The Impact of E-Procurement on Institutional Quality*

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Abstract

We examine the contribution of e-procurement to the institutional quality. To this end, we exploit the early adoption of large-scale e-procurement platforms in three EU countries to consistently estimate the effect of procurement policy change on the institutional quality. Our identification strategy relies on the institutional quality trends similarity between early-adopting countries and the rest of the world and uses a battery of covariates to match the treated and control group to parse out the level of early-adopters' institutional quality had the e-procurement not been implemented. Drawing on a large sample of 108 countries for the period 1996-2017, our synthetic control and difference-in-differences estimates indicate significant improvements in public sector efficiency and rule of law in the countries with a high-level of pre-reform institutional quality and a pervasive deterioration in the ability to control corruption and quality of regulation in the setting with lower pre-reform institutional quality. The estimated effects of adopting e-procurement on institutional quality are robust to a number of specification checks, treatment sensitivity analyses and donor sample selection issues.

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1 Introduction

The importance of inclusive institutional framework for economic outcomes has been almost undisputed (North 1987, Knack and Keefer 1995, Hall and Jones 1999, Rodrik et. al. 2004, Acemoglu and Johnson 2005, De Haan et. al. 2006, Fatas and Mihov 2013). Scholars agree that the set of institutions promulgating secure property rights (Torstensson 1994, Goldsmith 1995), low-cost enforcement of contracts (Clague et. al. 1999, Haber et. al. 2003, Prados de la Escosura and Sanz-Villaroya 2009), and impartial government administration (Gelb et. al. 1991, Dalamagas 2000) under a robust rule of law are crucial for sustained long-run growth and development (Rodrik 2000, Acemoglu et. al. 2003, Djankov et. al. 2003). Questions, such as what shapes the level of institutional quality, and why some countries have envious institutional quality while others are mired by the persistence of low-quality institutions, have received modest scholarly attention (Rajan 2009, Acemoglu et. al. 2010). In this respect, several scholars suggested that the adoption of e-procurement in the public sector may foster the citizens' trust in public services, which in turn facilitates a more impartial government administration, greater public sector efficiency and lower contract enforcement costs (Von Handelwang 2004, Gunasakaran and Ngai 2008, Shim and Eom 2008, Andersen 2009).

One of the main benefits of e-procurement implementation lies in its potential to reduce the discretion of public officials in public tendering as a remedy for moral hazard and short-run opportunistic behavior, as well as the adverse selection issues that beget the discretionary decisions in public tenders. In this respect, the introduction of e-procurement can reduce the discretionary power of public officials, foster public sector accountability, remove unreasonably long duration of tendering procedures, improve transparency and lead to higher quality of public goods. By curtailing the opportunities for ex-ante corruptive practices, e-procurement may represent an effective screening device that could potentially uphold the level of institutional quality (Auriol 2006).

The notion that e-procurement can reduce corruption has been disputed by several scholars (Heeks 1998). The adoption of e-procurement may encourage corrupt public officials, civil servants and businesspeople to enter into innovative practices in an attempt to avoid the barriers to rent-seeking opportunities and bypass the digital tendering procedures to affect scoring rules. In this respect, e-procurement might further consolidate the conflicts of interest and may have countervailing effects leading to more nepotism and influence peddling that encourage corrupt practices among more technology-literate officials and businesspeople. When public officials and civil servants lose full discretion in public tender decisions, they may still exert an overwhelming influence in the decision-

making by using alternative forms of political and rent-seeking technologies through multiple forms of non-institutionalized modes of influencing the tendering outcomes and policymakers (Scartascini and Tommasi 2012, Campos and Giovannoni 2017). Under these circumstances, the net effects of e-procurement can consist of lower institutional quality, increased economic inefficiency, distorted investment incentives, more inefficient and less competent public sector, higher income inequality and poverty, and talent diversion from more productive activities towards rent-seeking, unpredictable and volatile policy making, and possibly even institutional instability.

In this paper, we examine the impact of adopting e-procurement on the institutional quality in three distinct European jurisdictions to further explore the impact of e-procurement implementation in European context on institutional quality. To this end, the present paper focuses on the experience of three early e-procurement-adopting countries; namely Denmark, Netherlands and Portugal. To identify the effect of e-procurement on a range of institutional quality outcomes, we exploit the parallel institutional quality trends between early-adopting countries and a large sample of control group countries, and estimate the contribution of e-procurement to institutional quality using a variety of difference-in-differences and synthetic control estimators. By controlling for a battery of structural control variables that might confound the relationship between e-procurement and institutional quality, our identification strategy is able to parse out the contribution of e-procurement and generate the counterfactual scenarios to determine the institutional significance of adopting e-procurement.

The evidence suggests that the institutional quality effects of e-procurement are mixed. In particular, the adoption of e-procurement is associated with both an improvement as well as deterioration of institutional quality. By way of example, we find that the e-procurement adoption in the Netherlands is associated with an improvement of the rule of law while a similar type of reform in Denmark led to a significantly more effective government administration. By contrast, we find that the same type of reform adopted by Portugal led to the deterioration of institutional quality, particularly with respect to the level of corruption and regulatory quality. The strength and the direction of the effect moves in tandem and interacts significantly with the level of per capita income, pre-reform institutional quality patterns and the level of human capital investment. Our synthetic control estimates indicate a different nature of e-procurement as an institutional shock across the three countries considered. We show that the adoption of e-procurement mimics a structural institutional breakup in the Netherlands, a temporary institutional shock with no long-term effect in Denmark, and an institutional breakdown in Portugal with a permanent deterioration of institutional quality with respect to the level of corruption. Our findings for Portugal challenge the conventional perception of increased transparency, more rigorous competition among the bidders and more professional bureaucracy (Aguiar Costa et. al.

2013). We present a series of quasi-randomization checks to determine whether the effect of e-procurement is driven by chance, which show that our arguments are supported by the evidence.

The paper is therefore structured as follows: Section 2 presents the background, Section 3 discusses the policy framework, Section 4 proceeds with the identification strategy and Section 5 continues with the discussion of the data. Section 6 continues with the results and robustness checks and Section 7 concludes.

2   Conceptual Framework

2.1 E-Procurement

The evidence on the impact of e-procurement on the quality of institutions is scarce. While e-procurement might deliberately reduce corruption through less discretionary decision-making (Chawla and Bhatnagar 2004), some scholars argue that e-procurement may expand corruption-related and rent-seeking opportunities for technology-literate public officials (Heeks 1999). Hence, most of the evidence of the impact of e-procurement on institutional quality is largely anecdotal and calls for further empirical quantification.

To date, several studies empirically examined the impact of adopting e-procurement on institutional quality. Firstly, Elbahnasawy (2014) investigates the impact of e-government on the prevalence of corruption in a large panel of countries for the period 1995-2009 and finds corruption-reducing effect of e-government without the reverse causal link. Secondly, Kim et. al. (2009) examine the effect of anti-corruption program OPEN in South Korea that allows citizens to track and monitor full stages of the common procurement procedures, and find evidence of a significant decrease in the perceived level of corruption in the specific areas of public procurement where the program has been implemented. By contrast, several scholars argue that internet access may be more important than e-procurement in combating corruption (Anderson 2009, Lio et. al. 2011, Goel et. al. 2012).

Governments have been adopting e-procurement in the attempt to reduce the discretion of public officials and civil servants that might lead to wasteful allocation of public funds and poor provision of public goods, in the name of transparency and fair competition. By minimizing the amount of human discretion involved in public tendering, the adoption of e-procurement is set to remove the opportunities for corruption, rent-seeking, moral hazard and opportunism (Auriol et. al. 2016). Most arguments suggest that e-procurement is designated to improve the efficiency and accountability of

the public sector, and is set to produce direct and indirect benefits that outweigh the initial costs of implementation. The existing evidence suggests that e-procurement may be associated with more equal access to economic opportunities offered by e-procurement such as increased number of bidders, higher rates of prevalence of non-local winners, reduced prices, higher quality of tendered goods, lower costs, and higher level of competition among the bidders (Moon 2005, Singer et. al. 2009, Lewis-Faupel et. al. 2016, Baldi and Vannoni 2017, Grandia and Meehan 2017). These considerations are supported in practice by the mandatory imposition of e-procurement at the EU level at all public procurement stages in the year 2018.

If poorly implemented, the adoption of e-procurement may aggravate the level of pre-existing institutional quality. The general mechanism through which the aggravation of institutional quality occurs involves insufficient pre-qualification of bidders, prevalence of inaccurate bid specifications, participation of less efficient suppliers, and incompetence of public officials and civil servants in detecting, deterring and addressing these risks (Von Haldenwang 2006, Neupane et. al. 2012). In particular, if corrupt practices pervade the public procurement process in the initial stage, the electronic process may perpetuate and consolidate corruption throughout the tendering process, which tends to deteriorate the level of institutional quality. Hence, to determine the overall effect of e-procurement implementation across the EU, especially under the consideration of such process being made mandatory in 2018, this paper empirically estimates the effect of early e-procurement implementation in three distinct European institutional settings: Denmark in 2002, Netherlands in 2005 and Portugal in 2008. Appendix 1 provides a more elaborate discussion of reform background for each early-adopting country.

2.2 Institutional Quality

In a broad sense, institutions can be defined as the set of rules shaping the economic and social interactions (North 1991). The institutional framework consists of formal laws such as constitution and the electoral law, and informal constraints such as codes of conduct. In this respect, the institutional framework shapes the evolution of property rights and transaction costs and, hence, determines the balance of economic payoffs from productive vs. unproductive economic activities. There is a consensus amongst scholars that countries with an institutional framework supporting strong property rights and low contract enforcement costs under a robust rule of law are significantly more likely to achieve sustained economic outcomes than those without such a framework (Knack and Keefer 1995). The necessary condition to establish and maintain institutional quality is the change of the existing institutions. However, institutional change can be easily undermined if the groups that lose de jure

political power possess sufficient de facto economic power to undermine these changes through various forms of collective action such as lobbying, pressure, capital flight, coordinated economic disruption, bribery, threats or even use of brute force (Acemoglu and Robinson 2006, Scartascini and Tommasi 2012). When the groups whose economic payoffs are threatened by the de jure institutional changes have sufficient leverage to offset these changes, such institutional changes can seldom be effective. Institutional change cannot be achieved without the appropriately operationalized policy changes aiming to tackle the existing balance of political and economic power. From this perspective, e-procurement can be viewed as a policy tool targeting the institutional changes.

2.3   Prior Literature

The introduction of e-procurement is set to facilitate greater transparency and is therefore expected to decrease transaction costs and improve state capacity to deliver public goods and services at lower costs than in the counterfactual scenario. However, the effect of e-procurement might operate in two distinct directions. Firstly, the introduction of e-procurement might directly decrease the economic payoffs of well-organized interest groups that reap rents from an ill-transparent system of traditional procurement, involving significant personal interaction with the public officials and opens doors to the traditional hold-up and moral hazard problem. In the presence of asymmetric information, the bidders can undersupply the tendered good and therefore gain rents at the expense of higher public procurement cost. E-procurement can partially overcome moral hazard and asymmetric information problems through lower transaction costs of market exchange. Lower exchange costs are conditional on the ability and competence of public administration to use e-procurement for its intended purpose. By lowering transaction costs, the interest groups in the existing production process no longer reap benefits from the hold-up problems and distortionary barriers to technology adoptions (Parente and Prescott 2002), which enhances the control of corruption and is set to improve the rule of law by ending the preservation of rents through such policy-specific distortions (Rajan 2009).

Secondly, the introduction of e-procurement may impede the improvement of institutional quality. The e-procurement reform may be viewed as a de jure policy change readjusting the balance of economic power through the redistribution of resources. The groups that lose rents from the de jure policy change may combat the loss of rents by investing into numerous forms of collective action such as lobbying, bribery, co-optation with the existing elites and the media, coordinated economic disruption, downright intimidation, or even use of force, to preserve the previous set of economic institutions that facilitate widespread rent-seeking (Olson 1982, Scartascini and Tommasi 2012).

Under such conditions, e-procurement may even deteriorate the quality of policy-making processes, and expand rent-seeking preservation incentives. By increasing transaction costs, the institutional quality is expected to deteriorate in response to the reinforced pressure from the interest groups to undermine the economic benefits through the state capture to preserve the lost privileges (Dal-Bó and Di Tella 2003).

The balance between the positive and negative institutional quality effect of e-procurement is shaped by the endowment of contracting officer's full discretion. The literature provides mixed evidence of the full discretion on the range of economic and institutional outcomes (Coviello and Gagliarducci 2017). Di Tella and Schargrodsky (2003) study the prices paid for basic inputs during the corruption crackdown on public hospitals in the city of Buenos Aires in 1996. They estimate 18 percent price decrease for homogenous inputs such as ethyl alcohol and hydrogen peroxide, after the introduction of a mandatory anti-corruption policy by the newly elected government administration. They also find that a 10 percent increase in the wage of the procurement officer with an average perceived probability of punishment in the sample is expected to yield 1.2 percent reduction in input prices. On the other hand, Palguta and Pertold (2017) show that policy reforms that introduced new discretionary thresholds below which agencies are given autonomy to pre-select contractors for the bidding process can generate perverse manipulation of procurement contracts. Using the example of Czech Republic's public procurement system for construction works, they uncover evidence of substantial contracting officers' manipulation with a threefold increase in the probability that construction procurements are awarded to anonymous owners. Since anonymity can hide the identity of stakeholders in anonymously owned firms who are simultaneously procurement officials, this provides numerous incentives for hidden rent-seeking behavior. Hence, the notion that auctions might possibly be a superior alternative to competitive public procurement to address moral hazard and adverse selection-related issues has been disputed on several grounds. Examining a comprehensive dataset of private sector building contracts in Northern California in the period 1995-2000, Bajari et. al. (2008) highlight a number of limitations to the uses of auctions, which may perform poorly when products are complex, when contract design is incomplete in the presence of few available bidders. Furthermore, Manelli and Vincent (1995) demonstrate the inefficiency in auctions by characterizing the environments to ensure efficient allocation of goods where sellers are privately informed about the quality of supplied goods.

These accounts suggest that some discretion in the hands of the contracting officers is necessary to ensure a competitive selection of tendering bids yet at the same time calls for a decision on the optimal level of discretion. In this respect, Aghion and Tirole (1997) develop a theory of the allocation of formal authority and real authority within organizations. The former captures the right to decide while the

latter resonates with the effective control over decisions. They show that real authority is determined by the structure of information, which depends on the allocation of formal authority. Both types of authority oftentimes have conflicting goals. By way of example, expanding the real authority of the agent might promote initiatives at the expense of principal's loss of control. Their results suggest that the agent's real authority dominates the principal's formal authority in an environment characterized by overload, lenient rules, urgency of decision, reputation costs, performance measurement and multiplicity of superiors.

