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**PROCURING MEDICAL DEVICES:
EVIDENCE FROM ITALIAN PUBLIC
TENDERS**

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Abstract

The public procurement of medical devices is increasingly relying on auction mechanisms to move toward more transparent procedures and to promote competition between suppliers in a market where the quality of the products matters enormously and an improper auction design could be very harmful. Based on Italian hospital data, we present new evidence on the performance of the public tenders to procure orthopaedic prosthesis for hips, knees and shoulders. Focusing on three main outcomes, the number of participants, the presence of a single firm bidding and the winning rebate, for the first time we describe how features related to the tender, hospital, region and bidders' competition all contribute to explain the functioning of the procurement auctions. The evidence we obtain can meaningfully help policy makers in designing and implementing better public procurement systems.

JEL Classification: I18, J18, C21

Keywords: Procurement auctions, medical devices, orthopaedic prosthesis, tender characteristics, Italy

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Procuring Medical Devices: Evidence from Italian Public Tenders

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Abstract

The public procurement of medical devices is increasingly relying on auction mechanisms to move toward more transparent procedures and to promote competition between suppliers in a market where the quality of the products matters enormously and an improper auction design could be very harmful. Based on Italian hospital data, we present new evidence on the performance of the public tenders to procure orthopaedic prosthesis for hips, knees and shoulders. Focusing on three main outcomes, the number of participants, the presence of a single firm bidding and the winning rebate, for the first time we describe how features related to the tender, hospital, region and bidders' competition all contribute to explain the functioning of the procurement auctions. The evidence we obtain can meaningfully help policy makers in designing and implementing better public procurement systems.

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1 Introduction

The medical device industry (MDI) represents a large share of health expenditures with a total turnover for medical technology estimated in EU in about 77 US\$ billion per year. Global sales in the MDI are expected to grow between 2019 and 2022, especially in in-vitro diagnostics, cardiology, imaging, orthopaedics, and ophthalmics. Overall, the MDI global market is forecast to grow from 386.8 US\$ billion to 521.9 US\$ billion in 2022 at a CAGR of 5.1%. Italy represents the fourth largest medical device market in Europe and, in 2017, it was valued around 10.5 US\$ billion.

In the case of orthopaedic prostheses – the focus of this research – such a growth is expected to be driven by both demand and supply factors. Among the former, it is worth mentioning population ageing, as well as changes in preferences for fully preserving joints’ functionality, whereas the pandemic of obesity is responsible for the increasing incidence of arthritis. As for the supply side, improved technologies and innovative surgical procedures have played a key role in presenting the option of implanting orthopaedic prostheses as more alluring.

These demand and supply forces, coupled with the budgetary pressures to reduce public funding of healthcare, have resulted in significant transformations concerning how healthcare organizations purchase medical devices: both Europe and the US have witnessed a growing tendency to rely on procurement auctions. In particular, auctions are considered pivotal in the medical sector as they can be a helpful tool to deliver “value for money” for patients. This is in line with the tendency in public procurement to move toward more transparent and efficient procedures, while promoting competition between suppliers.

The actual fulfilment of such a goal depends on several factors: the procedures and criteria employed, the specification and strength of enforcement of contracts. Moreover, the sensitive purpose of medical devices and their impact on our well-being lead to place a significant emphasis on these products’ quality. An improper auction design, that does not ensure all dimensions are carefully considered, could be very harmful for both patients and healthcare organizations. Clearly then, understanding how auction details impact procurement outcomes concerning medical is of great relevance.

To the best of our knowledge, there have been few attempts to empirically test how auction rules differently affect medical sector’s procurement results. In the US, Merlob et al. (2012) has shown that the recently introduced Medicare auction format for durable medical equipment is an ill-designed mechanism, unable to ensure competitive prices and an efficient allocation of contracts. Grennan (2013) studies instead how different interventions in the negotiation process of coronary stents may affect US hospitals’ surplus: when price is set in a transparent procedure, hospitals’ surplus is squeezed, whereas centralized procurement slightly affects hospitals’ welfare.

In Europe, procurement practices of medical devices are mainly defined and regulated through the harmonized system laid down in the EU Procurement Directives, even though the broad organization of the healthcare sector can vary widely by country. As regards Italy, previous studies show mixed evidence on the relationship between auction rules and procurement results: Rizzo (2006) reveals that open auctions are more efficient than negotiations, whereas in Bonaccorsi et al. (2000) negotiations should be preferred when medical devices are highly complex and their quality is not easy to measure ex ante (in line with Bajari et al. (2001)). Contrarily, the work of Vellez (2011) shows that negotiations do not lead to higher prices and, instead, multilateral

negotiations allow to award contracts with even lower prices. Among the most recent studies, Borsoi et al. (2017) compare the tender dossier description issued by different Italian procurers of medical devices. Despite the homogeneity of the procured good (sanitary gloves), the description and awarding criterion vary significantly across procurers, with, for instance, the weight assigned to quality elements ranging between 30 and 60 % of the total score. Relatedly, Buccioli et al. (2017) find substantial price variation across public buyers for very narrowly defined, standardized products. Their work underscores that the different abilities of public buyers in organizing and handling the public tender are a key driver of this heterogeneity.

With this research, we aim to shed more light on the effectiveness of the auction-based public procurement procedures used to procure medical devices, by thoroughly considering the main peculiarities of medical procurement - relative to those of the non-medical sector- namely, the significant role of framework agreements (FA) and scoring rule (SR) auctions. Taken together, both these features play a key role in determining procurement outcomes, suggesting that this procurement area is characterized by great flexibility in the choice of suppliers. Furthermore, we will study how characteristics of the procuring hospitals (or any other purchasing body) and their relative regional healthcare systems could also be important. Similarly, features concerning the supply side and, especially, the degree of supplier's competition are likely to matter substantively.

