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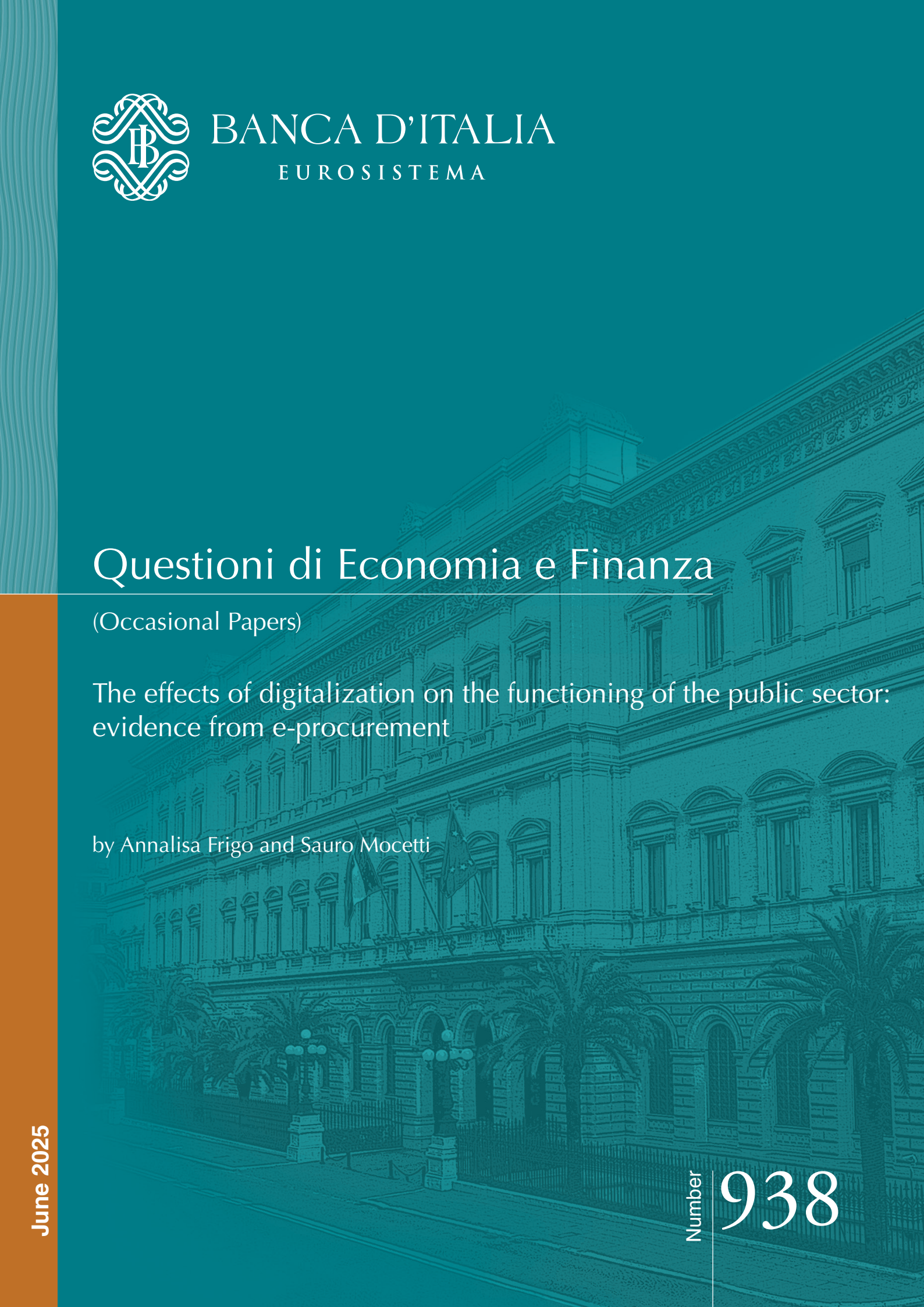

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THE EFFECTS OF DIGITALIZATION ON THE FUNCTIONING OF THE PUBLIC SECTOR: EVIDENCE FROM E-PROCUREMENT

by Annalisa Frigo* and Sauro Mocetti*

Abstract

The paper examines the effects of the introduction of e-procurement on the functioning of the public procurement system, with reference to procedures with a higher administrative content. Using a difference-in-difference approach, the paper compares the procurement outcomes of local authorities that had to introduce e-procurement at the beginning of 2024 with those of entities that were already using such digital tools. The results show that e-procurement has increased the transparency and speed of administrative proceedings: the availability of information on awards increased by between 4 and 8 percentage points, depending on the measure of treatment intensity used; the length of the awarding phase also decreased significantly. The positive effects were most pronounced for competitive tenders, in local authorities that used to be more opaque and in those with more qualified human resources, suggesting the existence of complementarities between human capital and digitalization in the public sector.

JEL Classification: D73, H57, H83.

Keywords: digitalization, public administration, e-procurement, transparency, length of the award procedures, human capital.

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1. Introduction

Digitalization is revolutionizing society, the economy, and the functioning of public administration alike. The impact on the latter can be significant: administrative activity can become more open, transparent, and accessible, improving interaction with citizens and businesses; internal workflows can be streamlined, enhancing speed and efficiency. However, the magnitude of these improvements crucially depends on how widely and effectively digital tools are adopted, effectively integrated into administrative processes, and leveraged to eliminate redundant procedures (Kim et al., 2022).

Among the areas most affected by digital transformation is public procurement, which accounts for a large share of public expenditure and is traditionally prone to inefficiencies and information asymmetries. In this context, e-procurement systems – the digital management of the entire procurement life cycle, from planning and tender publication to contract execution – have become central to reform strategies in many countries. Far from being a mere digitalization of existing procedures, e-procurement aims to re-engineer procurement processes through certified digital platforms, fostering transparency, competitiveness, and administrative efficiency.

This paper provides a quantitative assessment of the impact of the introduction of e-procurement on two fundamental dimensions of procurement performance: transparency and efficiency. Transparency is measured by the availability of information on contract awards, which was often missing prior to the adoption of e-procurement. Efficiency is proxied by the time elapsed between the publication of the contract notice and the final award date. These two dimensions are closely interrelated and, to some extent, overlapping, making a joint reading of the two phenomena essential for a comprehensive understanding of the impact of e-procurement.