To fill the literature gap, Spagnolo (2012) shows that the increased discretion and restricted competition can either facilitate corruption and improve the quality of the contracted goods in the tendering bids, and shows that reputational mechanisms can be designed to stimulate new entries in the procurement market (Banerjee and Duflo 2000). Limiting discretion of the public buyers to preserve their accountability may involve large costs if not allowing reputational forces to complement incomplete procurement-related contracts (Kelman 1990). In addition, Bandiera et.al. (2009) exploit the introduction of the centralized public procurement agency in Italy to estimate the gains from accountability of the public services. Based on the analysis of purchases of standardized goods by Italian public bodies, they distinguish between active and passive waste on public services where the former involves a direct utility to the public decision maker whereas the latter does not. They conclude that passive waste accounts for 83 percent of the total waste of spending on public services. Recent studies (Coviello and Gagliarducci 2017, Best et. al. 2018, Decarolis et. al. 2019) stress the importance of bureaucratic characteristics in accounting for passive waste such as the level of cooperation within the office, office tenure, and level of effectiveness. Two implications are immediate. Firstly, tighter procurement regulation reducing autonomy might not deliver large institutional accountability gains. And secondly, their evidence suggests that when public buyers with a reasonable degree of autonomy are endowed with more discretion, efficiency gains are substantially more likely, and the level of corruption is not higher compared to the rigid and highly regulated centralized procurement setup. Hence, the endowment of greater discretion can counteract the inefficiencies inherent in centralized public procurement. For instance, Coviello et. al. (2017) demonstrate the positive effects of officials' discretion in public procurement in a regression discontinuity design using a large dataset of public works in Italy by exploiting an easily identifiable cutoff separating open and restricted bids. Furthermore Calzolari and Spagnolo (2009) show that the elimination of firms with poor past performance can help public officials in providing high-quality procurements and limit the ex-post contract renegotiations, which may beget greater discretion. This is subject to extensive scholarly debate (Holmstrom and Milgrom 1991, Alonso and Matouschek 2008).

If endowment of greater discretion provides a more competitive and less biased selection of procurement bids, the issue that remains is whether the beneficial effect of discretion is conditioned by the costs of enforcing contracts (Bobilev et. al. 2015). Against this backdrop, Coviello et. al. (2018) construct a simple model showing how judicial inefficiency can prevent public buyers from enforcing a penalty for late delivery and induces sellers to delay contract delivery to avoid litigation. Using a large dataset on Italian public procurement, they show that in the presence of judicial inefficiency, public goods are delivered with significantly longer delays which tends to increase alongside with more valuable contracts, which are more likely to be awarded to larger suppliers, and markedly higher share of the payment is postponed after the delivery. Hence, investigating the effect of granting various degrees of official discretion in public procurement on a range of institutional outcomes may uncover several insights into the context-specific effectiveness of the allocation of discretion in improving the level of institutional quality.

3   Identification Strategy

Our aim is to examine the contribution of e-procurement to institutional quality consistently. In the presence of weak parallel trends between the treated countries and the control sample, the DD model estimates may be implausible if the parallel trend assumption is violated. In such cases, using synthetic control method for generating control groups may improve the validity of estimates when the parallel trend assumption possibly does not hold. To this end, we exploit the institutional quality trends between early-adopting EU countries (i.e. Denmark, Netherlands and Portugal) and the rest of the world, and compute the missing counterfactual institutional quality scenario in the absence of e-procurement by using the synthetic control estimator proposed by Abadie et. al. (2010, 2015).

We consider a simple canonical panel with $i = 1, 2, ...N$ countries observed for $t = 1, 2, ...T$ time periods. Suppose $J \in \left\{ i = 1, 2, ...N \right\}$ denotes the set of early adopters as a treatment group, and let Z be an indicator that j-th country is directly affected by the e-procurement policy. Hence, we assume that the full set of J countries are treated by the e-procurement policy that takes place at time $T_0 < T$ whereas others are excluded from the treatment sample, $Z_i = 0$. In total, we have $N_1 = \sum_{j=1}^{J} Z_j$ treated countries and $N_0 = N_1 - N_0$ control countries in the donor pool.

Our outcomes of interest are indices capturing the control of corruption, rule of law, government effectiveness and regulatory quality that plausibly indicate the level of institutional quality in treated and control countries alike. To this end, we use the potential outcomes framework proposed by Rubin (1974) and assume a well-defined treatment that excludes interference between countries. The potential institutional quality outcome in early-adopting countries based on interference-adjusted control samples is $y_{i,t}(0)$ and $y_{j,t}(1)$, which leads to the following observed outcomes:

$$Y_{i,t} = \begin{cases} y_{i,t}(0) & \text{if } Z_i = 0 \text{ or } t \leq T_0 \\ y_{j,t}(1) & \text{if } Z_j = 1 \text{ and } t > T_0 \end{cases} \tag{3}$$

Let $\mathbf{X}$ represent pre-policy outcomes and covariates associated with institutional quality that correspond to $N_0 \times T_0$ matrix where $\mathbf{X}_0^{Control}$ denotes the full set of covariates for the countries in the control sample and $\mathbf{X}_{j,1}^{Early-Adopter}$ is the set of pre-reform outcomes and covariates for j-th early-adopting country. The treatment effect of the e-procurement is then given by:

$$\lambda = \lambda_{1T} = Y_1(Z_j = 1) - Y_1(Z_i = 0) = Y_1 - Y_0 \tag{4}$$

We construct the counterfactual institutional quality trajectory by imputing the missing potential outcome for the treated early-adopting countries as a weighted average of the outcomes in the control sample. By following Abadie and Gardeazabal (2003) and Abadie et. al. (2010), the set of weights used to construct the counterfactual outcome is defined as a solution to the constrained optimization problem:

$$\min_{\mu} \sum_{t=1}^{T_0} \left(\mathbf{X}_{j,1}^{Early-Adopter} - \mathbf{X}_{i \neq j,0}^{Control} \mu \right)^2 \tag{5}$$

where $\sum_{i=1}^{n} \mu_i = 1$ and $\mu_1 \geq 0$ with $i = 1,2,...N$ and the minimization constraints set the limit of μ to the N_0 simplex such that $\mu \in \Delta^{N_0}$. The weights from Eq. (3) minimize the imbalance in covariates and pre-treatment outcomes between the early adopters and its synthetic control group. If the exact balance can be achieved such that $\sum_{t=1}^{T_0} \left(\mathbf{X}_{j,1}^{Early-Adopter} - \mathbf{X}_{i \neq j,0}^{Control} \mu \right) = 0$, the synthetic control

estimator for the treatment effect of interest is asymptotically unbiased. Country-level weights that yield the exact balance may be achieved if the treated country is inside the convex hull of the control sample.

We also assume that there are K latent time-varying covariates $\gamma_t = \{\gamma_{kt}\}$, $k = 1,2,...K$ with $\max_{kt}|\gamma_{kt}| < L$, where K will be small relative to N. Each country has a vector of factor loading denoted by $\theta_i \in \mathbb{R}^K$. This implies that the institutional quality outcome in the control group is a weighted average of these factors plus the additive error term:

$$Y_{it}(0) = \sum_{k=1}^{K} \theta_{ik} \gamma_{kt} + u_{it}$$

where u denotes the random error term, and γ represents the full set of pre-reform outcomes and covariates that may be collected into the matrix $\gamma \in \mathbb{R}^{T_0 \times K}$. By invoking temporal and cross-sectional independence in the random error term as a sub-Gaussian random variable with a certain scale parameter, we further assume that the latent time-varying factors are orthogonal, and that treatment assignment variable Z is ignorable given the country-level factor loadings which implies that:

$$E_{u_T}\left\lfloor Y_i(0), \theta_i, Z_i \right\rfloor = E_{u_T}\left\lfloor Y_i(0), \theta_i \right\rfloor$$

where under the linearity in parameters assumption and ignorable treatment assignment for given θ_i, the synthetic control estimator that balances the pre-reform outcomes and covariates between the early adopters and the control group, yields a reasonably unbiased estimate of $Y_1(0)$ if the ex-ante observed differences in outcomes are covariates between the treatment and control samples are sufficiently small to rule out large approximation errors. The bias of the weighting estimator with the series of non-negative and additive weights is (Ben Michael et. al. 2018):

$$E_{\varepsilon_T}\left[Y_1(0) - \sum_{Z_i=0} \mu_i Y_i \right] = \left(\theta_1 - \sum_{W_i=0} \mu_i \theta_i \right) \cdot \gamma_T =$$
$$= \frac{1}{T_0}\left(\gamma' \mathbf{X}_{j,1}^{Early-Adopter} - \sum_{Z_i=0} \mu_i \gamma' \mathbf{X}_{i \neq j}^{Control} \right) \cdot \gamma_T - \frac{1}{T_0}\left(\gamma' u_1 - \sum_{Z_i=0} \mu_i \gamma' u_i \right) \cdot \gamma_T$$

(6)

where the first term captures the imbalance in covariates and the second term captures the approximation error. Notice that the approximation error is typically small if the pre-treatment period T_0 is sufficiently large. Following Dube and Zippner (2015), Ferman et. al. (2018) and Adhikari and Alm (2016), we avoid using the average of pre-treatment outcomes in our specification. Instead, we further minimize the covariate imbalance by deploying the three lags of the outcomes into our key synthetic control specification, allowing us to fully exploit the time-series dynamics in institutional quality to further unravel the treatment effect of the e-procurement.

4   Data

Our dependent variables measuring the institutional quality are from Kaufmann et. al. (2011) and comprise the control of corruption, rule of law, government effectiveness and regulatory quality as the institutional outcomes most likely to be affected by the introduction of e-procurement. The control of corruption variable captures the perceptions to the extent to which public power is used for private gains, which includes petty and grand forms of corruption, and the capture of the state by the elites and private interests. The rule of law variable captures the perceptions of the extent to which private agents have confidence and abide by the rules of the society such as the quality of contract enforcement and functioning of the courts. Government effectiveness variables focusses on the quality of public services. It captures their overall quality in addition to the quality of the civil service, and the degree of its independence from political pressure, quality of policy formulation, implementation and the respective enforcement and the credibility of the government's commitment to such policies. The regulatory quality variable reflects the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Our aim is to examine whether the adoption and uptake of e-procurement tends to promote or restrain these institutional quality outcomes. In this respect, the key policy variable of interest is the post-adoption indicator of e-procurement policy for each respective treated country.

Our control variables consist of the macroeconomic, institutional, demographic and geographic characteristics that possibly confound the treatment effect of e-procurement on institutional quality. The set of macroeconomic control variables consist of the real GDP per capita, GDP shares of government expenditure,[4] investment and residual component, capital/labor ratio, combined index of human capital investment (Feenstra et. al. 2011), and the level of IQ (Lynn and Meisenberg 2010). The latter has been argued to be able to better capture the educational output and general intelligence than other measures of human capital formation such as average years of school, which tend to measure the educational inputs and may be too crude to yield a plausible effect on the outcome in question (Weede and Kämpf 2003). The set of institutional control variables consists of the level of democracy proxied through Polity2 overall score (Marshall et. al. 2018), OECD country membership indicator, civil law indicator variable (La Porta et. al. 1997), the average change in each institutional outcome variable in pre-adoption period, and the level of institutional quality constructed as a first principal components of three institutional outcomes, except the one used as a dependent variable. This effectively allows us to address the potential covariate imbalance between early adopters and the rest of the world that might arise from the neglect of institutional quality dissimilarities between the treatment and control samples. The set of demographic covariates consist of the population density (i.e. the number of inhabitants per 1,000 km2) while the geographic control variables consists of the size of the land area allowing us to compare early adopters with the control samples in terms of the country size. Our sample consists of 108 countries[5] in the period 1996-2016, which yields 2,376 country-year observations, and ensures that we are able to exploit the institutional quality trends between early-adopting countries and the rest of the world inasmuch as possible. Table 1 provides the key descriptive statistics for the outcomes and covariates.[6] Appendix 2 provides an additional overview of the institutional quality trends between early-adopters and the control sample.

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[4] Alternatively, the superior covariate would be the share of government procurement in the total government expenditure or the share of e-procurement in the total procurement expenditure. Unfortunately, the data limitations and the lack of availability of pre-2007 series on procurement expenditure for a very large number of countries do not allow us to consider it in the battery of covariates although it would yield much more meaningful input for the synthetic matching of early-adopting countries institutional quality with the result of the world.

[5] Albania, Algeria, Argentina, Australia, Austria, Azerbaijan, Bahrain, Belarus, Belgium, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Cape Verde, Canada, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Georgia, Germany, Ghana, Greece, Guatemala, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Japan, Kazakhstan, Kuwait, Kyrgyzstan, Latvia, Lebanon, Lithuania, Luxembourg, Malaysia, Malta, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Namibia, Netherlands, New Zealand, Nicaragua, Nigeria, North Macedonia, Norway, Oman, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Serbia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Tajikistan, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Venezuela, Vietnam, Yemen.

[6] In the appendix, we present the plots of institutional quality trends between early adopters and the control group before and after the adoption e-procurement in more detail.

TABLE 1 [INSERT HERE]

5 Results

5.1 Synthetic control estimates

We evaluate the institutional quality impact of adopting e-procurement using synthetic control estimator (Abadie and Gardeazabal 2003, Abadie et. al. 2010, 2015). For each early-adopting country we construct, we balance the covariates before the adoption of e-procurement and compose separate control group for each treated country. By balancing the covariates between treated and non-treated countries, we are able to match the early adopters with the non-adopters in the pre-reform period, provided that the pre-reform predictive discrepancy between the treated country and its artificial control group is sufficiently low. By comparing the institutional quality in the early-adopting country with the quality among non-adopters in the post-intervention period, we are able to observe the institutional quality gap, which we interpret as the counterfactual scenario and a rough indicator of the e-procurement reform impact. Compared to difference-in-differences model setup, the advantage of the synthetic control approach is that the generated counterfactual outcomes can have temporal variance in each post-reform period and may thus testify to the full impact of the reform rather than merely reflecting the average effect in the post-treatment period.

We envisage four possible counterfactual scenarios in response to the e-procurement adoption based on the classification of institutional shocks proposed by Garoupa and Spruk (2018). Firstly, the e-procurement may have no impact on institutional quality. In this case, the institutional quality of the early adopter and its synthetic control group does not differ much in the pre-reform and post-reform period. Secondly, the introduction of e-procurement may trigger a structural break in the institutional quality either by a permanent improvement or deterioration of a particular institutional quality dimension. And thirdly, the adoption of e-procurement may exert a temporary impact on the institutional quality which may disappear by the end of the post-treatment period.

Table 2 reports the covariate balance for each institutional quality variable and each country. For the sake of brevity, our focus is on the preferred synthetic control specification for each individual country since an exhaustive analysis of all possible combinations would be beyond the scope and limitations of this paper. Panel A reports non-averaged institutional quality variables in the pre-reform years using the level of institutional quality in the certain benchmark years before the reform and in the final year preceding the reform. Panel B reports the balancing of covariates other than pre-existing levels of institutional quality. It becomes apparent that the early-adopting countries are matched with the rest

of the world reasonably well. For example, the covariates means of real Portugal, Denmark and Netherlands and their synthetic counterpart in the control of corruption specification are very similar. The synthetic control units tend to have very similar pre-reform institutional dynamics, similar levels of per capita GDP and demographic structure, and very similar level of political institutions, human capital stock (proxied by a combined human capital investment index and level of IQ and macroeconomic outcomes). Since all three early-adopting countries are civil law jurisdictions, matching on the legal history and origin is arguably important. The share of non-adopters from civil law jurisdictions varies between 84 percent for the Netherlands and 98 percent for Portugal, which further strengthens our theoretical intuitions.