To reach this goal, we collect a rich set of auction-level data to study how features related to the tender, the buyer, the suppliers and the regional healthcare system all contribute to the performance of the procurement auctions. We focus on three outcome measures that are of clear importance: the number of bidders, the presence in the auction of a single bidder and the winning rebate (over a publicly announced maximum price).

With respect to the Italian case (and, more broadly, to the EU one), our study contributes to the literature on public procurement of medical devices in three different ways. First, the usage of such an integrated dataset allows us to consider additional covariates that may impact auctions' outcomes and that several related studies have failed to include. Second, we investigate the role of framework agreement as a contractual form, and its impact on the efficiency of the procurement system. Third, we test whether increased concentration, measured with two different indices, affects several dimensions of the Italian public procurement of medical devices.

Our main findings indicate that open auctions can be considered an useful tool to stimulate competition among bidders in the procurement of medical devices. First, open auctions induce more participation and lower prices than negotiated procedures where only selected firms are invited to bid and negotiate their offer. Second, with regards to the auction criterion, our findings show that medical devices' procurers can ensure higher bidders' participation and more significant rebate by employing the lowest price criterion instead of a scoring rule, probably due to increased transparency. Furthermore, we show that the contractual form privileged by the US, namely framework agreement, lead to a controversial trade-off: to grant more flexibility to the buyer, the procuring authority has to pay a higher price for the procured goods. Finally, region-wise programs aimed at curbing healthcare spending are associated with higher bidders' participation and lower winning prices.

In what follows Section 2 briefly describes the institutional background in the Italian healthcare system, Section 3 describes the data, and Section 4 provides the results and discusses some of the limitation of the study. Finally, Section 5 concludes.

2 Institutional setting

The Italian National Healthcare Service (NHS) is a tax-funded system, free at any point of usage. Even though setting out the main objectives of such a system is within the scope of the national government, the Italian NHS is highly decentralized: regional governments are entitled with the exclusive competence to organize and ensure the delivery of healthcare services, through a network of local public organizations in charge of healthcare commissioning and provision. Among these regional institutions, a key role is played by Local Health Authorities (Aziende Sanitarie Locali, ASLs henceforth), entitled to manage one or more Hospitals (Presidio Ospedaliero) which do not have the legal requirements to be fully independent. Indeed, even though a Hospital enjoys a certain degree of functional autonomy with separate accounting, this is only within the boundaries of the ASL, the only undertaking with a proper balance-sheet. On the other hand, Hospital Enterprises (Azienda Ospedaliera) are hospitals transformed into independent undertakings, autonomous in their management and balance-sheet. Given the relevant role that local healthcare bodies play in regional systems, auction-based procurement in the Italian NHS is mostly decentralized to territorial bodies, such as ASL, hospitals and hospital enterprises.

For their procurement of both goods and services, these institutions must comply with the rules laid down in the Directive 2004/18/EU, partially modified by the new Directive 2014/24/EU. These EU Procurement Directives aim to foster the use of transparent procedures, ensuring equal treatment to all bidders, as well as the widest publicity to the calls for tenders.¹ As we can see from Figure 1, following the EU legislation, procurement auctions can be categorized by combining an awarding criterion with an awarding procedure (see Decarolis and Giorgiantonio (2015)). The awarding criterion specifies the rule under which bidders' offers are evaluated. The two criteria are: *i*) the lowest price, where the winner is selected based on the bidding price only and *ii*) the Most Economically Advantageous Tender (MEAT), where the winner is selected following a stated combination of criteria, such as the bidding price, the quality of the products offered and the time necessary to execute the contract. On the other hand, the awarding procedures are the different methods to arrange the call for tenders that public contracting authorities can use. Simplifying a bit, there are two main types of procedures: *i*) Open and restricted procedures, that involve non-renegotiable offers, evaluated by the contracting authority without any degree of discretion; *ii*) various kinds of Negotiated procedures where the contracting authority can invite selected bidders and negotiate to some extent their offer. The former type of procedures are the default ones, while negotiated procedures can be used either for smaller contracts (i.e., those below a certain monetary threshold) or under exceptional circumstances of urgency or else. Furthermore, a special type of Negotiated procedure, known as Competitive Dialogue, can be used when the peculiar complexity of the work auctioned off requires the contracting public administration to directly consults with the firms participating to the auction.

By reducing such a granular classification to a broader one that overlooks some redundant legal prescriptions, the intersection between awarding criterion and awarding procedure identifies three auction formats typically encountered in the economics jargon: *i*) First price auctions (FP),

¹Among the most recent amendments to the Italian public procurement framework, it is worth mentioning the introduction of Central Procurers: these are contracting authorities entitled to manage procurement procedures for goods and services that are then used by other bodies of the public administration.

where the procedure must be either open or restricted procedure, combined with the lowest price as awarding criterion; *ii*) Scoring rule auctions (SR), where the procedure must be either open or restricted procedure, combined with the most economically advantageous offer as awarding criterion; *iii*) Negotiations (N), where the procedure must be a negotiated one, contract without prior tender publication or a competitive dialogue.