To address this research question, we exploit a reform that mandated the use of e-procurement for all contracting authorities in Italy starting from January 2024 as a natural experiment and apply a Difference-in-Differences identification strategy[1]. We compare procurement outcomes before and after the reform across two groups of contracting authorities: those that had already adopted e-procurement widely before the reform (control group) and those that introduced it only after the legal obligation came into effect (treated group). Our analysis draws on a rich and unique dataset combining administrative data from the Italian National Anti-Corruption Authority (ANAC) with survey-based information from the Bank of Italy on the pre-reform use of e-procurement by local authorities (IDAL). To ensure comparability over time and across authorities, we restrict the analysis to tenders with estimated values between EUR 40,000 and EUR 500,000.

[1] The mandatory use of e-procurement follows the Public Procurement Code (Legislative Decree 36/2023) and it is aligned with the European Commission's guidelines (2012), aimed to modernize the procurement system, making it more transparent, efficient, and competitive. See Bobowski and Gola (2019) for an overview of the evolution of e-procurement in the European Union and open issues.

Our findings show that e-procurement has increased transparency and reduced the length of procedures between the call and the award of the tender. Specifically, the availability of information on awards increased significantly and the increase was higher for local authorities that introduced e-procurement because of the reform. The effect ranges from 4 to 8 percentage points, depending on the measure of the intensity of the treatment, compared with an average of 51 per cent in the year before the reform. This result reflects both an increase in the reporting of such information within the system, for a given number of awards, and an actual rise in the number of awards themselves, driven by more streamlined and timely procedures. The share of notices awarded within a short timeframe– less than 20 days for calls for tenders between 40,000 and 150,000 Euros, 40 days for those between 150,000 and 350,000 and 60 days for those between 350,000 and 500,000 – increased by 3 to 5 percentage points in treated authorities relative to controls. Using a continuous measure of the length of the awarding phase and accounting for selection issues (i.e. the fact that the length is observed only for the awards noticed), we find that e-procurement has reduced the length from 12 to 18 per cent (compared with an average for the year prior to the reform of 40 days). Beyond transparency and efficiency, we also document a modest but statistically significant increase in competition, with the number of bids admitted rising by 3 to 4 percent – albeit within a segment of the market that remains generally characterized by low openness.

The effect of e-procurement on the transparency and timeliness of administrative processes varied across different dimensions. As regards the way in which the contractor is selected, the impact was concentrated in direct awards and, above all, in competitive tenders where the effects were also significant from a quantitative point of view. Concerning the characteristics of local authorities, the effects were more pronounced among local authorities that before the reform were characterised by greater opacity in feeding information on the awards into the system. Moreover, the impact was stronger for local authorities with more qualified and adequate administrative staff, suggesting that human capital of bureaucrats is complementary to digitalization and that it plays a crucial role in unlocking its full potential.

Our paper contributes to the growing literature on digitalization in the public procurement. However, the existing studies are essentially descriptive (Fazekas and Blum, 2021), with very few providing causal estimates of the impact of digital tools. An exception is Lewis-Faupel et al. (2016), who show that e-procurement increased competition and quality in public works projects in India and Indonesia by improving access to information and reducing opportunities for corrupt interactions. The existence of these channels has been also documented in Coviello and Mariniello (2014) – which show how greater publicity of calls could lead to more competition in the award procedures[2] – and Mélon and Spruk (2020) – which show a positive effect of e-

[2] On the relationship between transparency and corruption see also Bauhr et al. (2020) and Duguay et al. (2023). For a review of ICT tools' (e.g., digital public services, crowdsourcing platforms, whistleblowing tools, transparency portals, distributed ledger technology, and artificial intelligence) impact on corruption see Adam and Fazekas (2021).

procurement in terms of control of corruption in an analysis of some European countries[3]. More broadly, this paper contributes to the literature on the role of technology in strengthening state capacity. Recent studies have examined how digitalization improves transparency, reduces leakages, and enhances compliance across various government functions, from procurement (Lewis-Faupel et al., 2016; Deininger et al., 2023) to tax collection (Bellon et al., 2022; Okunogbe and Pouliquen, 2022), social programs (Muralidharan et al., 2016; Banerjee et al., 2020), and public sector personnel management (Dal Bó et al., 2021).

We contribute to the existing literature along several dimensions. First, we provide one of the first empirical assessments of digitalization in the public procurement in a developed country, focusing specifically on the award phase – a stage rich in administrative content and critical to procurement outcomes. Second, we leverage high-frequency, contract-level data combined with detailed information on individual contracting authorities to support a more granular and precise identification strategy. Third, we explore heterogeneous effects along different dimensions, also exploiting idiosyncratic characteristics of individual contracting authorities, which we can observe in very detail. They include direct and objective measures of the administrative opacity and the quality of human resources within local governments, a factor that, according to recent studies (Decarolis et al., 2020; Baltrunaite et al., 2021; Bosio et al., 2022; and Best et al., 2023), crucially shape procurement performance. This allows us to show novel evidence on the complementarity between human capital of bureaucrats and digital tools in the public sector [4].

The rest of the paper is organised as follows: Section 2 presents the data, the variables used and some descriptive evidence; Section 3 discusses the empirical strategy; Section 4 shows the main results, including robustness and heterogeneity analyses; Section 5 concludes.

[3] Although it is not specifically related to e-procurement, an influential paper for understanding the functioning of the procurement system in Italy is Bandiera et al. (2009), which distinguishes between active (corruption) and passive (inefficient bureaucracy) waste in award procedures.

[4] In the private sector, an influential paper examining the complementarities between the adoption of information and communication technologies, the workplace organization and the skills of workers is Bresnahan et al. (2002). See also Brynjolfsson and Milgrom (2013).

2. Data and variables

The dataset used for the analysis is based on the merge between ANAC data, which contains information on the universe of public tenders, and IDAL, a survey conducted by the Bank of Italy on local administrations and containing information at the level of the contracting authorities on the use of e-procurement before the reform.

From ANAC data, we extracted information on the universe of tenders launched between December 2021 and December 2024[5]. For each published call, we observe the tender identification code (CIG), which uniquely identifies each contract, the subject matter of the contract (i.e., works, services or supplies) and a more disaggregated classification of the contract with the CPV code (common procurement vocabulary), the awarded amount, the date of publication of the contract, the award method (distinguishing between direct awards, negotiated procedures and competitive tenders) and – if available – the date of award. For each CIG, we also observe the unique code of the contracting authority that is used to link ANAC and IDAL data.

As the time window after the reform is, for obvious reasons, still limited, in the rest of the analysis we only considered contracts with a call amount of between 40,000 and 500,000 Euros. The lower limit was introduced to ensure comparability of data over the entire time window, as prior to 2024 the obligation to report information on calls to ANAC existed only for those above the threshold of 40,000. The upper limit was introduced to consider only calls for which it is reasonable to assume that the completion of the awarding phase (and therefore its duration) is observed; indeed, the length of the awards increases with the amount of the call for tenders because of idiosyncratic factors such as, for example, the greater complexity of the assessment of the technical offer[6].