TABLE 2 [INSERT HERE]

Figure 1 presents the synthetic control estimated institutional quality impact of e-procurement for early-adopting countries. Notice that in each specification for one treated country, the other two early-adopters are excluded from the donor pool to facilitate a valid inference on the treatment effect in question. Compared to the difference-in-differences estimate in Table 3, the synthetic control evidence suggests stronger effects of e-procurement reform on institutional quality. Panel (a) exhibits the impact of e-procurement reform on the control of corruption using Portugal as a treated country. The evidence indicates a pervasive deterioration in the control of corruption in the full post-reform period. The negative effect of e-procurement on the control corruption tends to grow stronger over time since the real Portugal is falling behind its synthetic control group. The estimated control of corruption gaps clearly suggests that the adoption and implementation of e-procurement in Portugal mimicked the type of institutional shocks that produced the structural breakdown given the increasing corruption gap over time. Panel (b) reports the estimated impact of e-procurement on the rule of law in the Netherlands. Contrary to Portugal, the estimated rule of law gap with respect to the non-early adopting synthetic control group is positive and fairly stable over time, which we interpret as the evidence of the positive impact of the reform. Notice that the predictive discrepancy between the Netherlands and its synthetic control group prior to the adoption of e-procurement is very low, which arguably suggests that trends attributed to other institutional reforms do not seem to shape our counterfactual scenario.

Panel (c) presents the synthetic control estimated impact of e-procurement on government effectiveness using Denmark as a treated country in the year 2002. The synthetic control estimates for

Denmark tend to reconcile the positive static effect with the negative dynamic effect obtained using difference-in-differences specification. The evidence clearly highlights a positive gap in government effectiveness between Denmark and its synthetic control group in the post-reform years given a very low covariate-level discrepancy between Denmark and its control group in the pre-reform period. But unlike the Netherlands, the e-procurement reform in Denmark appears to have produced a temporary positive impact on government effectiveness. More specifically, our estimates are indicative of a relatively large gap in the initial post-reform years whereas the gap tends to disappear down to the present days, and suggests that certain domestic policies or political economy factors seem to have downgraded the initially large institutional benefits of e-procurement.

Lastly, Panel (d) reports the synthetic control estimated impact of e-procurement on the regulatory quality in Portugal. The estimated regulatory quality impact of e-procurement is comparable to the control of corruption impact in Panel (a) with the evidence of structural break triggered by the e-procurement intervention. The synthetic control estimate confirms a large and growing negative regulatory quality gap in the early post-reform period. Down to the present day, the gap between Portugal and its synthetic control group tends to narrow substantially although it does not disappear completely.

FIGURE 1 [INSERT HERE]

On balance, our synthetic control estimates confirm the mixed effect of e-procurement on institutional quality. Whereas the adoption and implementation of e-procurement is associated with a stronger rule of law in the Netherlands, we also find the deterioration of regulatory quality and weakening of control over corruption in Portugal as well as only a temporary positive effect of e-procurement in Denmark.

Our interest lies in the estimated gap in institutional quality between each early-adopting country and their control groups for the last year of our sample period. The institutional quality gains from implementing e-procurement appear to be modest at best. For instance, compared to the synthetic control group of countries that best describe its institutional quality trend before the reform, the level of government effectiveness in Denmark is about 7 percent higher whereas the control of corruption, rule of law and regulatory quality are between 2 percent and 3 percent lower compared to the control group. Synthetic control estimates of e-procurement impact for the Netherlands indicate between 3 percent and 5 percent improvement in regulatory quality and rule of law but, at the same time, a drop

in the control of corruption and government effectiveness indices by 2 percent and 1 percent, respectively. By contrast, Portugal stands out as the early-adopting country that gained and lost the most. For instance, our synthetic control estimates indicate notable increases in the strength of rule of law and government effectiveness. But these improvements are countervailed by the substantial drop in the ability to control corruption by 25 percent as well as in the regulatory quality by 14 percent.

The most obvious question begetting synthetic control estimates concerns the composition of synthetic control groups that best reproduce the trajectory of institutional quality in the years preceding the adoption of e-procurement. Table 3 reports the country-level weights used to construct the synthetic control groups. We find notable disparities in the country-level composition of synthetic control group for each institutional quality outcome variable. For instance, the intertemporal trajectory of control of corruption prior to the implementation of e-procurement in Portugal can be best reproduced as a linear combination of Norway (41%), Czechia (23%), Cape Verde (15%), Greece (12%), Israel (7%), Trinidad and Tobago (2%), and Mongolia (1%). Notice that the weights in the composition of the synthetic control group roughly indicate the degree of covariate-based outcome similarity between Portugal and the rest of the world. Since the pre-reform prediction error is reasonably low (=0.046), we interpret this as evidence that it is unlikely that policy changes in adjacent years shape the corruption gap between the real Portugal and its synthetic counterpart. By contrast, a significantly different set of countries best reproduces the trajectory of rule of law in the Netherlands in the years before the implementation of e-procurement. For instance, the level of the rule of law of synthetic Netherlands prior to the e-procurement take-up is best reproduced as a linear combination of covariate-level characteristics of Austria (31%), Switzerland (26%), Iceland (19%), Ireland (16%), Luxembourg (4%), Argentina (2%), Estonia and Belgium (both 1%), respectively. In a similar vein, a very low level of pre-reform prediction error testifies to the strong similarity between real Netherlands and its synthetic counterpart and highlights the real treatment effect of e-procurement on the rule of law. We also find that pre-reform Denmark resembles similar government effectiveness characteristics as the countries at its stage of development. More specifically, the synthetic control group for Denmark in the case of government effectiveness variable consists mainly of northern and continental non-early adopting European countries such as Finland (49%), Belgium (25%), Sweden (13%), Switzerland (10%), Luxembourg and New Zealand (both 2%), respectively. Notice that the pre-reform government effectiveness prediction error for Denmark is really low (i.e. 0.001) which self-suggests that the synthetic control group for Denmark can almost perfectly reproduce the trajectory of government effectiveness prior to the reform. Lastly, we find that the level of regulatory quality before the e-procurement reform in Portugal can be best reproduced as a linear combination of Chile (25%),

Norway (19%), Slovenia (17%), Austria (12%), Cyprus (10%), Turkmenistan (6%), Lithuania (3%), Sweden, Kuwait and Japan (each 2%), respectively. Hence, our evidence suggests that the level of institutional development in early-adopting countries prior to the reform is best predicted by different sets of countries that share institutional similarities with Denmark, Netherlands and Portugal to a significantly different degree, which can explain the mixed counterfactual scenarios in response to the introduction of e-procurement. As a robustness check, we carry out both static and dynamic differences-in-differences impact analysis in Appendix 3 and find the evidence consistent with the synthetic control estimates.

TABLE 3 [INSERT HERE]

5.2 Inference about synthetic control estimates

The most fundamental question concerning the plausibility of synthetic control estimates revolves around the notion whether the effects reflect the true treatment of interest, or are they simply driven by chance. To address this question, we perform a series of in-space placebo checks (Galiani and Quirtstorff 2018). To determine whether the results are specific to the early adopters of e-procurement, we assign the introduction of e-procurement to all non-early adopters. This effectively shifts the early adopters from the treatment sample to the donor pool. The intuition behind the placebo test is simple: if the effects of e-procurement on the institutional quality are specific to early adopters, then non-early adopters should have a markedly different post-treatment counterfactual scenario compared to the early adopters. We perform a series of quasi-randomization checks and calculate the p-value from various non-parametric tests, which roughly indicate the proportion of countries with the same direction and magnitude if the counterfactual scenario as the treated country. The idea is that if the effect of e-procurement is specific to the treated countries, the countries in the synthetic control group should have a very similar pre-reform trajectory of institutional quality but markedly dissimilar post-reform institutional quality trajectory.

FIGURE 2 [INSERT HERE]

Figure 2 summarizes the in-space placebo distributions for all four policy treatments. The evidence clearly suggests the baseline synthetic control estimates. For Portugal, the placebo distributions indicate a substantial drop in the control of corruption gap after the implementation of e-procurement reform, which does not seem to be generally prevalent in other donor countries. For the Netherlands, the placebo runs confirm a zero pre-reform gap between the Netherlands and its synthetic control

group, and a marked non-zero positive rule of law gap in the full post-treatment period. By contrast, the placebo distribution for Denmark indicates a reasonably strong positive reform-induced government effectiveness gap, gradually levelling off and reaching zero threshold by the end of the post-treatment period, confirming the nature of e-procurement reform best characterized as a temporary policy change with no long-lasting institutional effects. In Figure 3, we further present the probabilities that the observed gap happened by chance. It becomes apparent that the probability of observing a gap at random is less than 10 percent for the Netherlands and Portugal's control of corruption. For Denmark, the level of p-values appears to be low in the initial years and gradually rises by the end of the post-treatment period. On balance, this suggests that the introduction of e-procurement has had a positive long-run effect on institutional quality in the Netherlands, a negative effect in Portugal and a temporary effect in Denmark, which reinforces our theoretical notion that the effect of reform is far from uniform.

FIGURE 3 [INSERT HERE]

5.3 Sensitivity Analysis

Another important caveat arises from the ability of the control group to capture the pre-reform trends in institutional quality whilst providing a valid source of comparison for the early-adopting countries. To provide a valid and plausible comparison, the countries in the control should not have implemented the specific four-stage e-procurement. But since most countries in the control group have at least partially, albeit imperfectly, implemented e-procurement in the public sector, the estimates may pose a risk of contaminating the control group with at least some elements of e-procurement. To fully isolate the impact of e-procurement on institutional quality, we assess whether our synthetic control estimates are robust to the exclusion of countries that adopted other types of e-procurement. This implies that we only consider those countries that never use any kind of e-procurement as a control group.

Based on Djankov et. al. (2016) we review the state of e-public procurement across 180 countries and multiple years. By matching the review cards with our sample, we are able to identify 34 countries that have never adopted any kind of e-procurement.[7] We apply the synthetic control estimator to the early-

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[7] Algeria, Argentina, Azerbaijan, Belgium, Bosnia and Herzegovina, Botswana, Bulgaria, Cabo Verde, Chile, Colombia, Cote d'Ivoire, Dominican Republic, El Salvador, Ghana, Honduras, Iraq, Israel, Kuwait, Lebanon, Mozambique, Namibia, Peru, Qatar, Rwanda, Saudi Arabia, Senegal, Serbia, Slovenia, South Africa, Switzerland, Tajikistan, Tanzania, Uzbekistan, Yemen.

adopting countries by matching their pre-reform characteristics and covariates with the adjusted donor pool where no e-public procurement is perceivable.

Table 4 presents the composition of synthetic control groups for the early adopters when only countries without any e-procurement in place are considered in the control group. The composition of the synthetic control group appears to be consistent with the prior findings. For instance, the trajectory of corruption in Portugal prior to the reform can be best reproduced as a linear combination of covariate-level characteristics and dynamics of Chile (35%), Israel (30%), Slovenia (14%), Switzerland (12%), and Cote d'Ivoire (8%), respectively. By contrast, the pre-reform Netherlands' rule of law can be best approximated by the combination of covariate-level characteristics of Switzerland (81%), Chile (11%), and Qatar (8%) while the level of government effectiveness of pre-reform Denmark is best synthesized as a combination of Switzerland (85%) and Belgium (15%). Considering the impact of e-procurement on regulatory quality, the non-adopters of e-procurement that best reproduce Portugal's pre-reform regulatory quality are Slovenia (38%), Chile (37%), Argentina (4%), Uzbekistan (2%), and Kuwait (1%), respectively.

TABLE 4 [INSERT HERE]

Figure 4 presents the estimated impact of e-procurement on institutional quality by relying on the trends of non-adopters to capture pre-reform institutional quality dynamics. The evidence suggests that our results are very similar to the baseline effects of e-procurement where a large sample of countries is deployed to construct the control group for early adopters. Down to the last year of our sample period, we find 8 percent deterioration in the control of corruption in Portugal, 4 percent improvement in the strength of rule of law in the Netherlands, 4 percent drop in government effectiveness in Denmark, and 7 percent decline in regulatory quality in Portugal. At the conceptual level, our results indicate the institutional breakdown triggered by e-procurement in Portugal, an institutional breakup in the Netherlands, and a temporary institutional shock in Denmark.[8] To inspect the differences between the baseline institutional quality gaps and the corresponding gaps with the restricted control sample, Figure 5 plots both sets of gaps. In particular, it plots the institutional quality gaps for the original control sample with a large number of countries, and the institutional quality gaps

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[8] In Appendix 4, we carry out a less restrictive treatment sensitivity analysis where we exclude the OECD countries with the share of public procurement in GDP above the 75th percentile of the cross-country distribution from the donor pool and apply the synthetic control estimator to determine the institutional quality impact of adopting e-procurement. We reach quantitatively very similar evidence.

for the adjusted control sample where only countries with no e-procurement are included. The evidence suggests a high correlation between gaps across both samples. The correlation coefficient between the gaps amounts to +0.86 which confirms our prior theoretical arguments, and suggests that the results are unlikely tainted by the composition of the control group.

FIGURE 4 [INSERT HERE]
FIGURE 5 [INSERT HERE]

Several notions arise concerning the external validity of our findings. First, the generalizability of our results is not uniform but context-specific. Since our results indicate a significant improvement in the rule of law in the Netherlands and a deterioration in the ability to control corruption in Portugal, the general findings hinge on distinguishing between (i) e-procurement as an structural breakup, (ii) e-procurement as a structural breakdown, and (iii) e-procurement as a temporary institutional shock. This implies that our results are generalizable provided that the context of adopting e-procurement is empirically well-understood. One caveat should be added. Our results do not convey any notion of why e-procurement adoption led to improved institutional quality in the Netherlands, deterioration in Portugal and temporary impact in Denmark. To be able to address this caveat and generalize our results, the question that should be addressed in future research is what institutional, historical, economic, and policy-related factors shape the context to explain what can distinguish e-procurement as an institutional breakup from the e-procurement as an institutional breakdown. The ultimate test of the external validity of our findings would be based on the replication of the results on a different population such as firm-level economic outcomes, financial markets' behavior, sectoral specialization and firm-level innovation decisions, and corporate governance quality to name a few. The external validity of our findings hinges on the identification of similar effects across different settings where the effect of e-procurement may be perceivable.