Figure 1: EU auction taxonomy

<i>Award procedures</i>	Open Procedure + Restricted Procedure + Accelerated Restricted		Accelerated Negotiated + Award of a contract without prior tender publication + Competitive Dialog + Negotiated + Negotiated without a call for competition
<i>Award Criterion</i>	Lowest Price	Most Economically Advantageous Tender (MEAT)	Lowest Price or MEAT (but only MEAT for Competitive Dialog)
<i>Format</i>	FP	SR	N

In addition to the criterion and the procedure, the contractual form is the third characterizing feature of a public tender. There are different ways in which an auctioneer can arrange its relationship with the private supplier(s) winning the call for tenders: *i*) Public supply contract (C), where both the quantity and time are clearly stated; *ii*) Framework agreement (FA), – also known as indefinite time/quantity contract – which only specifies the conditions under which the firm winning the auction will be supplying the good or service (meaning, the price, technical specifications and, possibly, quantity) and the maximum amount of time (or products) for which the public buyers is guaranteed these conditions; *iii*) Dynamic purchasing system (DPS), an electronic process, mostly employed for commonly used purchases, even though its usage is not widespread.

3 Data

The data used for the empirical analysis in this work come from different sources that have been integrated together. The first set of data covers the public procurement auctions of orthopaedic prostheses for hips, knees or shoulders in Italy during 2012-2014. These data are obtained from the Italian National Anti-Corruption Authority (ANAC, hereafter), which collects data on the universe of public contracts whose reserve price – the maximum contractual price stated in the call for tenders – exceeds €40,000. These auction announcement can refer to either “single-lot” or “multi-lot” auctions, where each lot is run as an independent auction. For this reason, our unit of observation is the auction lot rather than the auction itself. In total there are 1,188 observations (auction lots), for which we have collected relevant information such as the description of purchasing good, the chosen awarding procedure and criterion, contractual form, auction’s reserve price, the identity of the procurer as well as that of the winner, the number of participants and the winner’s bid. Exploiting the announcement descriptions, we can distinguish between prostheses for hips, knees or shoulders, but we are unable to systematically identify the exact product purchased. However, this is of any relevance only in the case of knee implants, where

important differences exist between fixed-bearing knees and mobile-bearing knees.²

By employing the procurer identity, we supplement the ANAC dataset with additional information. In particular, we identify those regions subject to a national healthcare programme to restore budget balance (known as “Piano di Rientro”), and recover buyer-level information about procurer’s type, its participation in RIAP (Italian Registry of Arthroprostheses), and how accurately different types of information on prostheses are recorded.³ Similarly, by exploiting the winner identity, we integrate information on the type of supplier (distributor and manufacturer) and on its parent company (distinguishing between the larger manufacturers and all other suppliers).

Exploiting these original data, we construct three outcome variables: *(i) Single participant*, a dummy for those auction with only one bidder participating. This is likely to be pathological for the medical products we study, as all the main manufacturers produce the entire range of implants. Moreover, despite technical (and price) variations and surgical philosophies, different designs are regarded by most customers as satisfactory substitutes: “Despite particular preferences, the medical staff is typically familiar with the various surgical philosophies and/or is trained to face a change of design in a relatively short time.”⁴; *(ii) No. participants*, which captures the number of bidders in the auction; *(iii) Lot rebate*, the difference between the winning bid and the reserve price, calculated as a percentage of the reserve price. Both academic and policy analysis of public procurement markets often take advantage of these two latter outcomes, since they represent a good proxy for the degree of competition.

We calculate also two measures of competition at procurer-level, instead that auction lot-level: *(i) No. of firms*, the number of different firms a particular procurer contracted with during the period of study in our sample; *(ii)*, the Herfindahl-Hirschman Index (HHI), calculated in terms of volumes to overcome the issue. The first measure does not take into account the shares of contracts that each supplier is awarded over the total number of contract that the procuring body is auctioneering, whereas the second variable overcomes this issue. Finally, we define a dummy to capture the role of producers *vs.* distributors and a dummy to isolate the role of large producers among producers.⁵

Table 1 presents descriptive statistics for our variables. Concerning our dependent variables, auction lots with a single participant account for 29% of our observations, thus implying actual competition did not occur for these auctions. The average number of participant for each lot is 8.6, while the average rebate is 16%.

In terms of explanatory variables, our data display considerable variation in lot size (average lot reserve price is 2.2M EUR, with 3.5M EUR standard deviation). We classify 86% of our sample

²See, for instance, the DG Comp Decision No M.3146 on the proposed merger between Smith & Nephew and Centerpulse. That decision established that hips, knees and shoulders are separate markets. Moreover, among knee implants, fixed-bearing knees and mobile-bearing knees should also be considered as separate markets due to both supply (i.e., patent protection) and demand considerations (i.e., different cost and functionality).

³Information about the main goals of the “Piano di Rientro” program and the list of regions subject to it can be found here: www.salute.gov.it/portale/p5_1_1.jsp?lingua=italiano&id=145. Hospital level information about completeness of prostheses is collected by RIAP.

⁴From the market investigation of DG Comp Case No M.3146.

⁵We define as large producers the following producers: Johnson & Johnson Medical Spa, Synthes Srl, Zimmer Srl, Smith & Nephew Srl, Stryker Italia Srl, Biomet Italia Srl, Biomet Austria Gesmbh, Covidien Italia Srl and Medtronic Italia Spa.

as purchase of knee (27.6%), hip (48.7%), and shoulder (12.4%) prosthesis.⁶ Concerning the type of awarding procedure, open auctions (regular procedures) are the prevalent procedures (76.2%), while for the awarding criterion lowest price is not a widely used criterion (12.5%). Finally, for the contractual form framework agreements play a key role (37.2%).