The IDAL survey was carried out between July and October 2023 to gather detailed information on the degree of digitalisation of local governments[7]. As far as the degree of digitalization of procurement procedures is concerned, we use several questions to reconstruct, for each local authority, the share of purchases made using e-procurement tools.

This continuous variable has been discretised to distinguish between control and treated local governments. Specifically, we partition the contracting authorities in two different ways, depending on the different intensity of the use of e-procurement before the treatment. In the first case, the contracting authorities were divided into two groups,

[5] Instead, the latest data update data, useful for the award observation, is March 2025, i.e. 90 days after the last published call.

[6] See Baltrunaite et al. (2024) for a broader discussion on the length of the different phases for calls of different amounts and the measurement issues when the observation date is close to the date of publication.

[7] IDAL is an evolution of a previous survey already conducted by the Bank of Italy on the digitalization of local governments. Compared with previous survey rounds, both the number of entities surveyed and the areas on which information was collected have been increased. In particular, the section aimed at identifying the availability of e-procurement systems has been deepened. For more information on the survey, see Ciapanna et al. (2025).

those that used e-procurement, before the reform, for less than half of the purchases (treated) and those that were already using it for most purchases (controls). The treated units according to this definition are identified with the variable $Treated^M$. In the second case, we use a stricter definition distinguishing between contracting authorities that were not using, if not to a residual extent (less than a quarter of purchases), e-procurement and those that already used it to a significant extent (for more than three quarters of purchases). In this second case, the treated are identified with the variable $Treated^H$ and all entities that used e-procurement between 25 and 75 per cent of their purchases were excluded from the analysis. In the remainder of the analysis, we use both variables, as each has its own advantages and limitations. The second variable, indeed, provides a clearer distinction between treated and control units, but at the cost of excluding a portion of the observations from the analysis.

By merging the two data sources using the unique identification code of each local authority, we were able to reconstruct a sample of 1,815 contracting authorities for which information is available on both the level of digitalization of the procurement process and the conduct of nearly 120,000 public tenders.

Among the contracting authorities, the number of treated and control local authorities was respectively 684 and 1,131 using the first definition and 385 and 868 with the second definition (Table 1). In both definitions, the use of e-procurement was above 90 per cent for the control group and much lower for the treated group (less than 21 and 6 per cent respectively).

Table 1. Use of e-procurement in local authorities prior to the reform

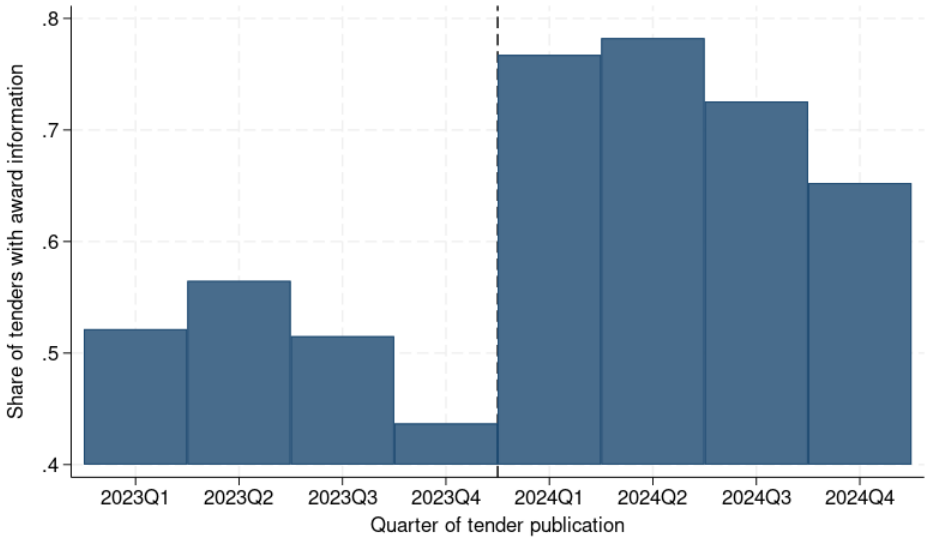
	Number of local authorities	Average (standard deviation) use of e-procurement
Various definitions of treated:		
E-Procurement < 25 per cent	385	0.057 (0.080)
E-Procurement < 50 per cent	684	0.207 (0.200)
Various definitions of controls:		
E-procurement > 50 per cent	1,131	0.914 (0.126)
E-procurement > 75 per cent	868	0.952 (0.073)

The table shows several groups of local authorities, classified according to the intensity of use of e-procurement prior to treatment. For each group, we show the number of local authorities that belong to it and the average (and standard deviation) of the share of purchases made with e-procurement in the year before treatment.
Source: authors' calculations based on IDAL data.

Some simple descriptive evidence shows that, following the introduction of e-procurement, the probability of observing awards for tenders increases significantly (we refer to this variable throughout the paper as $Trasparency$): in 2024, it stands at 72 per cent, compared with 51 per cent a year earlier (Figure 1). The break is even greater when comparing the last quarter of 2023 with the first quarter of 2024. In the most recent quarters, instead, the probability of seeing a contract awarded decreases although it

remains higher than before the reform, because it is typically lower for the most recent calls for tender.

Figure 1. Probability of observing the award



Source: authors' calculations based on ANAC data.

The significant increase in the probability of observing award information for published tenders can reasonably be attributed to the greater transparency introduced by the e-procurement system, and specifically to the obligation for individual contracting authorities to upload this information into the system. However, part of this increase may also stem from another effect of e-procurement: insofar as it is associated with faster administrative processes, it effectively raises the number of procedures that reach the award stage and can therefore be recorded as such in the information system.