Conclusion

In this paper, we examine the impact of adopting e-procurement on institutional quality by focusing on three early-adopting EU countries – Denmark, Netherlands and Portugal – for the period 1996-2017. To this end, we deploy a difference-in-differences policy analysis setup to estimate the average treatment effect of e-procurement on institutional quality. Since the parallel trend assumption between early-adopters and the rest of the world can be violated, we undertake the synthetic control analysis and construct the counterfactual scenario in response to e-procurement adopting by exploiting the similarity between the early-adopting countries and the control groups in the battery of

pre-reform institutional, macroeconomic, demographic and geographic characteristics that possibly predict the level of institutional quality.

Our findings suggest that the institutional quality effects of e-procurement reform are not uniform. We find substantial improvements in the level of the rule of law and government effectiveness in Netherlands and Denmark in the post-reform period. The estimated average treatment effect of e-procurement does not seem to disappear once a battery of structural confounders allows for simultaneous influence on the level of institutional quality. By contrast, our difference-in-differences estimates indicate pervasive deterioration in the control of corruption in Portugal in the post-reform period. The drop in the ability to control corruption after the implementation of e-procurement does not disappear once we control for the changing economic conditions, adverse demographic trends as well as for unobserved heterogeneity bias and common institutional shocks affecting all countries in the sample.

By adopting the extant synthetic control estimator to construct the counterfactual scenario, our approach can detect the institutional nature of the adoption of e-procurement with respect to the magnitude, persistence and direction of the institutional quality effect (Garoupa and Spruk 2018). Our synthetic control estimates are consistent with difference-in-differences estimates and confirm the improvement in institutional quality in the Netherlands and Denmark and the deterioration of quality in Portugal. Given that our setup comprises three treated countries, in-depth empirical analysis of the determinants of the institutional gains and losses from e-procurement is not possible. Nevertheless, we find that gains in institutional quality tend to move in tandem with the pre-existing level of institutional quality, level of development, average intelligence and human capital formation, and appear to be strengthened by solid macroeconomic fundamentals. To capture the pre-reform trends in the institutional quality, we construct a large sample encompassing 108 countries that serve as a potential control groups for the three early adopters and find notable dissimilarities in the composition of synthetic control groups.

Our synthetic control estimates show further that the introduction of e-procurement acted as an institutional change with the characteristics of the structural breakup with respect to the rule of law in the Netherlands. We find that the real Netherlands consistently outperforms its synthetic version with the early adoption of e-procurement with no evidence of pre-existing trends in the trajectory of

the rule of law. By contrast, we find that the adoption of e-procurement Denmark acted as a temporary change imposed by a policy shock with no long-lasting implication. This implies that in the initial post-reform years, the real Denmark strongly outperforms its synthetic counterpart but gradually moves back to its long-run equilibrium before the reform, suggesting that a combination of domestic political economy factors might have downplayed the institutional advantages of e-procurement. As a stark contrast, our synthetic control estimates show that the e-procurement failed to foster structural institutional change in Portugal. In particular, the control of corruption and de facto regulatory quality tend to deteriorate significantly after the reform, which suggests that the e-procurement most likely locked-in pre-existing corruption and expanded rent-seeking opportunities for public officials, promulgating an institutional breakdown as the synthetic Portugal without the reform consistently outperforms its real counterpart. In addition, we performed a series of randomization checks resting on in-space policy treatment substitution from the treated country to the donor pool and found that the effect of the reform is very strong in Portugal with respect to the level of corruption. In Denmark and the Netherlands, we found significant effects of the reform in the early post-reform years whereas the effect tends to disappear down to the present day.

The key implication of our research suggests that e-procurement can be an effective policy for improving the institutional quality but can have countervailing effects if it is introduced in the context of pervasive and widespread corruption opportunities that breed rent-seeking incentives for economic actors. E-procurement should not be viewed as a magic bullet that could fully alleviate institutional quality concerns. Even when it is adopted by the countries with envious level of institutional quality, its effect appears to be temporary at best with hardly any evidence of the structural break. Why some countries benefit more than others from e-procurement, and which combinations of domestic, external and political economy factors determines the level of gains and losses from e-procurement in terms of both institutional quality and economic performance remains, in our view, an important avenue for future research.

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Table 1: Full-Sample Descriptive Statistics

	# Obs	Mean	StD	Min	Max
Panel A: Institutional quality outcomes					
Control of corruption	2,376	0.236	1.049	-1.663	2.469
Rule of law	2,376	0.227	1.011	-2.338	2.100
Government effectiveness	2,376	0.332	0.950	-2.088	2.436
Regulatory quality	2,376	0.341	0.935	-2.334	2.260
Panel B: Covariates					
log real GDP per capita	2,376	9.467	1.036	6.015	11.941
log population density	2,376	0.001	0.006	0.00001	0.055
OECD member	2,376	0.33	0.47	0	1
Institutional quality (first principal component)	2,376	-0.0000	2.114	-4.729	4.618
Level of democracy	2,376	4.93	6.48	-10	10
Government expenditure GDP share	2,376	0.18	0.07	0.01	0.61
Export GDP share	2,376	0.31	0.29	0.001	2.56
Residual GDP share	2,376	0.02	0.08	-0.77	0.67
Human capital index	2,376	2.65	0.62	1.107	3.97
Capital/labor ratio	2,376	11.55	1.15	7.04	13.53
IQ	2,376	89.68	9.31	64	108
Land area size	2,376	12.07	2.11	5.755	16.61
Civil law	2,376	0.75	0.43	0	1

Notes: the table presents the full-sample descriptive statistics of the institutional quality measures and the covariates used in the empirical analysis.

Table 2: Pre-Reform Covariate Means

	Control of Corruption		Rule of Law		Government Effectiveness		Regulatory Quality	
	Portugal (2009)		Netherlands (2005)		Denmark (2002)		Portugal (2009)	
	Treated	Synthetic	Treated	Synthetic	Treated	Synthetic	Treated	Synthetic
Panel A: Non-Average Pre-Reform Covariates								
Outcome variable in 1996	1.37	1.35	1.69	1.69	1.75	1.75	1.21	1.21
Outcome variable in 2000	1.19	1.19	1.77	1.77	1.98	1.98	0.96	0.96
Outcome variable in pre-reform year t-1<T0	1.07	1.06	1.75	1.75			1.08	1.07
Panel B: Structural Covariates								
Log GDP per capita	10.04	10.01	10.53	10.50	10.39	10.38	10.04	10.01
Log population density	0.0001	0.0006	0.0006	0.0006	1	1	0.0002	0.0004
OECD member	1	0.82	1	0.98	3.48	3.37	1	0.81
Institutional quality (first principal component)	1.72	1.73	3.43	3.41	3.48	3.37	1.72	1.74
Level of democracy	10	9.56	10	9.88	10	10	10	8.23
Government expenditure GDP share	0.16	0.18	0.117	0.13	0.17	0.15	0.16	0.16
Export GDP share	0.23	0.38	0.67	0.54	0.52	0.60	0.23	0.37
Residual GDP share	0.02	0.02	0.02	0.02	0.03	0.01	0.02	0.03
Human capital index	2.21	3.02	3.14	3.11	3.26	3.11	2.21	2.94
Capital/labor ratio	12.26	12.17	12.24	12.39	12.33	12.47	12.26	12.07
Average rate of change in outcome variable	-0.027	-0.025	0.009	0.009	0.065	0.063	-0.011	-0.010
IQ	95	94.37	100	98.96	98	99	95	94.35
Log land area size	11.42	11.31	10.43	11.02	10.65	11.80	11.42	11.78
Civil law	1	0.91	1	0.84	1	0.98	1	0.98

Notes: the table presents the covariate means for the early-adopting countries prior to the adoption of e-procurement.

Table 3: Synthetic Control Groups

	Control of Corruption			Rule of Law			Government Effectiveness			Regulatory Quality		
	Denmark	Netherlands	Portugal	Denmark	Netherlands	Portugal	Denmark	Netherlands	Portugal	Denmark	Netherlands	Portugal
Pre-Reform RMPSE	**0.018**	**0.016**	**0.046**	**0.009**	**0.025**	**0.136**	**0.013**	**0.047**	**0.097**	**0.001**	**0.053**	**0.106**
Argentina	0	0	0	0	0.02	0	0	0	0	0	0	0
Austria	0	0	0	0	0.31	0	0	0	0	0.32	0	0.12
Belgium	0	0.01	0	0	0.01	0	0.25	0	0	0	0	0
Cape Verde	0	0	0.15	0	0	0.15	0	0	0	0	0	0
Chile	0	0	0	0	0	0	0	0	0.40	0	0	0.25
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0.10
Czech Republic	0	0	0.23	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0.02	0.01	0	0	0	0	0	0	0
Finland	0.78	0	0	0.42	0	0	0.49	0	0	0.26	0.47	0
Greece	0	0	0.12	0	0	0.04	0	0	0.24	0	0	0
Iceland	0	0.02	0	0	0.19	0.20	0	0	0	0	0	0
Ireland	0	0	0	0	0.16	0	0	0	0	0	0	0
Israel	0	0	0.07	0.06	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0.30	0	0	0	0	0	0.02
Kuwait	0	0	0	0	0	0	0	0	0	0	0	0.02
Lithuania	0	0	0	0	0	0	0	0	0.07	0	0	0.03
Luxembourg	0	0.12	0	0.04	0.04	0.02	0.02	0.19	0	0.05	0.03	0
Mongolia	0	0	0.01	0	0	0	0	0	0	0	0	0
New Zealand	0	0	0	0.02	0	0	0.02	0	0.02	0	0	0
Norway	0	0.36	0.41	0.08	0	0	0	0	0.18	0	0	0.19
Singapore	0	0.02	0	0	0	0	0	0	0	0.06	0.46	0
Slovakia	0	0	0	0	0	0	0	0.18	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0.17
South Africa	0	0	0	0	0	0	0	0	0.09	0	0	0.02
Spain	0	0	0	0	0	0.28	0.13	0	0	0	0	0
Sweden	0.22	0.31	0	0.16	0	0	0.10	0.64	0	0	0	0
Switzerland	0	0	0	0.20	0.26	0	0	0	0	0	0.03	0
Trinidad and Tobago	0	0	0.02	0	0	0	0	0	0	0	0	0
Turkmenistan	0	0	0	0	0	0	0	0	0	0	0	0.06
United Kingdom	0	0.16	0	0	0	0	0	0	0	0.33	0	0
# Countries with zero weights	104	99	99	97	98	100	100	103	100	101	102	96

Notes: the table presents the composition of synthetic control groups for the early-adopting countries per institutional quality outcome variable

Table 4: Composition of Synthetic Control Group from a Sample of Non-Adopting Countries

	Control of Corruption	Rule of Law	Government Effectiveness	Regulatory Quality
	Portugal (2008)	Netherlands (2006)	Denmark (2003)	Portugal (2008)
Estimated gap	-8%	+4%	-4%	-7%
Pre-Reform RMSE	0.051	0.046	0.015	0.118
Algeria	0	0	0	0
Argentina	0	0	0	0.04
Azerbaijan	0	0	0	0
Belgium	0	0	0.15	0
Bosnia and Herzegovina	0	0	0	0
Botswana	0	0	0	0
Bulgaria	0	0	0	0
Cabo Verde	0	0	0	0
Chile	0.35	0.11	0	0.37
Colombia	0	0	0	0
Cote d'Ivoire	0.08	0	0	0
Dominican Republic	0	0	0	0
El Salvador	0	0	0	0
Ghana	0	0	0	0
Honduras	0	0	0	0
Iraq	0	0	0	0
Israel	0.30	0	0	0
Kuwait	0	0	0	0.01
Lebanon	0	0	0	0
Mozambique	0	0	0	0
Namibia	0	0	0	0
Peru	0	0	0	0
Qatar	0	0.08	0	0
Rwanda	0	0	0	0
Saudi Arabia	0	0	0	0
Senegal	0	0	0	0
Serbia	0	0	0	0
Slovenia	0.14	0	0	0.38
South Africa	0	0	0	0
Switzerland	0.12	0.81	0.85	0
Tajikistan	0	0	0	0
Tanzania	0	0	0	0
Uzbekistan	0	0	0	0.02
Yemen	0	0	0	0

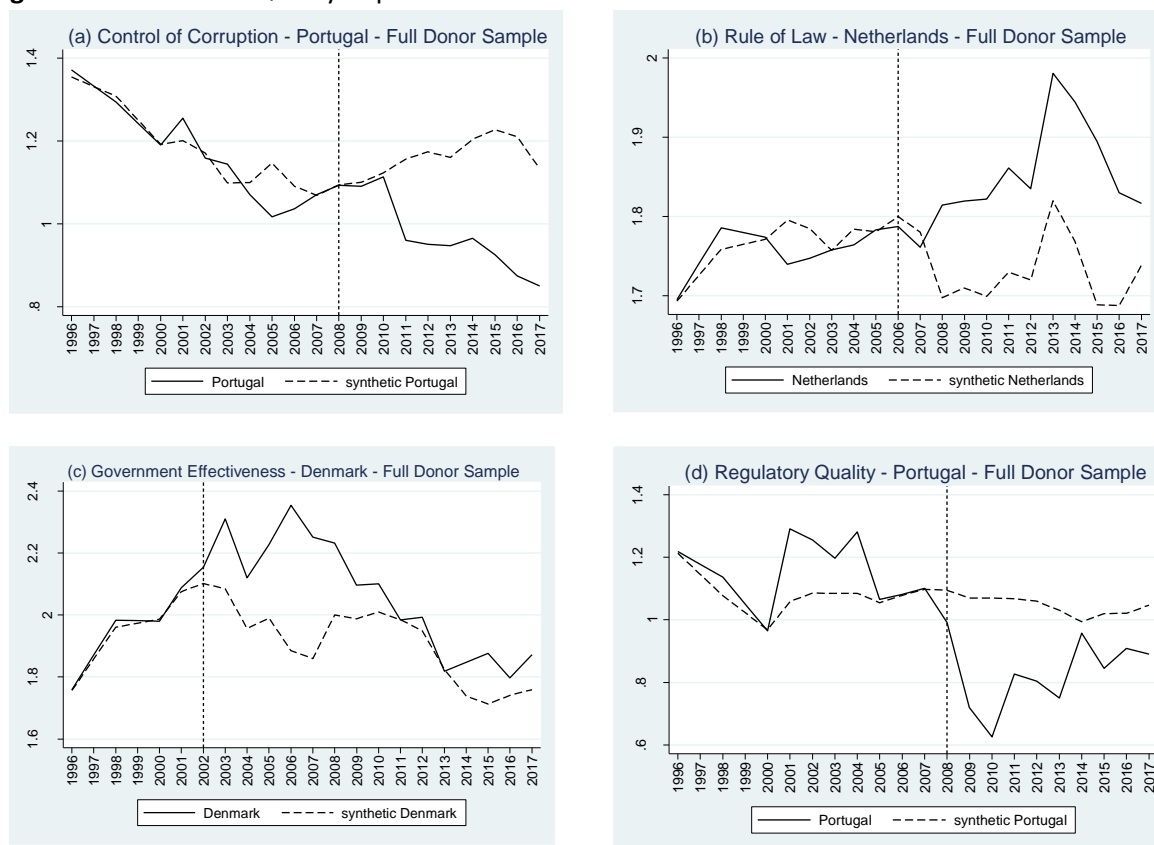Notes: the table presents the composition of synthetic control groups for the early-adopting countries per institutional quality outcome variable using a donor pool of countries that never adopted any kind of e-procurement to construct control groups.