Our auction lots refer to the purchase of 36 different public procuring bodies. Among them, the most represented procurer type is Hospital Enterprise (accounts for 51% of our observations), followed by Hospitals (29%) and centralized purchasing bodies (18%).⁷ Participation in RIAP database and in “Piano di Rientro” program is not uniform: 8 buyers are neither in RIAP database nor in “Piano di Rientro” program; 4 buyers are both in RIAP database and in “Piano di Rientro”; 17 in RIAP, but not in “Piano di Rientro”; 7 buyers are in RIAP, but not in “Piano di Rientro.” Overall, most contracts are concluded by procuring bodies that are either RIAP, but not “Piano di Rientro” participants or vice-versa. Summary statistics akin to Table 1 by “Piano di Rientro” program and RIAP participation are presented in Appendix (see Tables A1 and A2). Within RIAP, there are 20.2% (78.4%) of auctions procured by buyers in “Piano di Rientro”. Noteworthy that correlation between variables “Piano di Rientro” and Procurer in RIAP is -0.89, which indicates that these two variables are closely related.

Finally, in terms of market structure, as shown in Table 1, there are 26.9 different suppliers per buyer and the average value of the HHI is 0.08 (very high concentration). Producers are respondent in auctions in about 62% of cases and among them about 28% are large producers. Additional summary statistics are reported in the web appendix.

4 Empirical results

The empirical analysis is based on the estimation of a model whose general form can be represented as follows:

$$\mathbf{E}(y_i) = F(\alpha \mathbf{A}_i + \beta \mathbf{B}_{b(i)}), \quad (1)$$

where y_i is an outcome of auction i , \mathbf{A}_i is the vector of auction i characteristics, and $\mathbf{B}_{b(i)}$ is the vector of characteristics of the procurer $b(i)$, who runs the auction i . As previously discussed, the dependent variable y_i may have a different nature depending on auction outcome considered: *i*) single participant, *ii*) number of participants, *iii*) lot rebate. This feature implies to use different functional forms $F(\cdot)$ in equation (1). In particular, we will use a probit model in presence of the binary variable *Single participant*, a negative binomial model when we use the count variable *No. of participants* and, finally, a standard OLS model for *Lot rebate*, which is a continuous variable. Whenever a non-linear models is used, we report average marginal effects. While the regressions that we run are simple correlations with no pretence of a causal interpretation, we believe they

⁶These groups are not mutually exclusive, i.e. in a particular auction procurer may purchase goods of several types.

⁷IRCCS are a peculiar type of hospitals, awarded with the recognition of scientific excellence in pursuing specific research objectives related to pathologies of national interest. Such an institutional acknowledgement allows IRCCS to get access to additional financial resources granted by the Italian central government. They account for just 1% of the data.

represent an interesting conditional descriptive evidence on a crucial and little studied market.⁸ For each outcome we run several specifications to check the robustness of our estimates and the role that specific variables can have in improving the overall model fit. We conclude discussing the direction and sources of the potential bias in the estimates.

The results of the regressions for the *Single participant* outcome are presented in Table 2. Columns (1)-(2) show the results without measures of market competition, while the remaining columns add those regressors (columns (3)-(4) include the number of different firms the procurer works with, whereas in column (5)-(6) we insert procurer-level HHI). We include the dummy variables *Procurer in RIAP* and *Piano di Rientro* program separately, as these variables are highly correlated. Average marginal effects are presented for all the columns.

As expected, an higher reserve price attracts more bidders to compete, thus lowering the probability of having a single participant in the auction; auctions for either knee or hip prostheses have a lower probability of single participant compared to other procurements; having multiple lots is associated with an higher probability of single participant. As for the procurement procedures, a procuring body opting for a negotiation increases the probability of having a single participant, compared to one employing an open auction; on the contrary, neither the contractual form nor the awarding criteria have any stable impact on probability of auction to be with a single participant. With regards to procurer categories, Hospital Enterprises display an higher probability of a single participant compared to Hospitals, while participation in RIAP is negatively associated with the probability of a single participant. Finally, and not surprisingly, a lower number of firms working with the buyer, an higher concentration of suppliers in terms of HHI and the fact that the bidder is a distributor (as opposed to a manufacturer) are all associated with higher probability of single participant.

The results for the regressions involving the *Number of participants* outcome are presented in Table 3. As before, results are presented as average marginal effects and, as before, columns (1)-(2) show the results without measures of market competition, while columns (3)-(6) include such measures. Several estimates confirms our findings regarding the probability of a single participant as outcome variable: a higher reserve price increases the number of bidders, whereas multi-lot auctions and negotiated procedures are associated with lower participation. However, it is worth highlighting some interesting differences: participation increases if the procurement event involves knee prosthesis and lower if procurement includes shoulder prosthesis compared to auction without classification on type of procured good. It is also interesting that being located in a region subject to the Piano di Rientro program is associated with large increases in participation, both in terms of magnitude of the effect and of statistical significance. Finally, as in the analysis for the single participant outcome, the number of suppliers that the buyer works with are associated with a higher number of participants, while higher concentration (calculated using the HHI) is associated with fewer bidders.