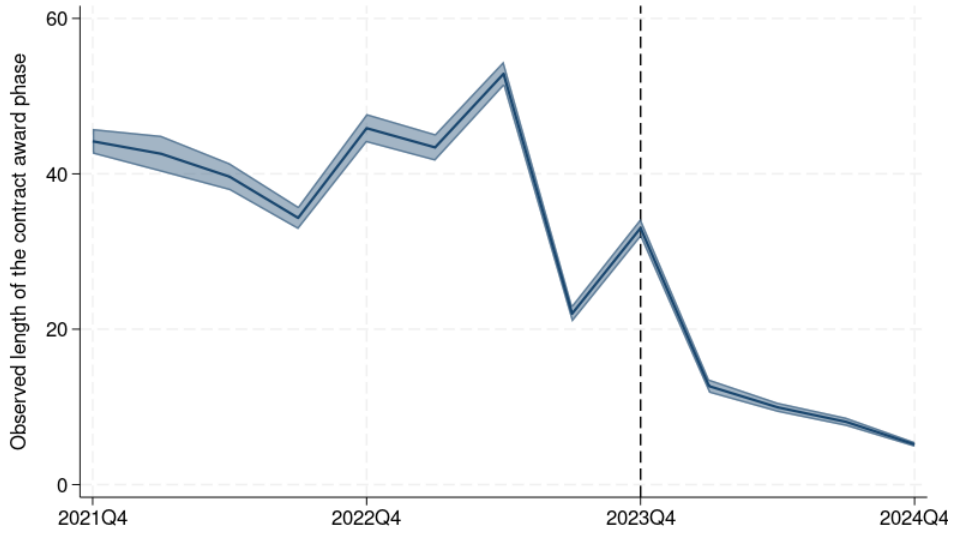
The possible existence of this second channel, indistinguitable from the former, is confirmed by the trend in the average duration of the awarding procedures, which progressively decreased in the same period (Figure 2).

This dynamic, in addition to the effect of e-procurement, may also reflect the impact of recent reforms as well as potential data selection issues. Regarding the reforms, there has been a progressive expansion of the scope for contracting authorities to resort to direct awards, which by design have shorter award times compared to other procedures[8]. For this reason, in the empirical analysis it is crucial to account for the evolving use of such award methods, to ensure that observed changes in duration are net of this composition effect. As for selection issues, duration can only be measured for tenders for which the award date is available; for more recent tenders, this information is only available for

[8] The Public Procurement Code (Legislative Decree 36/2023) confirmed some measures to speed up the procedures introduced from 2019 onwards (DD.LL. 32/2019, 76/2020 and 77/2021) such as raising the thresholds for using direct awards.

those that were completed more quickly, leading to a significant underestimation of the actual average duration.

Figure 2. Observed average duration of the award procedures



Source: authors' calculations based on ANAC data.

To address these issues, it is necessary to discuss the information content of each variable and – limited to measuring the length of award procedures – use other indicators that are less affected by the aforementioned distortions. More generally, and as already partially noted, the probability of observing an award and the duration of the award process are two closely related variables and it is neither possible nor correctly read them separately.

For example, considering the 2023 tenders in our sample, award information was available in just over half of the cases. The lack of this figure is sometimes due to award procedures still being ongoing (i.e., excessively long duration) and, in other cases, to the failure of the contracting authority to report the information, even though the award has already taken place. In this second case, the tender was awarded but the information in the system was missing. Therefore, any observed increase in the share of awarded tenders may reflect both a greater speed of the procedures and an improvement in the completeness (and transparency) of the available information.

The interpretation of award times is, in a mirrored way, affected by the same issues related to the availability of award information. By construction, the length of the award phase is observed and measurable only for those calls for which both the publication and award dates are available. The fact that this information is only available for a subset of tenders calls for careful consideration of both the interpretation of the variable and the potential estimation biases in the empirical analysis. In some cases, the non-observability may depend on the fact that the award procedure has not yet been concluded. If this is the

case, the missing data could be classified as ongoing procedures and thus positioned in the upper tail of the award time distribution. A discrete measure that captures award time in terms of the percentage of tenders awarded within a short timeframe – i.e., one that focuses only on the lower tail of the distribution – would be less affected by such selection issues. In other cases, non-observability may be due to the tender having been awarded, but the relevant information not being recorded [9]. In this case, a possible strategy to recover the missing values is to impute award duration based on the observable characteristics of the tender.

Based on these considerations, we have constructed two duration indicators that capture the likelihood of awarding the contract within a short timeframe, i.e. with less than 20 days for contracts between 40,000 and 150,000 Euros, 40 days for contracts between 150,000 and 350,000 and 60 days for contracts between 350,000 and 500,000. These values (20, 40 and 60) represent, with some approximation, the median of the distribution of durations observed prior to the reform for each size class.

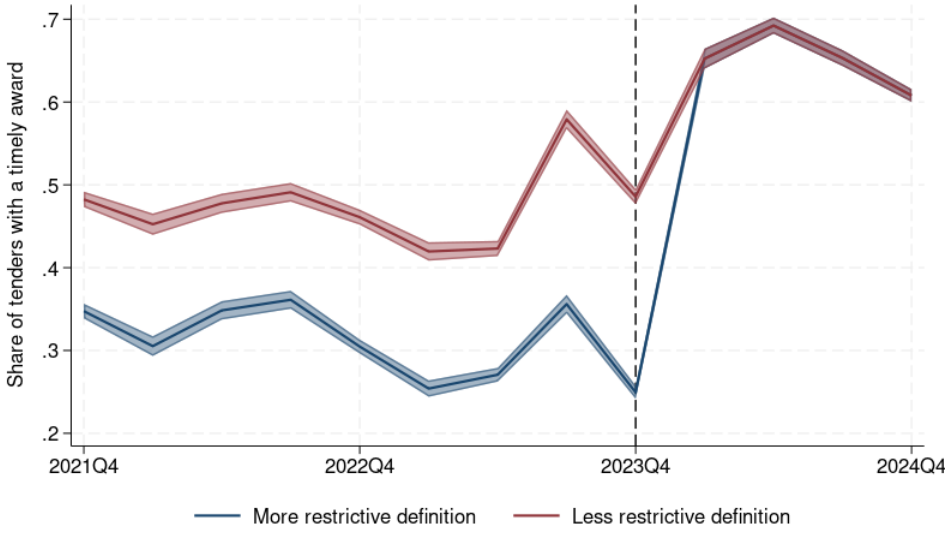
The first indicator (more restrictive) assumes that, for all tenders for which the award is not observed, the award procedure is still ongoing. In practice, this means that all such tenders are assigned a duration longer than the threshold used to define a timely award. The variable defined in this way is referred to throughout the paper as $Lenght^1$. The second indicator (less restrictive) assumes, on the other hand, that for all tenders for which the award is not observed, the award has in fact taken place. In this case, the length of the award phase is estimated by making an out-of-the-sample prediction based on the observable characteristics of the tender and the contracting authority[10]. The variable defined in this way is $Length^2$.

Both indicators, although to different extents, show that the probability of observing a timely award increased in 2024 compared to the previous period, reaching a share of over 64 percent (Figure 3). In the previous year, this share was 28 percent according to the more restrictive definition, and 47 percent according to the less restrictive one. The two indicators address different issues underlying the non-observation of the award date. Ultimately, a comprehensive understanding of the effects of e-procurement requires a joint interpretation of all the variables discussed so far.

[9] This is obviously, theoretically, only possible for the period prior to the introduction of e-procurement, because in the subsequent period reporting is mandatory.