Figure 1: Institutional Quality Impact of E-Procurement

Notes: the figure presents the synthetic control estimated impact of adopting e-procurement on institutional quality

Figure 2: In-Space Placebo Gaps
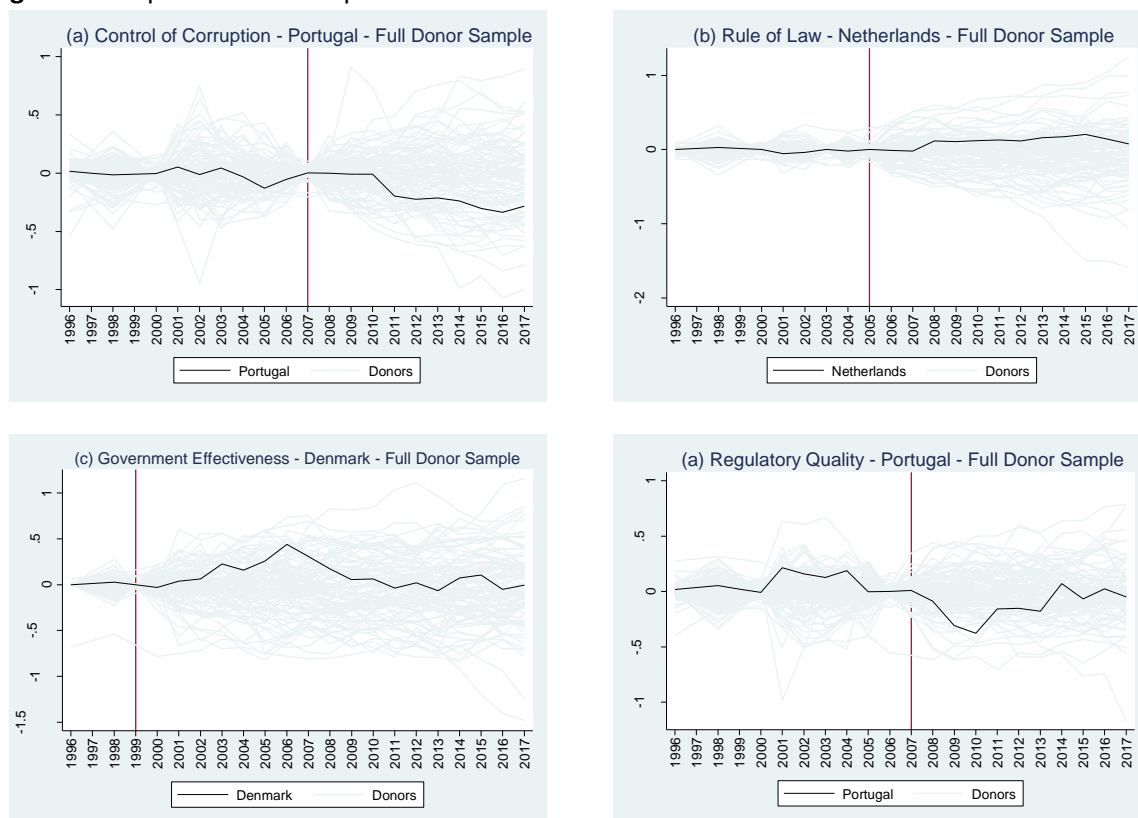
Notes: the table presents in-space placebo gaps for the adoption of e-procurement. The solid black curve represents the actual institutional quality gap for the treated country. The light grey curve represents the placebo gaps of the institutional quality for the untreated countries from the donor pool.

Figure 3: Randomization Inference on the Impact of Adopting E-Procurement

Notes: the table presents permutation-based p-values indicating the statistical significance of the institutional quality effect of e-procurement for the full post-treatment period.

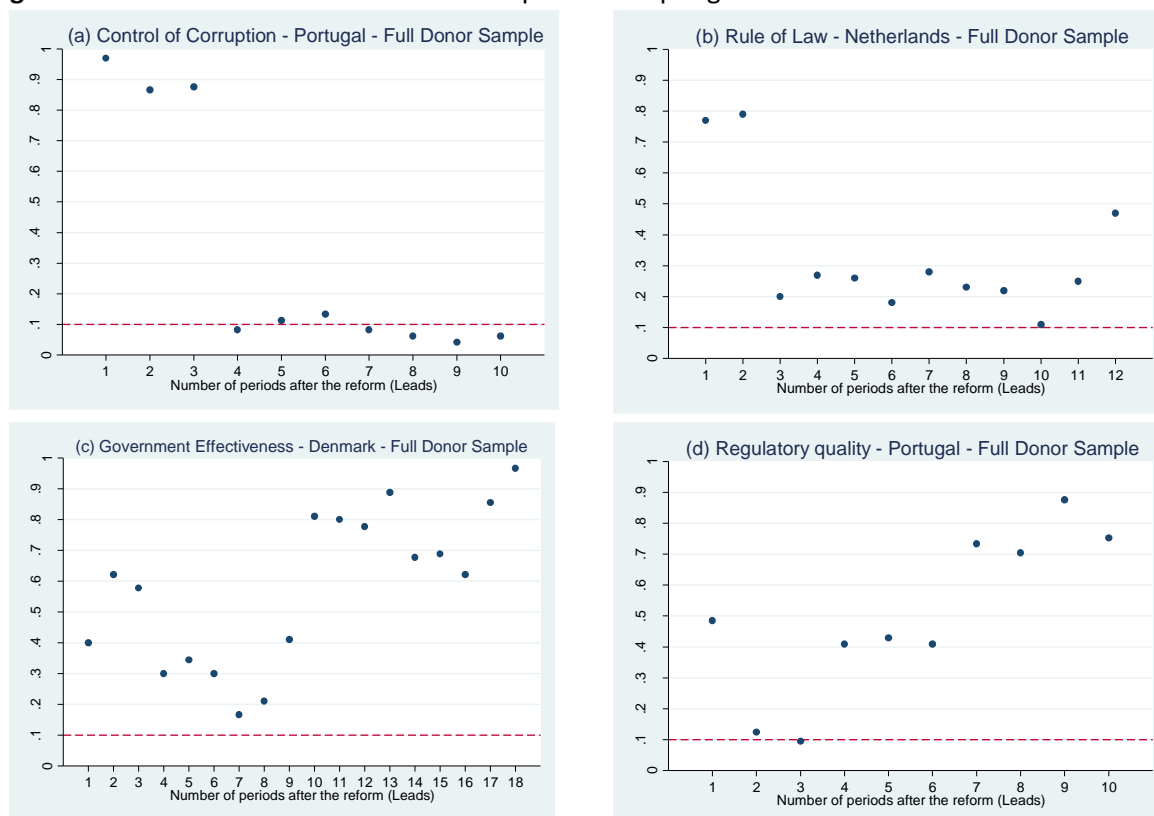**Figure 4**: Institutional Quality Impact of E-Procurement in a Control Sample without Any Kind of E-Procurement

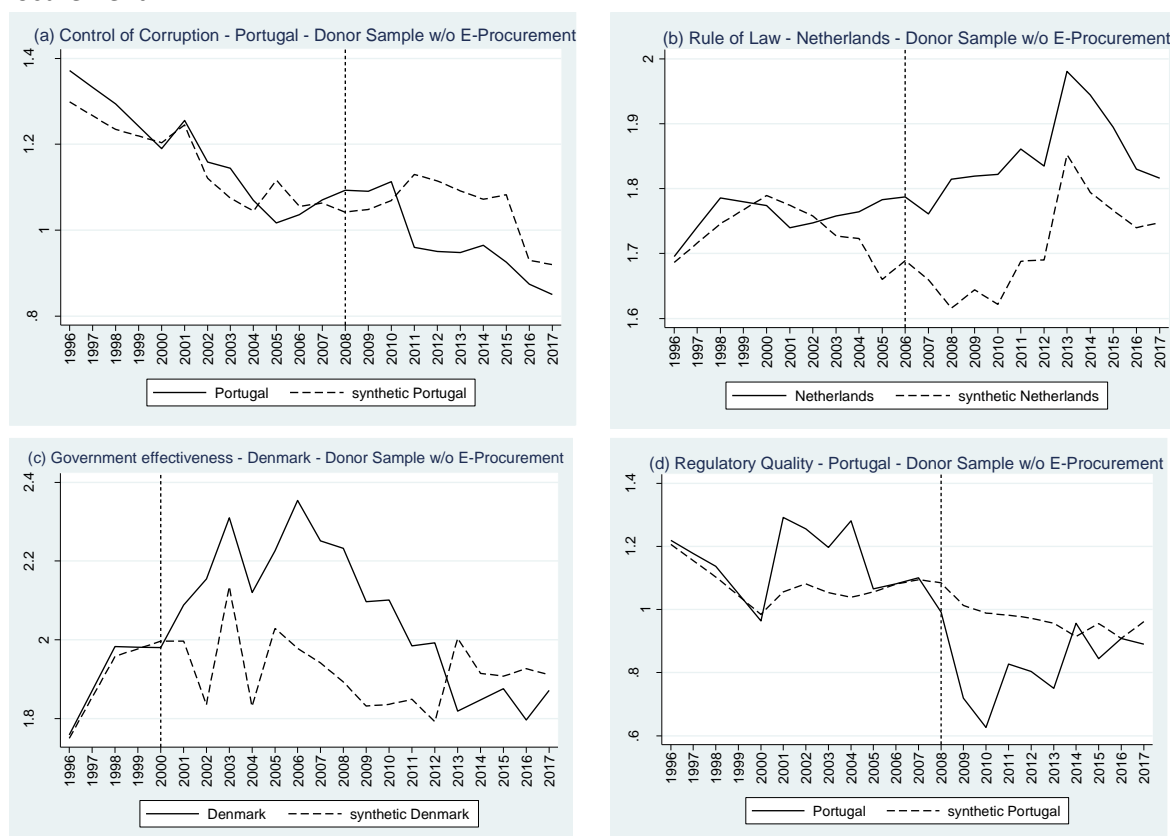Notes: the figure presents the synthetic control estimated impact of adopting e-procurement on institutional quality using a donor sample that excludes countries that never adopted any kind of e-procurement.

Figure 5: Comparison of Institutional Quality Gaps Across Different Control Samples
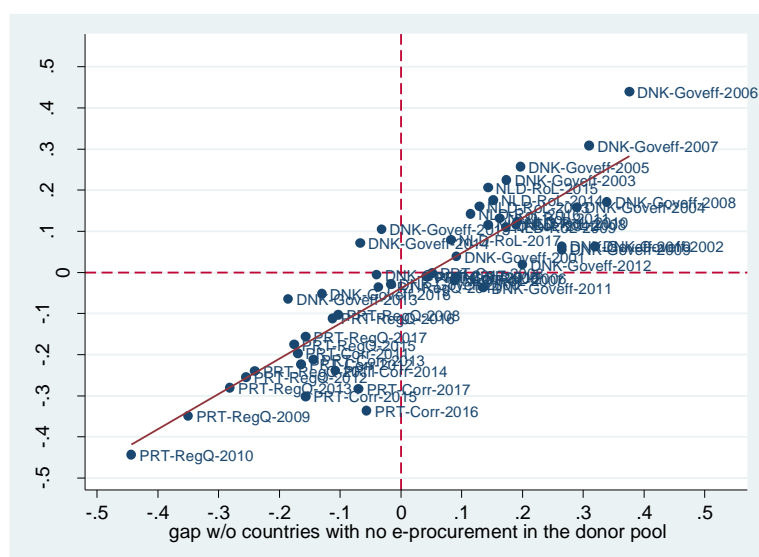
Notes: the figure plots the synthetic control estimated institutional quality gaps using a control sample of countries that adopted some kind of non-four-stage e-procurement against the estimated institutional quality gaps control sample of countries that never adopted any kind of e-procurement.

Appendix

Appendix 1: Comparative Assessment of E-Procurement Rules and Outcomes

Our focus is on the "early adopters" of the e-procurement in the European Union that decided to implement e-procurement on the large scale before the year 2016 when the three EU Directives[1] on mandatory e-procurement came into force, and allowed for adaptation and development of e-procurement framework to the national institutional setup. The three countries that implemented the full set of EU directives before they became mandatory and adopted e-procurement at the early stage comprise the Netherlands, Denmark and Portugal. Denmark implemented a large-scale e-procurement platform in the year 2002 across all five pillars of the public procurement process.[2] In 2005, the Netherlands transposed the Directive 2004/18/EU into the national institutional framework and implemented a similar e-procurement platform that digitalized all five stages of public procurement. In 2008, Portugal introduced e-procurement into Public Contracts Code (Código dos Contratos Públicos) by implementing Decree-Law No. 18/2008, of January 29th (Decreto-Lei nNo.º 18/2008, de 29 de janeiro) aiming at broad flexibility of administrative contract-award procedures and transparent tender evaluation model and mandating the use of electronic platforms in open procedures by 2009. Despite several similarities, a few differences exist between early-adopting countries in their e-procurement framework.

1.1 Denmark

The Danish government has been involved in implementing several e-procurement strategies. In the year 1999, the Danish government released a policy document eliciting e-procurement as one of the key pillars of the information society, approving the list of goods and service qualified as suitable for e-procurement. In 2002, Public E-Procurement Portal (PePP) was launched (Henriksen and Mahnke 2005). The transition to e-procurement was completed before the 2004 EU Public Procurement Directives were transposed into the national legislative framework. The primary role in Danish procurement system is played by Danish Competition and Consumer Authority, which, apart from its role in competition oversight in public procurement markets, has a range of other responsibilities in the functioning of the procurement system, such as the support of bidders through the advice on the correct interpretation of procurement rules, serving as a review body for case complaints at the early stage and the performance of compliance checks with regular reports on violations. It is also in charge of the operation of the online portal for e-notification of public procurement.

1.2 Netherlands

The Dutch procurement system is governed by the Public Procurement Decree (PPD) and the Proportionality Guide, which is legally binding and helps the contracting authorities to ensure that requirements in an administrative contract are aligned with the object of the contract. The general regulatory framework for public procurement is based on the political commitment set out in the national parliament, known as Koopmans-De Krom agreement. The agreement was set out in 2005 and called for the inclusion of sustainability as a key criterion in 100 percent of government purchases

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[1] These directives comprise *Directive 2014/24/EU* on public procurement, *Directive 2014/25/EU* on procurement by entities operating in the water, energy, transport and postal services sectors, and *Directive 2014/23/EU* on the award of concession contracts

[2] The five pillars of public procurement consist of (i) e-notification, (ii) e-tendering, (iii) e-submission, (iv) e-ordering, and (v) e-invoicing

by the year 2010. The criteria were immediately transposed into the national legislation, before the implementation of the EU Public Procurement Directives. Similarly to Denmark, the Netherlands has been developing strategies and policies on public procurement for more than a decade predating the Koopmans-De Krom agreement with several institutions involved in the process. But compared to Denmark, Netherlands has a highly decentralized public procurement management, where each contracting authority is responsible for the management of its own public procurement procedures whereas the coordination and policymaking is handled by the Ministry of Economic Affairs (MEA) and its Public Procurement Expertise Centre (PIANOo). The MEA has primary authority over procurement issues and is responsible for drafting procurement legislation, interfacing with the EU legislation, and compliance with procurement law. In 2013, it established the Commission of Public Procurement Experts to act as an alternative dispute resolution mechanism for procurement bidders with complaints. The commission acts as a mediator between the bidder and the contracting authority and has a de jure and de facto power to issue non-binding advice on how to resolve claims.