The third set of results concern the *Lot rebate* outcome. They are presented in Table 4 in standard marginal effects form, where columns (1)-(2) show the results without measures of market competition and columns (3)-(6) include such measures. We find that the reserve price does not

⁸It is worth mentioning that in this analysis we do not use panel data estimation techniques as for several participants we only have one observation in the time window. Limiting the sample only to participants with 3 or more observations reduces enormously the sample size and may also bias the estimates due to selection.

impact the rebate; auctions referring to knee, hip or shoulder medical devices have lower rebate compared to non-classified products; multi-lot auctions display an higher rebate, while negotiations lead to lower rebate compared to open auctions. Employing a framework agreement as contractual form leads to lower rebate, whereas adopting the lowest price as criterion leads to higher rebate. Regional centralized procurers are able to obtain higher rebate compared to Hospitals. It is to notice that procurers participating in RIAP show a lower rebate, whereas those localized in regions joining Piano di Rientro have higher rebate. We find no significant correlation between both our measure of competitive forces (number of different suppliers and HHI) and auction rebate.

Overall, the three sets of estimates are suggestive of some patterns in the data. First and foremost, regular procedures (open auctions) appear as an effective tool to foster sellers' competition into healthcare procurement as opposed to negotiations. We can see this across all our estimates: the choice of using a negotiation is systematically associated with a higher probability of a single participant, a substantially lower number of participants and, also, a lower winning rebate. In terms of magnitude, switching on the negotiation dummy variables produces changes in all the three outcome variables that are larger than those induced by any other considered covariate. Our findings on negotiated procedures are thus suggestive that something problematic might be happening in these procurement auctions and, possibly, that the margin within which public administrators are free to use negotiations should be reduced. This margin is mostly linked to a monetary threshold which, during the period of our analysis was approximately €200,000. Nevertheless, it is fundamental to point out that lower participation and lower rebate are not, by themselves, evidence of corruption and not even of an inefficient procurement process. Indeed, having less participants and paying the winner more might be the hidden cost of buying higher quality products. There are, however, at least three reasons why we can take the evidence on negotiations as a signal of an ineffective procurement rather than an attentive selection of reliable bidders. First, since we are studying types of medical devices for which the industry is mature and products are similar, having a single firm bidding is highly suspicious, since most of the large manufacturers can all produce most of the types of prostheses analyzed. Second, and even more watchful, is the fact that the probability of having a single participant increases in presence of a distributor, rather than a manufacturer. There are clearly possible explanations for these effects based, for instance, on relational contracts between buyers and their trusted distributors, but further evidence is certainly needed to rule out any wrongdoing and possibly restricting the scope for negotiated procedures. The third is that multi-lot auctions are likely to have a single participant, suggesting that firms might be splitting the market. Hence, further work would be required to explore the scope of both collusion and corruption risk in this environment.

A second, closely connected feature, is that the lowest price criterion (as opposed to scoring rule, i.e., the MEAT) is associated with more participation and higher rebates. This evidence is closely associated with the one described above for negotiations: price-only competition induces transparency. However, competition among many suppliers and price savings in the initial contract signed might come at the expense of quality. Interestingly, the same considerations apply to the Piano di Rientro. Indeed, this variable is positively and significantly associated to both the participation and rebate outcomes. This is likely because being in a region under the Piano di Rientro induces the buyer to seek price savings through enhanced participation. Thus, as before, this is *prima facie* a positive effect of the Piano di Rientro, which aligns well with the objectives

of this program aimed at reducing excessive public expenses in healthcare. However, it would be important monitoring its implications in terms of the quality of the products purchased.

Finally, it is worth mentioning the role of framework agreements. Like the MEAT criterion, the most novel EU regulations are promoting this type of contracting. However, in the estimates we observe the type of trade-off predicted by theory: even though framework agreements are associated with more participation, they go together with higher price. Indeed, as expected from standard models like Gur et al. (2017), when bidders are exposed to more uncertainty about which hospitals will buy their products and when, then they require an higher payment upfront. Therefore, the enhanced flexibility allowed to the buyer to just step into existing framework agreements comes at the cost of a lower winning rebate.

5 Conclusion

The medical device industry has grown at an unprecedented rate over the last decade and an even sharper growth is forecast in the next years, mainly driven by demand factors such as population ageing and obesity pandemic. The presence of such demand factors, in combination with tight fiscal policies at country level responsible for reducing public funding allocated to health care services, has highlighted the pivotal role of public procurement strategies: they are considered a tool to move toward more transparent procedures while promoting competition, in line with the final goal of guaranteeing public health care systems' sustainability.

Based on detailed data on Italian hospitals, we have been able to present new evidence on the performance of public tenders for orthopaedic prosthesis (specifically, for hips, knees and shoulders prosthesis). For the first time, our results show how features related to the tender, hospital, region and bidders' competition all contribute to explain three main outcomes in the procurement sector, such as the number of participants, the presence of a single firm bidding and the winning rebate.

In particular, our findings underscore that there are four elements that are particularly relevant in understanding these outcomes. Two elements pertain to the tender design and, specifically, to whether the tendering procedure is an open auction (as opposed to a negotiation) and whether the criterion to select the winner is the price offered (as opposed to a multi-criteria scoring rule system). A third element regards the contractual form and, in particular, whether the contract is for a fixed amount of devices to be delivered at a predetermined timing or, instead, it is an indefinite time/indefinite quantity framework agreement. The fourth major element is whether the buyer is located in a region subject to the special budgetary provisions – known as Piano di Rientro – imposed on those regions excessive imbalances in their healthcare spending.

Although we are perfectly aware that our results cannot claim to describe a causal relationship, the economic interpretation behind them is fully in accordance with the theoretical predictions stemming from this field of the economic literature. Furthermore, the useful evidence we obtain can be employed to define an interesting research agenda to drive future empirical analyses, especially in those fields where economic theory fails to provide indisputable answers. This is particularly crucial the case in the analysis of healthcare procurement where observable savings in quality might come at the cost of unobservable (to the analyst) drops in the intrinsic quality of the products purchased or in the conditions of their delivery. Albeit within the broad realm of medical devices,

orthopaedic prostheses represent a mature industry where most of the products are standardized, future research should explore whether the savings induced by greater competition are coming at the cost of lower quality.