[10] Specifically, the duration of the awarding phase, where observed, was regressed on a broad set of variables including the subject matter, the mode of award and the size class of the tender and the region, the type of administration and the degree of transparency of the local entity. Based on the estimated coefficients, duration was imputed where not observable.

Figure 3. Share of timely awards



In order to be awarded without delay, a call for tenders must be awarded within 20 days for those between EUR 40.000 and EUR 150.000, within 40 days for those between EUR 150.000 and EUR 350.000 and 60 days for those between EUR 350.000 and EUR 500.000. The strictest definition assumes that notices for which the award is not observed have not yet been awarded. The less restrictive definition estimates, on the basis of the observable characteristics of the notice and of the contracting authority, an award date where it is not observed.
Source: authors' calculations based on ANAC data.

Table 2 shows the descriptive statistics of our key variables – $Trasparency$, $Length^1$ and $Length^2$ – before the treatment and separately for the treated and the control group. As expected, there are significant differences in the transparency indicator: contracting authorities that made greater use of e-procurement prior to the reform displayed higher rates of reporting contract awards in the ANAC information system. By contrast, no substantial differences emerge between the various groups of local authorities in terms of the duration of award procedures.

Table 2. Transparency and length of procedures before the treatment

	$Trasparency$	$Length^1$	$Length^2$
Various definitions of treated:			
E-Procurement < 25 per cent	0.445 (0.497)	0.271 (0.445)	0.473 (0.499)
E-Procurement < 50 per cent	0.455 (0.498)	0.275 (0.446)	0.498 (0.500)
Various definitions of controls:			
E-procurement > 50 per cent	0.519 (0.500)	0.278 (0.448)	0.465 (0.499)
E-procurement > 75 per cent	0.524 (0.499)	0.276 (0.447)	0.457 (0.498)

The table shows several groups of local authorities, classified according to the intensity of use of e-procurement prior to treatment. For each group, the table shows the average (and the standard deviation) of the share of awards communicated to ANAC and the share of awards carried out timely, according to the two definitions used.
Source: authors' calculations based on IDAL and ANAC data.

3. Empirical strategy

To quantify the impact of the measure, we employ a Difference-in-Differences (DiD) model, a method commonly used in the literature to evaluate public policies. This technique allows us to estimate the effect of a treatment (the mandatory introduction of e-procurement starting from January 1st, 2024) by comparing changes in the procurement outcomes over time between two groups: those exposed to the treatment (treated) and those not exposed (control), under the assumption that both groups exhibited similar trends prior to the intervention.

In our context, a binary variable distinguishes between local authorities that were already using e-procurement for most of their purchases (the control group) and those that were not using it or only doing so to a minimal extent (the treated group). The reform that made the use of e-procurement mandatory, serves as our treatment variable.

The estimated specification is described by the following equation:

$$y_{imt} = \beta\, Treated_m \times Post + \theta X_{imt} + \delta_m + \rho_t + \varepsilon_{imt}$$

where y_{imt} is the procurement outcome (e.g. probability of observing the award, probability of a timely award, etc.) for the tender procedure i of the contracting authority m launched in the quarter-year t. The specification also includes fixed effects at the level of the contracting authority (δ_m) – to account for time-invariant characteristics that are not directly observable for each contracting authority – and time (ρ_t) – to control for shocks that are common to all contracting authorities. The model also includes a broad set of fixed effects (X_{imt}) that control for the observable characteristics of the individual tender – such as the subject matter of the contract, the award procedure, the tender amount, etc. – and of the local authority – the region and type of government – and are also interacted with time fixed effects, to capture shocks that may affect specific types of tender and/or local entities. The coefficient β captures the average effect of e-procurement on contracting authorities either did not use it or did so only for a minority part of their purchases.

To test the hypothesis of absence of divergent trends prior to the reform between treated and control units and to analyse how the effect of the reform varies over time, we also adopt a specification that allows us to estimate the effect of the treatment for each quarter, having normalized the difference between the treated and the control group to zero in the last quarter of 2023. Formally we estimated the following:

$$y_{imt} = \sum_{t=2022,Q4}^{2023,Q3} \gamma_t\, Treated_m + \sum_{t=2024,Q1}^{2024,Q4} \vartheta_t Treated_m + \theta X_{imt} + \delta_m + \rho_t + \varepsilon_{imt}$$

If the coefficients estimated before the treatment (γ_t) are not significantly different from zero, then it can be concluded that the parallel trend hypothesis is not empirically rejected. The estimated coefficients after treatment (ϑ_t) instead show the dynamics of the effect of the treatment over time.

As a robustness check for the analysis of length of the award phase and to examine further procurement outcomes (such as the number of bidders admitted to the tender) that can only be observed on the sub-sample of calls for which information on the award is available, we also employed a two-stage regression model à la Heckman. This approach explicitly accounts for potential biases arising from sample selection issues[11].

4. Results

4.1 Main findings

Table 3 presents the main results of the transparency analysis. We consider the two definitions of treatment previously discussed, along with model specifications that feature varying (and increasing) levels of fixed effects saturation.

The estimated coefficients are relatively stable and always highly significant from a statistical point of view. According to the most saturated model specification, the probability of observing an award among contracting authorities that introduced e-procurement systems as of January 1st, 2024, increased by more than 4 percentage points relative to the others (compared to an average of 51 percent in the year prior to the reform). Using a sharper distinction between treated and control units – i.e., the alternative definition comparing local authorities more exposed to the introduction of e-procurement with those largely unaffected by the reform – the estimated effect is considerably larger, reaching nearly 8 percentage points.

[11] Specifically, in the first stage (the selection equation), we regress using a Probit model the probability of observing the award on the full set of controls, with the inclusion of a polynomial of the number of days since the publication of the tender. This variable is correlated with the likelihood of observing the award but is reasonably uncorrelated with the procurement outcomes observed in the second stage. Based on the estimation of the selection equation, we compute the inverse Mills ratio, which is then included in the second-stage equation (the main equation). This approach allows us to obtain second stage estimates that are not biased by the sample selection mechanism (Heckman, 1979).