1.3 Portugal

The new Public Procurement Law of 2008 (Decreto-Lei n.º 18/2008Decreto-Lei No. 18) transposed the EU procurement directives 2004/17 and 2004/18 to consolidate, modernize and adapt the legal framework for public procurement. About a year before Portugal created The central feature of the reform was the creation of thea Central Purchasing Body (Agência Nacional de Compras Públicas) as public law body managing the newly created public procurement systempurchases of supplies and services of the Central State (Decree-Law no. 144/2007, of February 19th) as well as a Construction and Real Estate Institute (Instituto da Construção e Imobiliário), focused on the regulation of the public works market. Public Institutes. (Decree-Law no. 144/2007, of April 27th). The latter would eventually carve its way as the Portuguese regulator of all public contracts, particularly from 2012 on, and now on the new post 2014 Directives reform of the Portuguese public procurement code. Mandatory e-procurement was introduced into all public bodies for tendering and awarding all public procurement procedures above the EUR 5,000 threshold. The reform led to a significant overhaul of the previous legal framework on public procurement. Electronic procedures were mandated for central administration while local authorities retained autonomy for their own procurement. Procurement policymaking is handled by the Ministry of the Economy, in charge of procurement policy development. The central purchasing body is, since 2012, the Entity of Share Services of Public Administration (esPaP), which oversees numerous large-framework contracts through which central government agencies are required to purchase standardized items. Portuguese Competition Authority (PCA) oversees the e-procurement compliance with the competition rules, and that public procedures do not violate those rules. In principle, sanctions for breaches can be applied by the Court of Auditors whereas internal controls of procurement pare conducted by the Inspectors Generals of the various ministries.

Table A1 summarizes the key differences in the de jure public procurement rules and de facto outcomes of e-procurement in the post-implementation period for the three early adopting countries as of 2014 for which we were able to obtain the data. The comparison is broken down by the procurement share of GDP, composition of procedures applied, share of contract notices by the buyer, contract type, e-procurement adoption scorecard, and several additional indicators. The GDP share of public procurement ranges from 10 percent in Portugal to 23 percent in the Netherlands. The Netherlands relies mostly on open procedures, which comprise 71 percent of the total. Both Denmark and Netherlands retain 29 percent and 14 percent of restricted procedures for tendering bids whereas the share of such procedures in Portugal is very low (i.e. 3 percent). By contrast, Portugal strongly relies

on unspecified procedures strongly, representing about 44 percent of total procedures, while Denmark and the Netherlands do not rely on such procedures at all. The composition of contract notices by the buyer is roughly comparable between the Netherlands and Denmark with reasonably similar shares. In a stark contrast, about 68 percent of buyer-related contract notices are dealt with a separate body governed by public law compared to 22 percent and 28 percent in Denmark and the Netherlands. The latter of the two countries delegated more than 40 percent of contract notices to the regional level whereas only 12 percent of the contract notices in Portugal is delegated to the regional level in spite of the individual political statutes and some legislative autonomy of Azores and Madeira, which allows them to adapt the national legislation according to their own specificities.

The major differences between the three early-adopting countries arise from the types of procurement contracts. In this respect, Denmark and the Netherlands procure most contracts for services whereas almost two thirds of contracts in Portugal relates to supplies. In all three countries, e-notification of the bid is mandatory, whereas the Danish law stipulates a voluntary e-access compared to the mandatory one in the Netherlands and Portugal. In the Netherlands and Denmark, the e-submission of the bid is only partially voluntary whilst it is fully mandatory in Portugal. The overall uptake rate for procured contracts is 6 percent and 7 percent in Denmark and the Netherlands respectively, whereas the rate is almost 41 percent in Portugal. By contrast, e-procurement represents more than a third of total procurement in Denmark, 8 percent in the Netherlands and 16 percent in Portugal. A striking feature of the Portuguese e-procurement framework is a relatively large share of single bids compared to the other two countries, and a benign share of bids won by foreign firms. The adoption of e-procurement in Denmark and the Netherlands established the use of most-economically-advantageous tender (MEAT) criteria, and both countries rely on this criterion in 73 percent and 90 percent of the contracted bids. They seem to rely less on price criteria which prevails in 27 percent and 10 percent of the contracted bids. By contrast, Portugal relies strongly on price criteria which prevails in 56 percent of the bids.
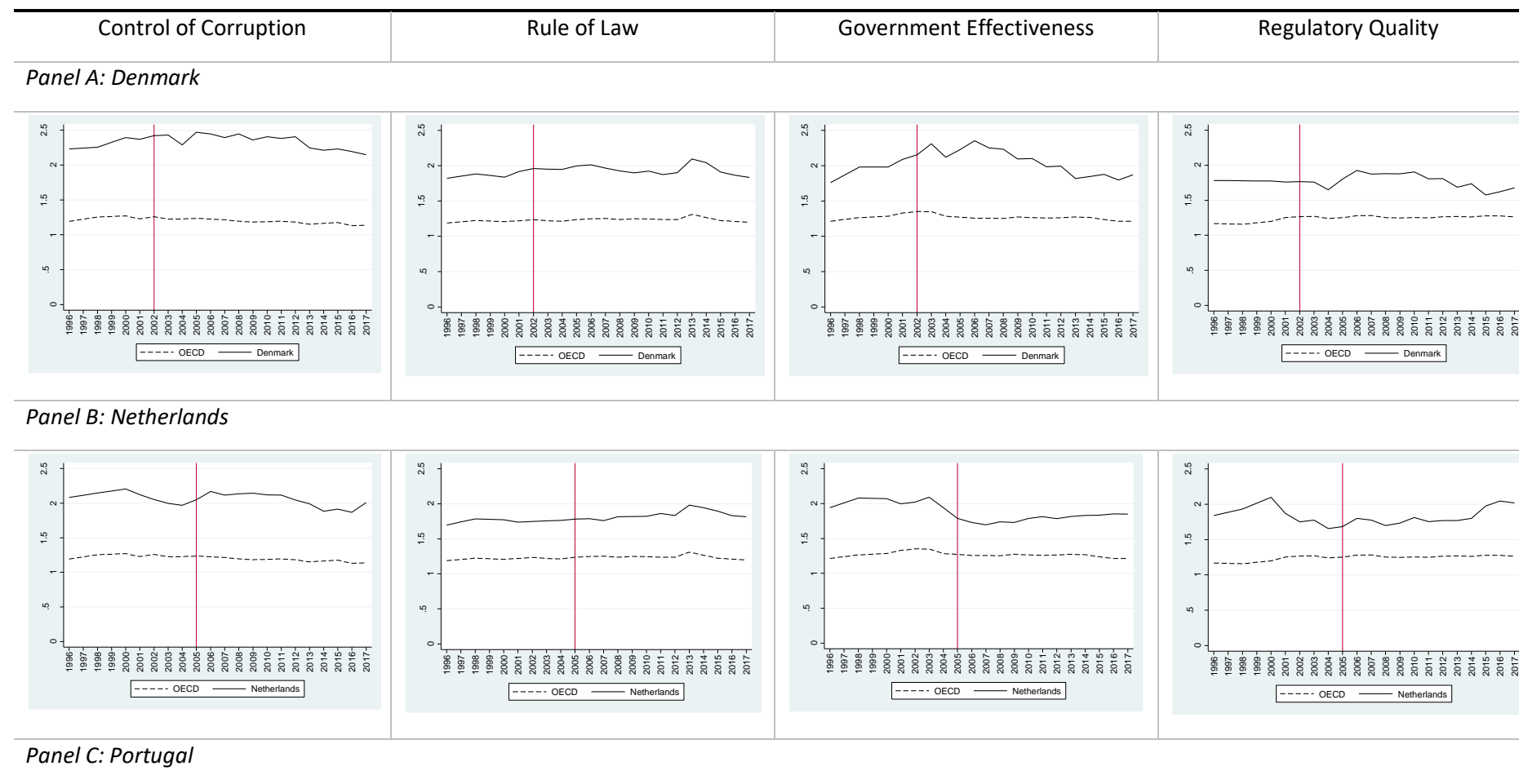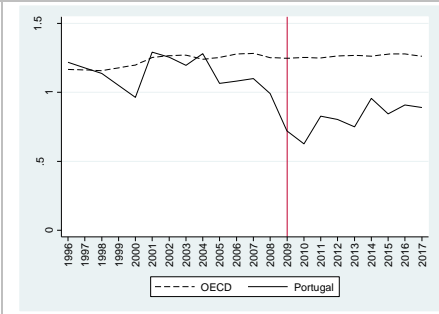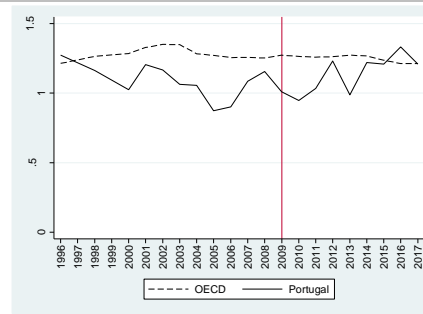
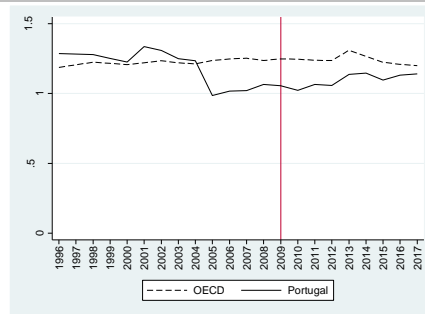**Table A1:** Comparative Public Procurement Framework

	Denmark		Netherlands		Portugal	
Procurement share (% GDP)	14%		23%		10%	
Procedures applied	Open	50%	Open	71%	Open	48%
	Restricted	29%	Restricted	14%	Restricted	3%
	Negotiated with call	10%	Negotiated with call	2%	Negotiated with call	1%
	Negotiated without call	3%	Negotiated without call	3%	Negotiated without call	0%
	Competitive dialog	9%	Competitive dialog	1%	Competitive dialog	0%
	Direct award	9%	Direct award	10%	Direct award	5%
	Other	0%	Other	0%	Other	44%
Share of contract notices by buyer	National	16%	National	18%	National	7%
	Regional	42%	Regional	44%	Regional	12%
	Body governed by public law	22%	Body governed by public law	28%	Body governed by public law	68%
	Other	20%	Other	10%	Other	13%
Contract type	Services	47%	Services	56%	Services	28%
	Works	15%	Works	11%	Works	6%
	Supplies	38%	Supplies	33%	Supplies	66%
	Framework agreement	37%	Framework agreement	15%	Framework agreement	6%
E-procurement adoption	E-notification	Mandatory	E-notification	Mandatory	E-notification	Mandatory
	E-access	Voluntary	E-access	Mandatory	E-access	Mandatory
	E-submission	Partially mandatory	E-submission	Voluntary	E-submission	Mandatory
	Uptake rate	6%	Uptake rate	7%	Uptake rate	41%
E-procurement (% total procurement)	37%		8%		16%	
Contract notices	2,694		3,874		1,599	
Contract awards	2,062		3,412		2,026	
% received single bid	7%		8%		15%	
% won by foreign firms	4%		3%		1%	
% related to EU funds	2%		1%		27%	
# days for first decision	49.1		64.2		94.1	
MEAT criteria	73%		90%		44%	
price criteria only	27%		10%		56%	
% joint purchases	14%		3%		2%	
central purchasing	Yes		No		Yes	

Notes: this table reports the key features of public procurement framework in early-adopting countries in the EU, i.e. Denmark, Netherlands and Portugal. Source: European Commission (2019).

Appendix 2: Institutional quality trends between treatment and control samples

Figure A2: Institutional Quality in Early Adopters
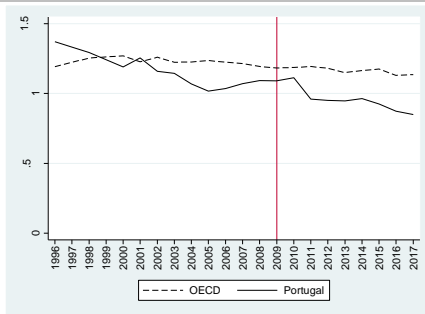
Control of Corruption	Rule of Law	Government Effectiveness	Regulatory Quality

Panel A: Denmark

Panel B: Netherlands

Panel C: Portugal

Notes: the figure presents institutional quality trends in early e-procurement adopters against OECD average

Figure A3: Institutional Quality Trends
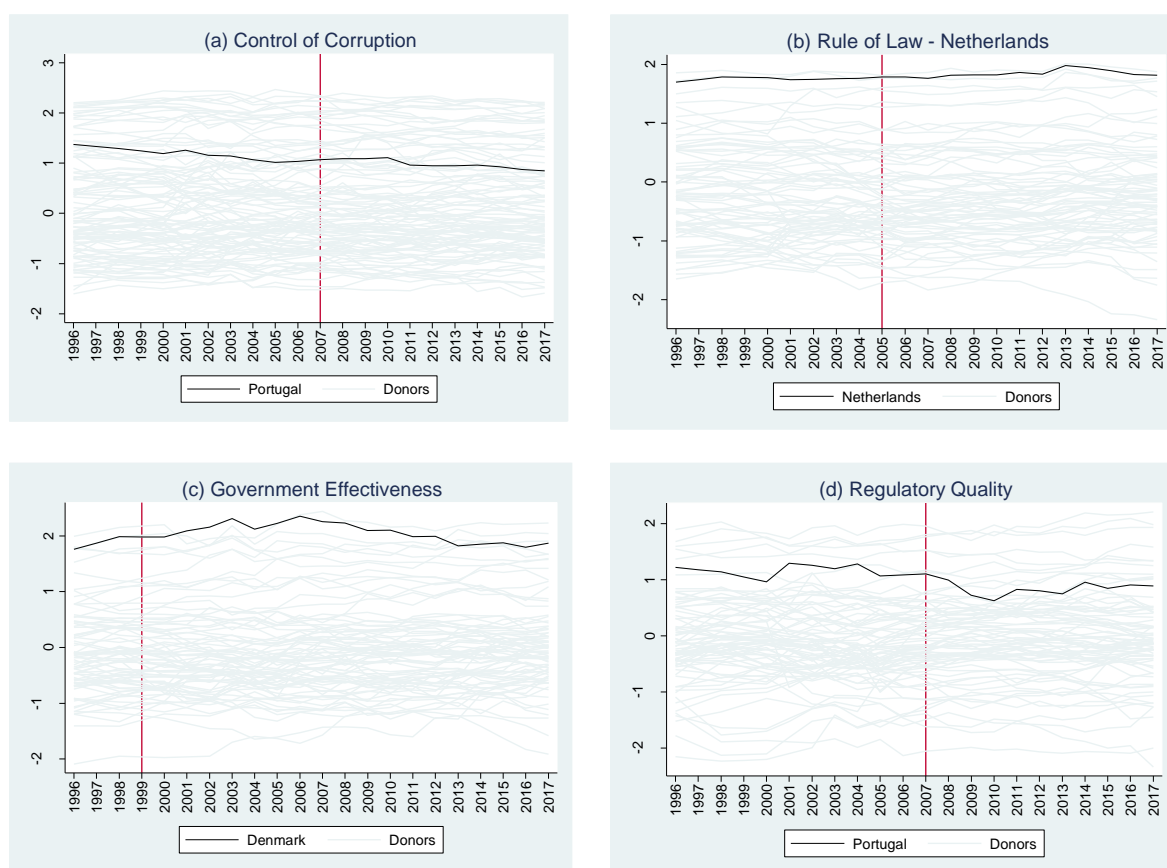
Notes: the figure presents institutional quality trends in early e-procurement adopters and the full set of countries in the control sample.