Overall, and despite the above-mentioned limitations, we believe that these results could be useful for policy makers to design and implement better public procurement systems.

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Table 1: Descriptive statistics

VARIABLES	(1) mean	(2) sd	(3) min	(4) max	(5) N
<i>Dependent Variables</i>					
Single participant	0.290	0.454	0	1	1,185
No. of participants	8.630	6.650	1	21	1,185
Lot rebate (%)	16.500	21.800	0	83.400	1,185
<i>Independent Variables</i>					
Lot reserve price (x 000 EUR)	2,254	3,569	40	21,273	1,185
Multilot auction	0.943	0.231	0	1	1,185
Knee prosthesis	0.277	0.448	0	1	1,185
Hip prosthesis	0.487	0.500	0	1	1,185
Shoulder prosthesis	0.124	0.330	0	1	1,185
Awarding proc. (1=Negotiation 0=Reg proc.)	0.762	0.426	0	1	1,185
Awarding crit. (1=Lowest price 0=Scoring rule)	0.125	0.331	0	1	1,185
Contractual form (1=Fram. agr. 0=Other)	0.373	0.484	0	1	1,185
Central procurer	0.181	0.385	0	1	1,185
Hospital Enterprise	0.513	0.500	0	1	1,185
Hospital	0.294	0.456	0	1	1,185
IRCCS	0.013	0.112	0	1	1,185
Piano di Rientro	0.203	0.402	0	1	1,185
Procurer in RIAP	0.784	0.412	0	1	1,185
No. of firms	26.900	9.060	1	42	1,185
Herfindahl-Hirschman Index	0.081	0.122	0.045	1	1,185
Type of supplier (1=Producer, 0=Distributor)	0.619	0.486	0	1	1,185
Large producer	0.282	0.450	0	1	1,185

Table 2: Probit model with *Single participant* outcome

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	ME Prob	ME Prob	ME Prob	ME Prob	ME Prob	ME Prob
Log of reserve price	-0.063*** (0.007)	-0.063*** (0.006)	-0.058*** (0.007)	-0.060*** (0.007)	-0.049*** (0.007)	-0.050*** (0.007)
Multilot auction	0.160*** (0.045)	0.144*** (0.044)	0.204*** (0.047)	0.178*** (0.046)	0.325*** (0.051)	0.306*** (0.051)
Knee prosthesis	-0.056*** (0.020)	-0.042** (0.020)	-0.069*** (0.022)	-0.053** (0.023)	-0.058*** (0.020)	-0.052** (0.021)
Hip prosthesis	-0.048*** (0.018)	-0.034* (0.018)	-0.069*** (0.020)	-0.050** (0.020)	-0.067*** (0.019)	-0.057*** (0.019)
Shoulder prosthesis	-0.048** (0.024)	-0.034 (0.023)	-0.064*** (0.025)	-0.047* (0.024)	-0.058** (0.023)	-0.050** (0.023)
Awarding proc. (1=Negotiation 0=Reg proc.)	0.259*** (0.040)	0.256*** (0.041)	0.269*** (0.041)	0.264*** (0.041)	0.356*** (0.046)	0.345*** (0.043)
Awarding crit. (1=Lowest price 0=Scoring rule)	-0.030 (0.022)	-0.028 (0.022)	-0.030 (0.023)	-0.028 (0.023)	-0.048* (0.028)	-0.045 (0.028)
Contractual form (1=Fram. agr. 0=Other)	0.025 (0.024)	0.026 (0.024)	0.048* (0.026)	0.041 (0.026)	0.036 (0.025)	0.035 (0.025)
Central procurer	-0.022 (0.024)	-0.008 (0.023)	0.018 (0.030)	0.015 (0.029)	-0.019 (0.023)	-0.011 (0.022)
Hospital enterprise & IRCCS	0.046** (0.023)	0.066*** (0.024)	0.045* (0.024)	0.062*** (0.024)	0.037 (0.024)	0.049** (0.024)
Piano di Rientro	-0.000 (0.024)		-0.009 (0.026)		-0.023 (0.026)	
Procurer in RIAP		-0.054** (0.023)		-0.038 (0.026)		-0.008 (0.029)
No. of firms			-0.003*** (0.001)	-0.002* (0.001)		
Herfindahl-Hirschman Index					0.516*** (0.105)	0.480*** (0.105)
Type of supplier (1=Producer, 0=Distributor)	-0.038** (0.018)	-0.038** (0.018)	-0.039** (0.017)	-0.039** (0.018)	-0.032* (0.017)	-0.033* (0.018)
Large producer	0.023 (0.018)	0.019 (0.019)	0.020 (0.018)	0.018 (0.019)	0.020 (0.018)	0.019 (0.019)
Observations	1,185	1,185	1,185	1,185	1,185	1,185

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Table 3: Negative binomial model with *Number of participants* outcome