Table 3. E-procurement and probability of observing the award

	I	II	III
Dependent variable:		$Trasparency$	
$Treated^M \times Post$	0.061***	0.069***	0.044***
	(0.015)	(0.013)	(0.010)
# observations	118,821	118,821	118,821
$Treated^H \times Post$	0.079***	0.101***	0.079***
	(0.017)	(0.014)	(0.013)
# observations	99,093	99,093	99,093
Contracting authority fixed effect	YES	YES	YES
Time fixed effect	YES	YES	YES
Set of further fixed effects (1)	YES	YES	YES
Set of further fixed effects (2)	NO	YES	YES
Set of further fixed effects (3)	NO	NO	YES

The table shows the effect of e-procurement on transparency, measured with the likelihood of observing the award of the call. Each specification includes fixed effects per contracting authority, time (quarter-year) and characteristics of the calls (e.g. subject of award, award procedures, etc.). The model has also been progressively saturated with fixed effects interacting with the time variable the subject matter of the call and the award method (first set of further fixed effects), the size of the call and the details of the subject matter of the call (second set of further fixed effects) and the region and type of administration of the contracting authority (third set of further fixed effects). The standards errors are clustered at a level obtained by interacting all the variables that characterize the tender and the contracting authority. *** p<0.01, ** p<0.05, * p<0.1.

Table 4 replicates Table 3 but using different dependent variables. Specifically, it considers two alternative measures that capture the probability of observing a timely award. The effect of e-procurement varies slightly depending on the treatment definition used, the chosen dependent variable, and the model specification. Under the most saturated specification, the estimated coefficients range between 3 and 5 percentage points.

Table 4. E-procurement and timely awards

	I	II	III
Dependent variable:		$Length^1$	
$Treated^M \times Post$	0.059***	0.053***	0.042***
	(0.011)	(0.011)	(0.010)
# observations	118,821	118,821	118,821
$Treated^H \times Post$	0.062***	0.060***	0.047***
	(0.013)	(0.013)	(0.013)
# observations	99,093	99,093	99,093
Dependent variable:		$Length^2$	
$Treated^M \times Post$	0.040***	0.026*	0.033**
	(0.016)	(0.015)	(0.013)
# observations	118,821	118,821	118,821
$Treated^H \times Post$	0.054***	0.035**	0.032**
	(0.017)	(0.017)	(0.016)
# observations	99,093	99,093	99,093
Contracting authority fixed effect	YES	YES	YES
Time fixed effect	YES	YES	YES
Set of further fixed effects (1)	YES	YES	YES
Set of further fixed effects (2)	NO	YES	YES
Set of further fixed effects (3)	NO	NO	YES

The table shows the effect of e-procurement on the likelihood of a timely award, using two different definitions. Each specification includes fixed effects per contracting authority, time (quarter-year) and characteristics of the calls (e.g. subject of award, award procedures, etc.). The model has also been progressively saturated with fixed effects interacting with the time variable the subject matter of the call and the award method (first set of further fixed effects), the size of the call and the details of the subject matter of the call (second set of further fixed effects) and the region and type of administration of the contracting authority (third set of further fixed effects). The standards errors are clustered at a level obtained by interacting all the variables that characterize the tender and the contracting authority. *** p<0.01, ** p<0.05, * p<0.1.

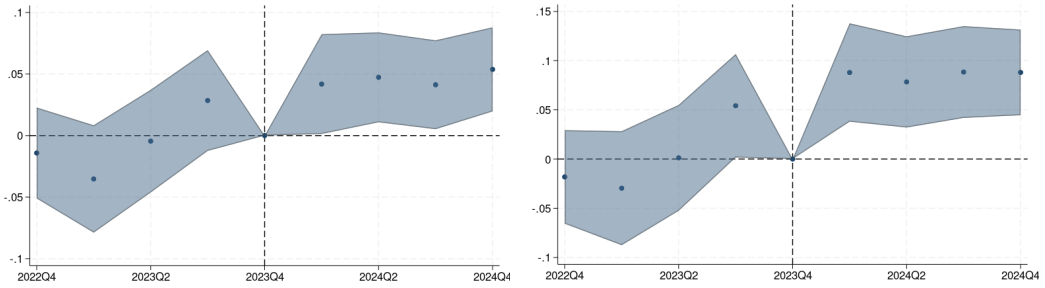
To assess the validity of the parallel trends assumption and to analyse the dynamic effects of e-procurement, we adopt a specification that allows us to detect both the presence of any anticipatory effects and the dynamics of the impacts over time following the introduction of the treatment. Figure 4 illustrates the evolution of the difference between treated and control units, having normalized to zero that in the fourth quarter of 2023.

The analysis uses the three dependent variables considered so far (one per row) and the two different definitions of treatment intensity (one per column). The differences between treated and control units in the quarters preceding the reform are not statistically different from zero, suggesting the absence of divergent trends between the two groups and thus supporting the validity of the empirical approach. In the quarters following the mandatory introduction of e-procurement, instead, we observe a positive and statistically significant effect.

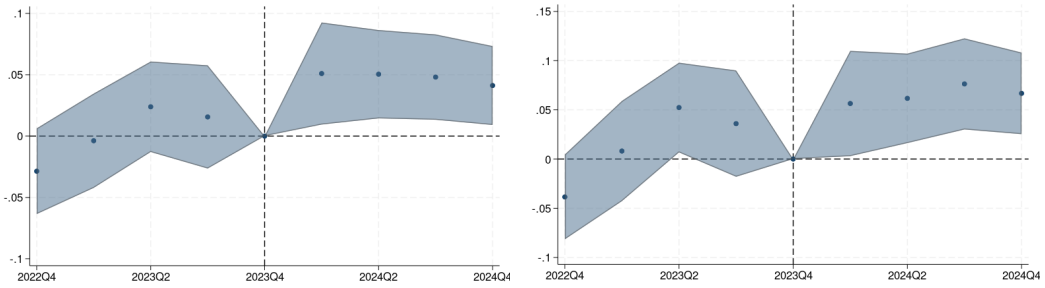
Figure 4. E-procurement: anticipated and delayed effects

Column I: $Treated^M$ Column II: $Treated^H$

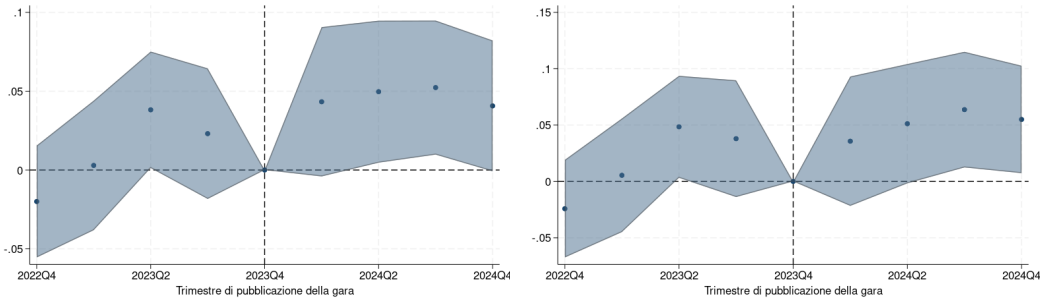
Panel (a): $Trasparency$



Panel (b): $Length^1$



Panel (c): $Length^2$



The figure shows the dynamic effect of e-procurement. Each column refers to a different treatment intensity definition and each panel to a different dependent variable. The specification used is the most saturated specification corresponding to column III of Tables 3 and 4. The standards errors are clustered at a level obtained by interacting all the variables that characterize the tender and the contracting authority. Shaded areas represent the 95 per cent confidence interval.