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Appendix 3: Difference-in-differences model setup

C.1. The setup

Our identification strategy is to estimate the impact of e-procurement on the range of institutional quality outcomes affected by procurement reforms such as the level of corruption, strength of the rule of law, government effectiveness and regulatory quality. To this end, we exploit the timing of e-procurement take-up to consistently estimate the effects of procurement policy change on the set of institutional quality response variables. More specifically, our basic fixed-effects difference-in-difference (DD) relationship that takes place is as follows:

$$y_{c,t} = \hat{\alpha}_0 + \hat{\beta}_1 \cdot \left(\text{E-Procurement} \right)_{\tau_0 + t} + \mathbf{X}'_{c,t} \hat{\lambda} + \eta_c + \theta_t + u_{c,t} \tag{1}$$

where y denotes the respective institutional quality outcome for country c at time t. Our key coefficient of interest is $\hat{\beta}_1$ which captures the contribution of procurement reform in the post-reform period $\tau_0 + t$. The vector **X** denotes the set of economic and institutional covariates that prevent the key DD coefficient $\hat{\beta}_1$ to be contaminated by omitted variable bias. The term η_c captures the country-level heterogeneity unobserved to the econometrician, whereas θ denotes the set of time-varying institutional technology shocks common to all countries. Note that the stochastic disturbances are denoted by u, and capture the systematic innovations under i.i.d assumption with zero mean and constant error variance. Each DD specification is estimated for each country separately rather than in a unique model.

Note that the DD estimated e-procurement parameter can be undermined if the e-procurement policy impact is confounded by a pre-existing non-stationary trend in institutional quality. More specifically, if e-procurement reforms are introduced in the presence of non-zero upward or downward institutional quality trend, the parameter $\hat{\beta}_1$ can be undermined by the perceptible pre-reform changes in the outcome variables. In addition, the strict exogeneity assumption might possibly be violated since the lagged levels of institutional and economic outcomes are likely to be correlated with the stochastic disturbances. To account for these endogeneity concerns, we follow Besley and Burgess (2004) and adjust our core DD model specification by introducing the lagged dependent variable as a separate covariate, and estimate Arellano and Bond (1991) panel-level model specification of the following form:

$$y_{c,t} = \hat{\alpha}_0 + \hat{\alpha}_1 \cdot y_{c,t-1} + \hat{\beta}_1 \cdot \left(\text{E-Procurement} \right)_{\tau_0 + t} + \mathbf{X}'_{c,t} \hat{\lambda} + \eta_c + \theta_t + u_{c,t} \tag{2}$$

A valid inference on $\hat{\beta}_1$ may be a concern since the residuals are most likely correlated within countries if i.i.d assumption is violated. The failure to control for cluster-specific correlation of the residuals can lead to massively underestimated standard error and the subsequent over-rejection of the null

hypothesis on $\hat{\beta}_1$ (Moulton 1986, 1990). Bertrand et. al. (2004) show that intra-cluster serially correlated residuals can persist in two-dimensional panel data, and do not disappear once the country-specific unobserved effects and time-fixed effects are controlled for (Davis 2002, Pepper 2002). We address the potential intra-cluster residual correlation by using a non-nested multiway clustering scheme proposed by Cameron et. al. (2011) based on cluster-specific error component model under the i.i.d. assumption.

B.2 Parallel trend assumption

The central question pervading the empirical analysis of the e-procurement impact on institutional quality concerns the existence of parallel trends between the early-adopters and the rest of the world prior to the policy implementation. Our main outcomes of interest comprise the set of institutional quality variables in a difference-in-differences and synthetic control framework. The first difference compares the outcomes across early-adopting countries and the rest of the world. As this difference is likely to be contaminated by several other macroeconomic and institutional changes, we use the remaining 105 countries as a control sample because they would have been exposed to the other changes that took place in early-adopting countries but did not launch e-procurement on a similar scale. In Table A2, we test the parallel trend assumption by comparing the institutional quality outcomes between the early adopters and non-adopters in the years prior to the implementation of e-procurement and find mixed evidence. In some cases, we do not reject the null hypothesis of parallel trends, while we reject it in others, providing a further rationale on the combined use of difference-in-differences and synthetic control setup to evaluate the impact of e-procurement on institutional quality. As a first glimpse of graphical evidence, Figure 2 plots the institutional quality trends for the selected institutional quality variables in the early-adopting countries and compares them with the trends in the donor countries. It becomes apparent that the institutional quality trends in all affected countries are within the highest-observed and lowest-observed institutional quality range, confirming that parallel trends are perceptible, and that separate control groups may be constructed for each treated country.

Table A2: Testing Parallel Trend Assumption

	Denmark		Netherlands		Portugal	
	Full Sample	OECD	Full Sample	OECD	Full Sample	OECD
Panel A: Dependent Variable: Control of Corruption Index						
	(1)	(2)	(3)	(4)	(5)	(6)
Year	-.0002	.004	-.0001	-.005*	-.0001	-.005
	(.002)	(.002)	(.002)	(.003)	(.002)	(.002)
Country-Level Treatment	2.084***	1.480	1.875***	.825***	.945***	-.11
Indicator	(.101)	(.089)	(.101)	(.132)	(.101)	(.135)
Country-Level Treatment	**.041**	**-.048***	**-.051****	**.008**	**-.209****	**-.152**
Indicator × Year	**(.025)**	**(.027)**	**(.025)**	**(.033)**	**(.025)**	**(.032)**
Constant Term	.721	-7.823	.619	12.581**	.433	12.015**
	(4.634)	(5.045)	(4.637)	(6.013)	(4.623)	(5.951)
R2	0.03	0.02	0.02	0.03	0.01	0.01
Panel B: Dependent Variable: Rule of Law Index						
Year	.002	.001	.002	.001	.002	.001
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
Country-Level Treatment	1.669***	.627***	1.557***	.514***	.988***	-.063
Indicator	(.097)	(.103)	(.096)	(.103)	(.097)	(.104)
Country-Level Treatment	**.005****	**.066****	**.061****	**.072****	**-.128****	**-.119****
Indicator × Year	**(.024)**	**(.030)**	**(.024)**	**(.030)**	**(.024)**	**(.030)**
Constant Term	-4.755	-1.681	-4.734	-1.611	-4.961	-2.302
	(4.544)	(5.490)	(4.548)	(5.499)	(5.542)	(5.469)
R2	0.02	0.03	0.02	0.02	0.01	0.01
Panel C: Dependent Variable: Government Effectiveness						
Year	.004*	-.002	.004	-.001	.004*	-.002
	(.002)	(.003)	(.002)	(.003)	(.002)	(.003)
Country-Level Treatment	1.659***	.642***	1.735***	.727***	.791***	-.219**
Indicator	(.094)	(.104)	(.093)	(.102)	(.092)	(.100)
Country-Level Treatment	**.075****	**.148****	**-.284****	**-.215****	**-.012**	**.059**
Indicator × Year	**(.025)**	**(.038)**	**(.025)**	**(.038)**	**(.025)**	**(.038)**
Constant Term	-7.896*	6.359***	-8.320*	5.120	-7.979	6.155
	(4.647)	(.038)	(4.637)	(7.062)	(4.650)	(7.088)
R2	0.03	0.04	0.02	0.03	0.01	0.01
Panel D: Dependent Variable: Regulatory Quality						
Year	.004	.003	.004	.003	.004*	.004
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
Country-Level Treatment	1.480***	.552***	1.568***	.643***	.823***	-.115
Indicator	(.089)	(.072)	(.088)	(.071)	(.088)	(.073)
Country-Level Treatment	**-.048***	**-.044**	**-.096****	**-.093****	**-.372****	**-.372****
Indicator × Year	**(.027)**	**(.029)**	**(.027)**	**(.029)**	**(.027)**	**(.028)**
Constant Term	-7.823	-6.110	-7.894	-6.321	-8.224*	-7.326
	(5.045)	(5.323)	(5.052)	(5.350)	(5.030)	(5.156)
R2	0.02	0.03	0.02	0.04	0.01	0.01
# Observations	2,376	792	2,376	792	2,376	792
# Countries	108	36	108	36	108	36

Notes: the analysis uses the Worldwide Governance Indicators data on control of corruption, rule of law, government effectiveness and regulatory quality at the country level by year. Each observation corresponds to the standardized latent factor score by country and year. The data includes 108 countries. Standard errors are clustered by country to remove arbitrary heteroskedastic distribution of random error variance and serially correlated stochastic disturbances, and denoted in the parentheses.

Table A3 reports the baseline difference-in-differences estimated impact of e-procurement adoption on the institutional quality of early-adopting countries. Each specification contains the flexible set of country-fixed effects and time-fixed effects. The former allows us to partially mitigate the country-level heterogeneity bias unobserved to the econometrician whereas the latter allows us to separate time-varying institutional shocks common to all countries from the treatment effect of e-procurement. Columns (1) and (2) exhibit the impact of e-procurement on the control of corruption. Estimates in column (2) are our preferred specifications for the control of corruption since we can flexibly interpret the estimated impact in the presence of heterogeneity bias and time-varying and country-invariant common institutional shocks related to the control of corruption. Our estimates indicate mixed effects of e-procurement on the control of corruption. The difference-in-difference estimate in Panel A suggests that the shift to e-procurement in Denmark is associated with 0.07 standard deviation increase in the control of corruption. The estimated impact appears to be reasonably large and statistically significant at 1%. By contrast, in Panel B, we find no effect of adopting e-procurement on the control of corruption in the Netherlands. Panel C reports the treatment effect of e-procurement on the control of corruption in Portugal. In a stark contrast to the corruption-reducing effect of e-procurement in Denmark, we find a relatively large negative impact. Pointwise, our estimate suggests that the adoption of e-procurement in Portugal is associated with 0.16 standard deviation drop in the control of corruption index, which appears to be statistically significant at 1%, respectively. The estimated impact of e-procurement does not seem to be driven by the prevailing macroeconomic conditions, physical geographic characteristics, legal origins or the underlying demographic structure. In each control of corruption specification, the adoption of e-procurement explains up to 5 percent of the variation in cross-country institutional quality over time.

Columns (3) and (4) present the impact of e-procurement on the rule of law. Our preferred specifications are indicated in column (4) with the full set of country-fixed effects and time-fixed effects. The evidence unveils an effect similar to the control of corruption impact of e-procurement. Our difference-in-differences impact estimate suggest that the rule of law improved by about 0.1 standard deviation in Denmark and Netherlands, respectively. The estimated DD coefficient is statistically significant at 1% and appears to be robust to the confounding influence of macroeconomic conditions, physical geography, legal history and demographic structure. By contrast, in Panel C, our treatment effect estimates for Portugal uncover a negative impact of e-procurement on the rule of law. In particular, we find that in response to e-procurement, the rule of law tends to decrease by 0.1 standard deviation, and is statistically significant at 1%. The deterioration of the rule of law in Portugal in response to the implementation of e-procurement appears to be reasonably robust to the various covariates set that could potentially confound the treatment effect of interest. In all three respective cases, the adoption of e-procurement may explain up to 8 percent of the cross-country differences in the strength of the rule of law. Our estimates confirm the institutional quality pattern from columns (1) and (2). Namely, the adoption of e-procurement is associated with mixed institutional quality effects. It may either improve the control of corruption and the rule of law, as evident in the cases of Denmark and Netherlands, or deteriorate both the control of corruption and the rule of law as demonstrated by the case of Portugal.

The differential effects of e-procurement implementation on institutional quality are further confirmed in columns (5) and (6), where the impact of e-procurement on government effectiveness is examined in greater detail. Controlling for the unobserved country-level heterogeneity bias and institutional quality shocks common to all countries, the difference-in-differences estimate in Panel A

suggests that the adoption of e-procurement is associated with 0.1 standard deviation improvement in the efficiency of public sector in Denmark. By contrast, we find a notable deterioration of public sector efficiency in response to the e-procurement reform in the Netherlands in Panel B, and no effect in Portugal in Panel C. Since each specification contains the full set of confounding covariates together with time-fixed effects and country-fixed effects, it is unlikely that the estimated impact of e-procurement on public sector efficiency would be driven by factors other than the reform itself.

Furthermore, columns (7) and (8) present the evidence on the impact of e-procurement on the regulatory quality. In contrast to the other institutional quality variables, we do not find any evidence of the positive effect of e-procurement on the quality of regulation regardless of whether unobserved heterogeneity bias is appropriately controlled for and regardless of the number and type of covariates plugged into each specification. By contrast, the difference-in-differences estimates in Panel B and C indicate a negative impact of adopting e-procurement on the quality of regulation in Netherlands and Portugal compared to zero effect in Denmark. The estimated negative impact of e-procurement on the quality of regulation does not disappear with the inclusion of year-fixed effects in column (8), which suggests that common institutional shocks are unlikely to exert a strong confounding influence on the quality of regulation. The negative effect of e-procurement on institutional quality is particularly strong for Portugal (i.e. Panel C), where we find 0.3 standard deviation drop in the quality of regulation in response to e-procurement adoption. According to our estimates, the adoption of e-procurement may explain up to 5 percent of the cross-country variability in the quality of regulation. On balance, our evidence suggests that e-procurement policy generated beneficial institutional quality effects in Denmark and, for the most part, in the Netherlands whereas it triggered the deterioration of institutional quality, especially with respect to the control of corruption and rule of law, in Portugal.