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	ME NegBin	ME NegBin	ME NegBin	ME NegBin	ME NegBin	ME NegBin
Log of reserve price	2.241*** (0.106)	2.413*** (0.122)	2.048*** (0.106)	2.168*** (0.114)	2.012*** (0.107)	2.221*** (0.106)
Multilot auction	-0.582 (0.769)	0.482 (1.389)	-3.511*** (0.966)	-2.345* (1.255)	-1.841** (0.812)	-0.646 (1.200)
Knee prosthesis	1.242** (0.513)	0.899* (0.512)	1.616*** (0.529)	1.448*** (0.519)	1.291** (0.513)	0.942* (0.509)
Hip prosthesis	0.494 (0.501)	0.086 (0.498)	0.915* (0.517)	0.704 (0.508)	0.611 (0.505)	0.190 (0.496)
Shoulder prosthesis	-1.626*** (0.537)	-1.878*** (0.538)	-1.439*** (0.545)	-1.561*** (0.547)	-1.793*** (0.538)	-2.036*** (0.546)
Awarding proc. (1=Negotiation 0=Reg proc.)	-9.497*** (0.694)	-8.930*** (0.607)	-9.485*** (0.657)	-8.972*** (0.579)	-8.834*** (0.685)	-8.367*** (0.605)
Awarding crit. (1=Lowest price 0=Scoring rule)	7.343*** (0.526)	6.973*** (0.615)	7.762*** (0.560)	7.505*** (0.623)	7.868*** (0.540)	7.336*** (0.612)
Contractual form (1=Fram. agr. 0=Other)	4.511*** (0.567)	4.301*** (0.605)	3.260*** (0.571)	2.998*** (0.600)	4.841*** (0.579)	4.523*** (0.614)
Central procurer	0.612 (0.791)	-0.796 (0.732)	-3.595*** (1.370)	-5.101*** (1.232)	0.097 (0.840)	-1.482* (0.805)
Hospital enterprise & IRCCS	1.581* (0.832)	-0.118 (0.833)	1.509* (0.854)	0.044 (0.849)	1.121 (0.882)	-0.791 (0.881)
Piano di Rientro	3.630*** (0.784)		3.704*** (0.779)		4.067*** (0.786)	
Procurer in RIAP		-1.046 (0.931)		-1.570* (0.818)		-1.045 (0.779)
No. of firms			0.247*** (0.052)	0.264*** (0.050)		
Herfindahl-Hirschman Index					-17.356*** (2.013)	-16.826*** (2.106)
Type of supplier (1=Producer, 0=Distributor)	0.205 (0.198)	0.204 (0.209)	0.174 (0.197)	0.180 (0.201)	0.141 (0.196)	0.152 (0.203)
Large producer	-0.401* (0.208)	-0.348 (0.219)	-0.349* (0.204)	-0.298 (0.210)	-0.384* (0.203)	-0.314 (0.212)
Observations	1,185	1,185	1,185	1,185	1,185	1,185

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Table 4: Linear model with *Lot rebate* outcome

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Linear	Linear	Linear	Linear	Linear	Linear
Log of reserve price	0.202 (0.420)	0.451 (0.427)	-0.139 (0.434)	-0.030 (0.400)	-0.334 (0.470)	-0.035 (0.412)
Multilot auction	14.574*** (3.267)	16.548*** (3.319)	12.252*** (3.858)	13.968*** (3.820)	11.274*** (3.827)	13.931*** (3.720)
Knee prosthesis	-5.493*** (1.315)	-5.808*** (1.376)	-4.708*** (1.625)	-4.623*** (1.706)	-5.090*** (1.336)	-5.371*** (1.373)
Hip prosthesis	-6.144*** (1.459)	-6.837*** (1.533)	-5.305*** (1.752)	-5.604*** (1.845)	-5.597*** (1.490)	-6.318*** (1.540)
Shoulder prosthesis	-5.425*** (1.650)	-6.040*** (1.732)	-4.919*** (1.767)	-5.255*** (1.886)	-5.290*** (1.637)	-5.901*** (1.741)
Awarding proc. (1=Negotiation 0=Reg proc.)	-10.995*** (2.179)	-9.801*** (2.123)	-11.132*** (2.191)	-9.875*** (2.120)	-10.764*** (2.195)	-9.429*** (2.141)
Awarding crit. (1=Lowest price 0=Scoring rule)	42.169*** (2.256)	42.266*** (2.376)	43.137*** (2.312)	43.687*** (2.517)	44.474*** (2.308)	44.454*** (2.433)
Contractual form (1=Fram. agr. 0=Other)	-7.827*** (1.564)	-7.315*** (1.622)	-8.269*** (1.622)	-7.740*** (1.660)	-6.803*** (1.568)	-6.284*** (1.648)
Central procurer	38.343*** (2.494)	35.522*** (2.303)	34.574*** (4.597)	31.047*** (4.764)	37.516*** (2.558)	34.598*** (2.402)
Hospital enterprise & IRCCS	6.822** (2.795)	3.214 (2.322)	6.329** (2.985)	2.838 (2.470)	5.977** (2.972)	2.216 (2.579)
Piano di Rientro	10.463*** (2.524)		11.072*** (2.531)		12.034*** (2.710)	
Procurer in RIAP		-5.679** (2.241)		-7.148*** (1.952)		-6.971*** (1.992)
No. of firms			0.204 (0.185)	0.253 (0.196)		
Herfindahl-Hirschman Index					-18.525* (11.043)	-16.618 (10.683)
Type of supplier (1=Producer, 0=Distributor)	-0.104 (0.716)	-0.030 (0.718)	-0.167 (0.701)	-0.092 (0.705)	-0.340 (0.685)	-0.227 (0.684)
Large producer	-0.045 (0.764)	0.038 (0.758)	0.091 (0.754)	0.153 (0.758)	0.104 (0.743)	0.153 (0.745)
Constant	-6.265 (6.867)	-2.067 (7.587)	-5.210 (6.700)	0.588 (6.845)	4.505 (8.630)	8.680 (8.257)
Observations	1,185	1,185	1,185	1,185	1,185	1,185
R-squared	0.761	0.753	0.763	0.755	0.768	0.759