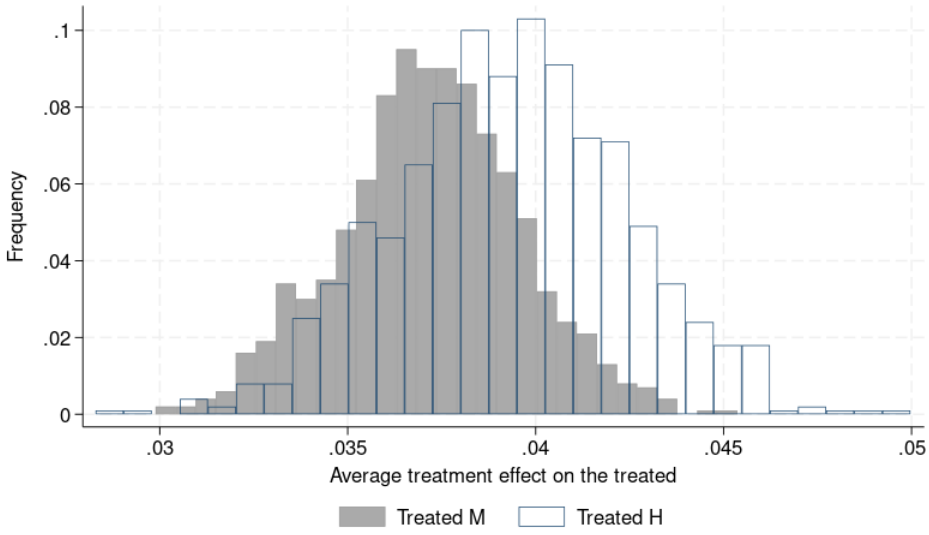
4.2 Robustness

The results presented in the previous section – particularly those concerning the timeliness of award procedures – critically depend on certain assumptions made regarding duration when it is not observed. In this section, we test the robustness of these findings both by introducing perturbations to the imputation choices and by directly addressing potential distortions caused by sample selection. Based on this second model, we also analyse other variables that are only available for tenders for which award information is recorded in the ANAC system.

As previously discussed, each tender for which award information is not observed in the ANAC data may either not have been awarded yet or may have been awarded without the information being entered into the system. For each tender, we therefore randomly assign one of these two possible states and consequently computed the indicator of timely award. This exercise has been repeated 1,000 times, and in each iteration, we estimated the coefficient measuring the effect of the introduction of e-procurement.

Figure 5 shows the distribution of the estimated coefficients, using the two different variables approximating the intensity of the treatment. The distribution is quite compressed, and the values range from just below 3 percentage points to around 5 percentage points, in line with the results reported in Table 4, suggesting that the estimated effects are not significantly affected by the assumptions made. As expected, the average estimated effect is higher when we use a sharper distinction between treated and control groups.

Figure 5. E-procurement and timely awards: robustness



The figure shows the distribution of the estimated coefficients of the e-procurement effect, using the two different treatment definitions, on the likelihood of a timely award. The specification used is the most saturated specification corresponding to column III of Table 4. Estimates refer to 1,000 different random allocations, for each call, of the probability of being awarded timely according to one of the two different definitions.
Source: authors' calculations based on ANAC data.

Table 5 shows the results for two variables that are only observed for the subsample of tenders for which award information is available in the ANAC database. Since estimates based on this subsample may be severely biased due to selection issues, we also applied two-stage regression models à la Heckman to explicitly account for such problems, including the inverse Mills ratio in the second stage[12].

[12] For sake of brevity, we do not report the results of the selection equation. The latter has been estimated on the same variables used in the second stage and with the inclusion of a polynomial of the number of

Concerning the length of the award phase, the correction for the selection bias leads to larger estimated effects of e-procurement, ranging from 12 to 18 percent depending on the definition of treatment intensity (against an average duration of 40 days in the year prior to the reform). The correction factor is statistically significant and negative, suggesting that unobservable factors are positively correlated with the probability of observing an award are negatively correlated with the length of the award procedures. They might include, for example, unobservables capturing quality dimensions of the contracting authority.

As for the number of bids admitted – an indicator that can approximate the level of competition in procurement procedures – this increased by between 3 and 4 percent (compared to an average of 2.1 bids admitted in the year before the reform). In this case, the estimated coefficients are slightly lower than those obtained from the uncorrected regression, in quantitative terms. The results are also weakly statistically significant.

Table 5. E-procurement: estimates corrected for sample selection

Dependent variable:	(log) length of award phase		(log) number of admitted bids	
	I	II	III	IV
$Treated^M \times Post$	– 0.138**	– 0.177***	0.036**	0.026*
	(0.055)	(0.053)	(0.015)	(0.016)
Inverse Mills ratio		– 0.334***		– 0.075***
		(0.082)		(0.018)
# observations		72,534		
$Treated^H \times Post$	– 0.082	– 0.120**	0.051**	0.039*
	(0.060)	(0.060)	(0.022)	(0.023)
Inverse Mills ratio		– 0.283***		– 0.081***
		(0.0913)		(0.022)
# observations		60,161		

The table shows the effect of e-procurement on the length of the award procedure and on the number of accepted bids. The specification used is the most saturated specification corresponding to column III of Table 4. Columns I and III report the regression results on the subsample for which the dependent variable is observable; columns II and IV report the results of the same regressions, with the correction factor for sample selection. The standards errors are clustered at a level obtained by interacting all the variables that characterize the tender and the contracting authority. *** p<0.01, ** p<0.05, * p<0.1.

4.3 Heterogeneity

This section presents a set of analyses that explore how the effects of e-procurement vary depending on specific characteristics of the tenders and/or the broader institutional context.

days since the publication of the tender. As expected, the probability of observing the award is an increasing function of the days since the publication of the tender, although this relationship is non-linear and differs between the pre- and post-reform periods.

Table 6 replicates the results from Tables 3 and 4 for different subsamples of observations, selected based on the characteristics of the tender. Namely, we analyse the effects across different types of procurement objects (supplies, works, or services) and across different award procedures (direct award, negotiated procedure, or competitive tender). Each coefficient therefore refers to the effect of e-procurement on the outcome variable indicated in the column, estimated for the subsample of tenders described in the corresponding row[13].