Table A3: Difference-in-differences (DD) estimate of the impact of e-procurement on institutional quality

	Control of Corruption		Rule of Law		Government Effectiveness		Regulatory Quality	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects
Panel A: Treated Country: Denmark								
E-Procurement Post-Adoption Indicator	.049**	.069***	.072***	.105***	.092***	.106***	-.020	-.020
	(.018)	(.026)	(.019)	(.024)	(.019)	(.027)	(.021)	(.029)
Partial R2	0.038	0.047	0.06	0.08	0.03	0.04	0.05	0.05
Panel B: Treated Country: Netherlands								
E-Procurement Post-Adoption Indicator	-.039*	-.012	.071***	.104***	-.268***	-.254***	-.068***	-.071***
	(.020)	(.067)	(.021)	(.024)	(.021)	(.027)	(.021)	(.027)
Partial R2	0.038	0.047	0.06	0.08	0.03	0.04	0.05	0.05
Panel C: Treated Country: Portugal								
E-Procurement Post-Adoption Indicator	-.176***	-.165***	-.108***	-.101***	-.004	-.001	-.340***	-.347***
	(.030)	(.030)	(.027)	(.026)	(.040)	(.038)	(.037)	(.035)
Partial R2	0.04	0.049	0.06	0.08	0.03	0.04	0.06	0.05
Macroeconomic Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Legal History Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Demographic Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
# Observations	2,376	2,376	2,376	2,376	2,376	2,376	2,376	2,376
# Countries	108	108	108	108	108	108	108	108
#Years	22	22	22	22	22	22	22	22

Notes: the table presents the effect of e-procurement adoption on the range of institutional quality outcomes. Standard errors are adjusted for serially correlated stochastic disturbances and arbitrary heteroskedastic distribution of error variance using finite-sample adjustment of the empirical distribution function with Cameron-Gelbach-Miller two-way error component model to construct multi-way clustered standard errors. Country-year clustered standard errors are denoted in the parentheses. Asterisks denote statistically significant coefficients at 10% (*), 5% (**), and 1 % (***), respectively.

A.3   Dynamic difference-in-differences estimates

The evidence so far portrays mixed and generally inconclusive effect of e-procurement implementation on institutional quality. More specifically, the e-procurement may generate large institutional quality gains in terms of improved control of corruption or strengthened rule of law as a result of reduced human discretion in public procurement. On the other hand, e-procurement may also legitimize pre-existing corrupt practices, which can possibly undermine the rule of law, further deteriorate the control over corruption and may backlash public sector efficiency as well as the quality of the regulatory framework. One potential drawback of the difference-in-differences estimates in Table A.2 is the neglect of dynamic aspect of institutional quality. The institutional gains attributed to the e-procurement may simply be explained by a high level of each dimension of institutional quality prior to the reform in Denmark and the Netherlands and the corresponding lower level of quality in Portugal. The second concern arises from the potential endogeneity of the e-procurement reform since the timing of the reform can be anticipated in response to the deteriorating economic conditions, which may bring the validity of difference-in-differences estimates into question.

To mitigate these concerns, we expand our baseline difference-in-differences specification with two lags of the dependent institutional quality variable and focus on the dynamic effects of e-procurement reform. Controlling for pre-reform levels of each institutional quality variable allows us to partially address the endogeneity issue and aggregate uncertainty arising from the neglect of dynamic aspect of institutional quality. One additional advantage of the dynamic difference-in-differences specification is that it allows us to distinguish between short-run effect and long-run effect of the e-procurement implementation.

Table A4 reports the dynamic difference-in-differences institutional quality estimates. Columns (1) through (3) exhibit the estimated impact of e-procurement on the control of corruption. By taking into account the pre-reform levels of corruption, proxied by two lags of the control of corruption variable, we find that the e-procurement reform in the Netherlands has a positive impact on the control of corruption and tends to strengthen it by 0.01 standard deviation in the post-adoption period. By contrast, the adoption of e-procurement tends to have a negative effect on the ability to control corruption in Denmark and Portugal. In both cases, the estimated coefficient implies that the control of corruption deteriorates by 0.02 standard deviation points in the post-reform period. In Denmark, the effect of the reform can be explained by a departure from exceptionally high levels of control of corruption in the initial years to the lower levels afterwards. In the case of Portugal, the control of corruption has lagged behind other OECD countries in the years preceding the reform, implying that a decline of high level of control of corruption prior to the reform, unlike Denmark, cannot be attributed to the post-treatment effect of e-procurement.

We find similar evidence in columns (4) through (6) where the impact of e-procurement on the strength of rule of law is examined. Taking into account the possible state dependence in the persistence of institutional quality in the pre-reform years, the evidence suggests that the rule of law improved by about one half of one standard deviation point in the Netherlands, whereas it drops by 0.1 standard deviation points in Denmark in response to the reform and does not change significantly in Portugal. Based on our dynamic specification, we estimate the long-run impact of e-procurement on the rule of law at about -0.1 standard deviation point in Denmark and 0.05 standard deviation points in the Netherlands. Columns (7) through (9) revisit the impact of e-procurement on public sector efficiency. We find negative effect and significant effect of the e-procurement reform in Denmark and Netherlands and slightly positive impact in Portugal. Columns (10) through (12) confirm the negative

effect of the e-procurement reform in Portugal on the quality of regulation alongside the positive effect of e-procurement reform in the Netherlands. In each specification, we use simple non-linear Wald restrictions to compute long-run institutional quality effects of the reform and find that the magnitude of the negative impact of the reform is higher than the magnitude of the positive impact of the reform. Hence, our evidence casts doubt on whether e-procurement is both a necessary and sufficient condition to improve the institutional quality.

Table A4: Dynamic difference-in-differences (DD) estimate of the impact of e-procurement on institutional quality

	Control of Corruption (m = 2)			Rule of Law (m = 2)			Government Effectiveness (m = 2)			Regulatory Quality (m = 2)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Denmark	Netherlands	Portugal	Denmark	Netherlands	Portugal	Denmark	Netherlands	Portugal	Denmark	Netherlands	Portugal
E-Procurement Post-Adoption Indicator	-.028***	.017***	-.028***	-.012***	.007*	.002	-.055***	-.045***	.016***	-.002	.037***	-.049***
	(.005)	(.004)	(.005)	(.004)	(.004)	(.005)	(.005)	(.007)	(.005)	(.005)	(.006)	(.009)
Long-Run Effect	-.165***	.100***	-.167***	-.085**	.050*	.019	-.334***	-.277***	.098***	-.017	.228***	-.300***
	(.048)	(.032)	(.029)	(.035)	(.028)	(.036)	(.056)	(.032)	(.035)	(.032)	(.062)	(.033)
Outcome Persistence (p-value)	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
# Countries	108	108	108	108	108	108	108	108	108	108	108	108
Wald Test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Notes: the table presents the dynamic effect of e-procurement adoption on the range of institutional quality outcomes using Arellano-Bond dynamic panel estimator . Standard errors are adjusted for serially correlated stochastic disturbances and arbitrary heteroskedastic distribution of error variance using finite-sample adjustment of the empirical distribution function one-way error component model to construct single-way clustered standard errors. Robust Huber-White standard errors are denoted in the parentheses. Asterisks denote statistically significant coefficients at 10% (*), 5% (**), and 1 % (***), respectively.

**Appendix 4**: Treatment Sensitivity Analysis of E-Procurement Impacts

Lastly, we impose additional restrictions the composition of the synthetic control groups to further isolate the treatment effect of e-procurement on institutional quality. The key caveat is that the composition of synthetic control groups for each country affected by e-procurement implementation should consist only of those countries that do not rely significantly on the e-procurement in pre- and post-implementation period time span. In an ideal setup, we would be able to match early adopters' institutional quality model prior to the e-procurement take-up with the control sample of countries that do not rely on electronic payments and interactions in public procurement. This implies that only countries with the share of e-procurement in GDP near zero threshold would comprise the donor pool to form the corresponding synthetic control groups. Given the data limitations, we were not able to construct a variable measuring the variation in share of e-procurement for our treatment and control samples. As a partial remedy, we exclude the OECD countries with the share of public procurement in GDP above the 75th percentile of the cross-country distribution. Although this is a lenient cutoff, it largely ensures that the countries significantly reliant on public procurement in terms of its GDP share are excluded from the donor pool,[3] which in our view provides a reasonably feasible characterization of institutional quality trends between early adopters and the rest of the world.[4]

Figure A4 plots the synthetic control estimates of e-procurement impact on institutional quality. The evidence based on the restricted donor pool suggests that the underlying effects are consistent with prior estimates. In particular, our findings confirm the deterioration in the control of corruption in Portugal in the post-reform period; a marked improvement in the rule of law in the Netherlands; a temporary positive impact on government effectiveness in Denmark; and a temporary negative impact on the regulatory quality in Portugal. Figure A5 presents the composition of the synthetic control groups on alternative country sets for each affected country. Notice that the pre-reform prediction error is very similar to the original estimates, which confirms that the covariate-level weights pick up countries with very similar pre-reform institutional quality characteristics. The differences in the composition of control groups are noteworthy and significant. Pre-reform trend in the control of corruption in Portugal can be best reproduced as a linear combination of covariate-level characteristics of Norway (31%), Slovenia (28%), Cape Verde (9%), Israel (8%), and a couple of other countries with smaller weight shares. By contrast, the trajectory of the rule of law in the Netherlands prior to the uptake of e-procurement is predicted almost exclusively of a combination of Switzerland (47%), and Austria (36%), and we find that Switzerland and Austria also provide the best characterization of the government effectiveness trajectory of Denmark, albeit in different proportions than in the case of the Netherlands. By contrast, the trajectory of regulatory quality in Portugal prior to the implementation of e-procurement can be best reproduced as a combination of covariate-level characteristics of Chile (24%), Slovenia (23%), Norway (17%), Austria (12%), and a couple of other countries with the control group weight share at less than 10 percent of the total. The estimate of e-procurement on the institutional quality inferred from the restricted synthetic control groups indicates a very strong similarity with the original estimates both in terms of magnitude, direction and institutional nature of e-procurement policy shock.

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[3] This implies that the following countries are excluded from the donor pool: Czech Republic, France, Germany, Sweden, New Zealand, Hungary, Japan, Slovakia and Finland.
[4] Although e-procurement/GDP ratio would be a better cutoff variable, we were not able to find a measure of e-procurement share of GDP beyond rough cross-sectional estimates for a few countries in our sample.

Figure A4: Institutional Quality Impact of E-Procurement – Restricted Donor Sample
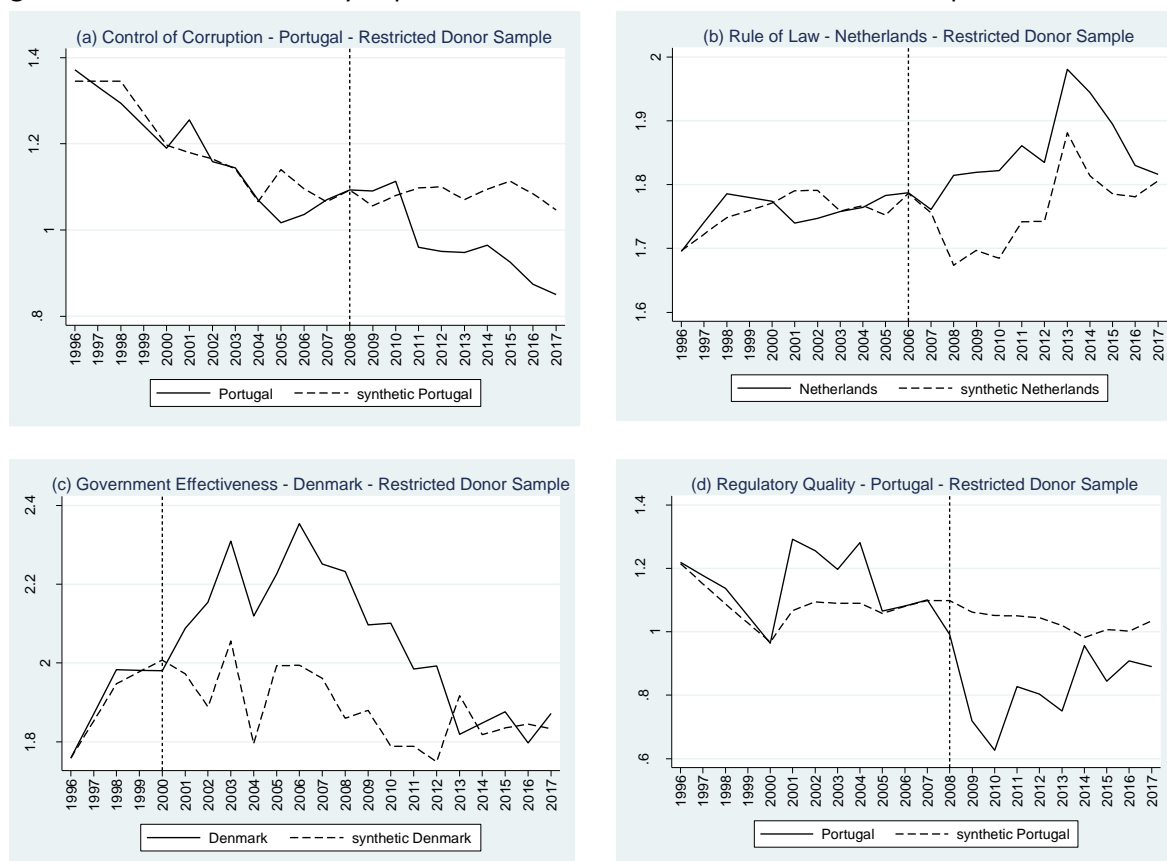
Notes: the figure presents the synthetic control estimated impact of adopting e-procurement on institutional quality using a restricted donor sample that excludes countries with high share of e-procurement in the GDP

Figure A5: Restricted Synthetic Control Groups

(a) Control of Corruption - Portugal - Restricted Donor Sample

RMSPE = 0.049

0,05   0,04   0,03
0,07
0,07   0,31
0,08
       0,09   0,28

- Norway   - Slovenia   - Cape Verde
- Israel   - Greece   - Mongolia
- United States   - Trinidad and Tobago   - Cyprus

(b) Rule of Law - Netherlands - Restricted Donor Sample

RMSPE = 0.027

0,04   0,03 0,03 0,02
   0,05
                          0,47
         0,36

- Switzerland - Austria - Qatar - Iceland - Estonia - Singapore - Belgium

(c) Government Effectiveness - Denmark - Restricted Donor Sample

RMSPE = 0.019

         0,05
0,37
              0,59

- Switzerland   - Austria   - Singapore

(d) Regulatory Quality - Portugal - Restricted Donor Sample

RMSPE = 0.102

       0,03   0,02   0,02
    0,05
0,05
0,08   0,24
   0,12
        0,17   0,23

- Chile   - Slovenia   - Norway   - Austria   - Cyprus
- Italy   - Turkmenistan - Lithuania   - Kuwait   - Spain

Notes: the figure presents the composition of synthetic control groups for the early-adopting countries per institutional quality outcome variable using a restricted donor pool without countries with high share of e-procurement in GDP.

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