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.10

6 Appendix

Table A1: Summary Statistics by Piano di Rientro

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Not in Piano di Rientro					In Piano di Rientro				
	mean	sd	min	max	N	mean	sd	min	max	N
Single participant	0.320	0.467	0	1	945	0.175	0.381	0	1	240
No. participants	8.600	6.910	1	21	945	8.730	5.540	1	19	240
Lot rebate (%)	16.500	23.700	0	82.700	945	16.100	11.800	0	83.400	240
Lot reserve price (x 000 EUR)	1,869	2,685	40	11,620	945	3,771	5,631	40	21,273	240
Knee prosthesis	0.262	0.440	0	1	945	0.333	0.472	0	1	240
Hip prosthesis	0.548	0.498	0	1	945	0.246	0.431	0	1	240
Shoulder prosthesis	0.126	0.332	0	1	945	0.117	0.322	0	1	240
Multilot auction	0.943	0.232	0	1	945	0.946	0.227	0	1	240
Regular procedure	0.732	0.443	0	1	945	0.879	0.327	0	1	240
Awarding proc. (1=Negotiation 0=Reg proc.)	0.268	0.443	0	1	945	0.121	0.327	0	1	240
Contractual form (1=Fram. agr. 0=Other)	0.455	0.498	0	1	945	0.050	0.218	0	1	240
Awarding crit. (1=Lowest price 0=Scoring rule)	0.150	0.358	0	1	945	0.025	0.156	0	1	240
Central procurer	0.226	0.419	0	1	945	0	0	0	0	240
Hospital Enterprise	0.636	0.481	0	1	945	.029	0.169	0	1	240
Hospital	0.122	0.327	0	1	945	0.971	0.169	0	1	240
IRCCS	0.016	0.125	0	1	945	0	0	0	0	240
Procurer in RIAP	0.969	0.173	0	1	945	0.054	0.227	0	1	240
No. of firms	27.800	9.180	1	42	945	23.100	7.460	1	27	240
Herfindahl-Hirschman Index	0.073	0.109	0.045	1	945	0.112	0.162	0.051	1	240
Type of supplier (1=Producer, 0=Distributor)	0.630	0.483	0	1	945	0.575	0.495	0	1	240
Large producer	0.252	0.434	0	1	945	0.400	0.491	0	1	240

Table A2: Summary Statistics by RIAP

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Producer Not in RIAP					Producer in RIAP				
	mean	sd	min	max	N	mean	sd	min	max	N
Single participant	0.180	0.385	0	1	256	0.321	0.467	0	1	929
No. participants	8.950	5.670	1	19	256	8.540	6.890	1	21	929
Lot rebate (%)	15.300	12.300	0	83.400	256	16.800	23.700	0	82.700	929
Lot reserve price (x 000 EUR)	3.956	5.509	40	21,273	256	1,785	2,625	40	11,620	929
Knee prosthesis	0.281	0.450	0	1	256	0.276	0.447	0	1	929
Hip prosthesis	0.254	0.436	0	1	256	0.551	0.498	0	1	929
Shoulder prosthesis	0.113	0.318	0	1	256	0.127	0.333	0	1	929
Multilot auction	0.898	0.303	0	1	256	0.956	0.206	0	1	929
Regular procedure	0.906	0.292	0	1	256	0.722	0.448	0	1	929
Awarding proc. (1=Negotiation 0=Reg proc.)	0.094	0.292	0	1	256	0.278	0.448	0	1	929
Contractual form (1=Fram. agr. 0=Other)	0.105	0.308	0	1	256	0.447	0.497	0	1	929
Awarding crit. (1=Lowest price 0=Scoring rule)	0.027	0.163	0	1	256	0.152	0.359	0	1	929
Central procurer	0.027	0.163	0	1	256	0.223	0.416	0	1	929
Hospital Enterprise	0.023	0.152	0	1	256	0.648	0.478	0	1	929
Hospital	0.891	0.313	0	1	256	0.129	0.336	0	1	929
IRCCS	0.059	0.235	0	1	256	0	0	0	0	929
Piano di Rientro	0.887	0.318	0	1	256	0.014	0.118	0	1	929
No. of firms	22.500	7.670	1	27	256	28.100	9.040	1	42	929
Herfindahl-Hirschman Index	0.115	0.169	0.051	1	256	0.072	0.104	0.045	1	929
Type of supplier (1=Producer, 0=Distributor)	0.559	0.498	0	1	256	0.635	0.482	0	1	929
Large producer	0.398	0.491	0	1	256	0.250	0.433	0	1	929

Table A3: Summary statistics by regions

Region name	Number of observations	Number of buyers	Share of single participant	Mean number participants	Mean rebate
Abruzzo	74	4	0.26	5.89	24.00
Basilicata	2	2	1.00	1.00	0.00
Friuli Venezia Giulia	206	1	0.09	9.49	36.68
Liguria	14	5	0.71	1.86	13.48
Lombardia	620	12	0.40	9.28	11.80
Marche	1	1	1.00	1.00	4.01
Puglia	16	3	1.00	1.00	7.12
Sicilia	150	4	0.05	10.96	13.19
Toscana	1	1	1.00	1.00	0.00
Trentino Alto Adige	101	2	0.23	3.83	5.63