number of countries	133	133	133	133

Note: e-GP and OECD are binary variables (0 or 1). Robust standard errors in brackets, ***, **, * indicate statistical significance at 1, 5 and 10% level respectively.

Source: Authors compilation.

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