The positive effects of e-procurement are quite common but do not apply uniformly to all types of tenders. In particular, the effects are concentrated on works and services, in terms of transparency, and on supplies and services in terms of timeliness of the award procedure. With reference to the awarding method, the positive effects concern both direct awards and competitive tenders but are particularly important for the latter.

Table 6. E-procurement: effects by characteristics of the tender

	$Trasparency$	$Length^1$	$Length^2$
By subject of the tender:			
Supplies	0.019	0.051*	0.066***
	(0.029)	(0.030)	(0.025)
Work	0.048**	0.015	– 0.004
	(0.023)	(0.022)	(0.026)
Services	0.098***	0.059***	0.039*
	(0.018)	(0.017)	(0.020)
For award methods:			
Direct awards	0.084***	0.064***	0.025
	(0.015)	(0.015)	(0.018)
Competitive tenders	0.314***	0.192***	0.192***
	(0.053)	(0.048)	(0.048)
Negotiated procedures	0.015	– 0.011	0.010
	(0.042)	(0.038)	(0.038)
Contracting authority fixed effect	YES	YES	YES
Time fixed effect	YES	YES	YES
Full set of further fixed effects	YES	YES	YES

The table shows the effect of e-procurement for different dependent variables reported in the columns – i.e., the likelihood of observing an award and that of observing a timely award, using the two different definitions – and for different subsamples based on the characteristics of the tender and reported in the rows. Each specification includes fixed effects per contracting authority, time (quarter-year) and characteristics of the calls (e.g. subject of award, award procedures, etc.). The specification used is the most saturated specification corresponding to column III of Tables 3 and 4. The standards errors are clustered at a level obtained by interacting all the variables that characterize the tender and the contracting authority. *** p<0.01, ** p<0.05, * p<0.1.

The results also show heterogeneity based on the characteristics of the contracting authority (Table 7). Specifically, we consider the geographical area in which the entity is located, the degree of transparency – measured by the tendency to report contract awards

[13] For the sake of exposition simplicity, only one treatment variable, the high intensity, was considered. However, the results are confirmed if the mid-intensity definition is used.

to ANAC prior to the reform – and the quality of the local bureaucracy, as measured by the indicator developed by Cerqua et al. (2025)[14].

Table 7. E-procurement: effects by contracting authority characteristics

	$Trasparency$	$Length^1$	$Length^2$
By geographical area:			
Centre-North	0.063***	0.042***	0.0218
	(0.016)	(0.016)	(0.019)
South	0.086***	0.058***	0.057**
	(0.023)	(0.021)	(0.026)
By level of pre-reform transparency:			
Low	0.066***	0.045***	0.031
	(0.015)	(0.015)	(0.020)
High	0.056**	0.034	0.006
	(0.024)	(0.026)	(0.024)
For quality of bureaucracy:			
Low	0.047***	0.002	0.008
	(0.015)	(0.016)	(0.020)
High	0.133***	0.124***	0.045**
	(0.024)	(0.021)	(0.023)
Contracting authority fixed effect	YES	YES	YES
Time fixed effect	YES	YES	YES
Full set of further fixed effects	YES	YES	YES

The table shows the effect of e-procurement for different dependent variables reported in the columns – i.e., the likelihood of observing an award and that of observing a timely award, using the two different definitions – and for different subsamples based on the characteristics of the contracting authority and reported in the rows. Each specification includes fixed effects per contracting authority, time (quarter-year) and characteristics of the calls (e.g. subject of award, award procedures, etc.). The specification used is the most saturated specification corresponding to column III of Tables 3 and 4. The standards errors are clustered at a level obtained by interacting all the variables that characterize the tender and the contracting authority. *** p<0.01, ** p<0.05, * p<0.1.

The results show that the positive effects of e-procurement are widespread across the country, although they are more pronounced in the South of Italy. This finding does not appear to be driven by differences in treatment intensity between the two areas, as the share of purchases made through e-procurement by local authorities in our sample is quite similar. Rather, it may be attributable to the lower level of transparency among local authorities in the South, and to the fact that the introduction of e-procurement has had stronger positive effects for contracting authorities that were more opaque prior to the reform[15]. Moreover, the effects are more significant in municipalities with more highly qualified human resources[16]. This finding suggests that the positive impact of

[14] Specifically, the indicator of local bureaucratic quality accounts for the following dimensions: the education level of local public employees, employee turnover, the number of employees relative to the population, and the average number of absences per year.

[15] In 2023, the share of calls for tenders for which there was information on the award in our sample was 67 per cent in the Centre-North, compared with 48 per cent in the South.

[16] The quality indicator of local bureaucracy is higher in the Centre-North, but in this case the difference between the two areas is small and there is indeed significant heterogeneity within them.

digitalization critically depends on the quality of the personnel implementing it, and that, more specifically, there is a complementary relationship between public sector human capital and the effective use of digital technologies.

5. Conclusions

This paper provides evidence on the effects of a major digital transformation in the field of public procurement, focusing on the introduction of mandatory e-procurement for all contracting authorities in Italy starting from January 2024. To assess the impact, the study focuses on two fundamental dimensions of public sector performance: transparency, measured by the availability of award information, and efficiency, proxied by the duration of award procedures.

Leveraging a Difference-in-Differences strategy and a unique dataset that combines administrative procurement data with detailed information on pre-reform e-procurement adoption, we identify a positive and statistically significant effect of the reform on both transparency and procedural timeliness.

The results also reveal significant heterogeneity in the effects: improvements are more pronounced for competitive procedures and among municipalities that, prior to the reform, were characterized by greater administrative opacity and by a more qualified human capital base. This latter finding suggests that digitalization yields greater benefits where the quality of administration is higher, supporting the idea that technology does not replace bureaucratic capacity but rather complements it.

This study contributes to a still relatively underdeveloped empirical literature on the effects of digitalization on the functioning of the public sector. Moreover, it reveals significant heterogeneities along key dimensions such as the opacity of public administrations and the quality of the human capital of their workforce.

In terms of policy implications, these findings suggest that digital investments enhance the quality of public action; that such investments should be accompanied by policies aimed at strengthening the skills and capabilities of public sector personnel, particularly at the local level; and that digitalization processes may require tailored implementation strategies that account for pre-existing institutional disparities.

The impact of digitalization on the functioning of the public sector remains, surprisingly, a largely underexplored area of research. Within the context of public procurement, future studies could focus on additional outcome variables such as prices, contractor selection, and ultimately the quality of goods and services delivered. Moreover, if more granular data were available on the internal organization of contracting authorities and on the digital skills of public employees, it would be possible to better understand the mechanisms through which digital tools interact with administrative structures and human capital in the public sector.

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