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To My Mother

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Abstract

Accounting for about 15-20% of GDP in developed economies, public procurement is both a paramount economic phenomenon and a leading activity of governments. Sound procurement policies and practices are therefore essential not only to achieve best value for money when purchasing goods and services of public utility, but also to pursue strategic objectives of crucial importance (e.g., sustainable growth and innovation) and to optimize spending in an era where public money has a high opportunity cost.

This dissertation contributes to the research on public procurement by providing original investigations and results in an interdisciplinary fashion. The three essays presented adopt different methodologies to analyze relevant issues in public procurement which have been so far neglected by the literature.

The first essay provides an auction-theoretical analysis of "Pre-commercial Procurement" (PCP), which is an innovative step-wise practice recently introduced in the EU for the public procurement of R&D. In particular, PCP is modeled as a multi-stage elimination contest with budget-constrained players and non-sunk bids. The non-sunk feature constitutes a novelty in the modelization of elimination contests and relies on the consideration that when budget-constrained contestants initially strategize on how much to bid in each stage, they do not regard bids spent in earlier stages as strategically irrelevant. This is due to the fact that contestants face a trade-off when allocating scarce resources over stages: the more they spend earlier the less they have to spend later, and vice versa. In a simple two-stage all-pay framework with complete informa-

tion and asymmetric players, it is found that, notwithstanding the trade-off, the ex-ante strongest player is always able to deter other players from submitting a positive bid in the first stage, guaranteeing herself shortlisting with the smallest outlay, and saving most resources for the second stage. This is shown to imply that the two-stage all-pay contest has a lower performance, in terms of expected revenue, than the single-stage one. On the basis of these results, PCP does not seem to be a very advantageous practice for the procurement of R&D.

The second essay provides a contract-theoretical framework to explain the occurrence of embezzlement of public money in the execution of public contracts. It is argued that at the core of the phenomenon is an agency problem where the room for the contracting firm's moral hazard is created by the opportunism of its principal - a corruptible top-tier politician. It is considered that often corruption interests the execution stage of a contract (rather than only the award stage) and has a political nature (rather than only bureaucratic): top-level politicians may as well have to gain from large-scale corruption. In particular, the model allows for the political principal to be partially selfish and for both the auditing technology and the stakes of corruption to be endogenous and dependent on the selfishness of the politician. The model shows that while a moderately opportunist politician prevents the firm from embezzling money, an enough opportunist politician creates an incentive for embezzlement in optimal contracts, in order to ask for a share of the money conditional upon detection.

The third essay investigates empirically the relationship between the degree of centralization in a procurement system and its performance. Despite its centrality, this issue has been only marginally considered by the literature, and without conclusive findings. The essay exploits the TED dataset to provide a preliminary investigation of the issue for Italy. The Italian case is appropriate in this context since all levels of government plus a number of other public institutions are involved in procurement, and are largely subjected to the same rules. Using winning rebate as a measure of procurement performance, and controlling for other determinants of rebate, it is found that small decentralized units (i.e., municipalities and public enterprises) are less efficient than (more) central purchasers, despite they currently award most procurement contracts. It is argued that at the basis of this performance gap is the fact that small decentralized purchasing units lack the specialized and competent human resources which are needed to efficiently administrate the procurement process. It is therefore concluded that the Italian procurement system is probably too much decentralized and that some reorganization on a more centralized basis could improve on the general performance gap.

Chapter 1

Introduction

Accounting for about 15-20% of GDP in developed economies, public procurement is both a paramount economic phenomenon and a leading activity of governments (OECD, 2011[1]).
It is therefore essential that governments design and implement sound public procurement policies in order to achieve best value for money when purchasing goods and services of public utility. Well-designed procurement would also enable governments to pursue other strategic objectives of foremost importance for public welfare and competitiveness, such as promoting sustainable growth, innovation, and Small-medium Enterprises (SMEs). These objectives are particularly urgent nowadays, in an era of economic instability and crisis, where a key concern for governments is to optimize public spending in order to consolidate public finances and clear fiscal space for other policies.
Given its large practical relevance, a great deal of economic research has focused on public procurement. Whereas the methodologies adopted and the specific issues under analysis differ across research agendas in the literature, the central theme is the same, namely *procurement performance*. Procurement performance can be defined as the extent to which public procurement meets the objectives it is designed for. The literature

[1] The average for OECD countries is 12% when excluding procurement by state-owned utilities. When these purchases are also accounted for, the size of procurement can increases by an additional 2 to 13 percentage points of GDP (OECD (2011)).

has been studying this issue with both a positive approach, with the aim of identifying the determinants of the *actual* level of performance, and with a normative approach, aiming at characterizing the mechanisms which *optimize* performance.

Three economic disciplines which are central in the study of procurement, and have been fostering a number of fertile research agendas, are *auction theory*, *contract theory* and *empirical research*.

Insofar most public procurement contracts are awarded to suppliers by means of auctions, it is both natural and relevant to study procurement as an *auction-theoretical* problem. Indeed, many central issues in auction theory have been applied to the study of procurement as well[2]. Studied topics include, among the others, the role of adverse selection and of the nature of incomplete information (see e.g., Manelli and Vincent (1995) and Albano et al. (2006c)), corruption (see e.g., Celentani and Ganuza (2002), Burguet and Che (2004), Compte et al. (2005) and Lengwiler and Wolfstetter (2006)) collusion (see e.g., Bajari and Ye (2003) and Albano et al. (2006a)), procurement risk (see e.g., Arvan and Leite (1990), Zheng (2001), Calveras et al. (2004) and Ganuza (2007)), multidimensional procurement (see e.g., Che (1993), Branco (1997) and Asker and Cantillon (2010)), repeated and dynamic procurement (see e.g., Laffont and Tirole (1988), Lewis and Yildirim (2005)), multi-unit procurement (see e.g., Dimitri et al. (2006b)), competition and entry (see e.g., Albano et al. (2006d)) and procurement of innovation (see e.g., Cabral et al. (2006), Ding and Wolfstetter (2011)).

Therefore, auction theory provides useful frameworks and tools to properly analyze the issues related to the tender stage of procurement, hence allowing to focus on *ex-ante* procurement performance. However, great attention should be also given to the post-tender stage of procurement, namely *contract execution*. At the contract implementation stage a typical incentive problem may emerge, namely that the selected firm can exploit its informational advantage to engage in post-contractual opportunism (i.e., moral hazard) in order to ex-post increase its profit. Typi-

[2]For extensive reviews of central themes in auction theory see e.g., Klemperer (2004), Milgrom (2004) and Krishna (2009).

cally, the firm can provide sub-optimal levels of cost-reducing effort or quality, i.e, activities that are difficult or costly to monitor. Obviously, this has negative consequences on *ex-post* procurement performance. This information problem is at the core of the *contract-theoretical* analysis of procurement. Accordingly, an important research agenda in this literature focuses on *optimal procurement contracting*, i.e., the design of optimal incentives for cost-reduction and quality in procurement contracts (Laffont and Tirole (1993)). Other central themes are the optimal allocation of procurement risk, contract flexibility and reputation issues, which are essential when contracts are not (fully) enforceable (see e.g., Bolton and Dewatripont (2005), Albano et al. (2006b)). Moreover, to the extent that the incentive structure of procurement contracts influences the behavior of bidders at the tendering stage, many contributions stand at the intersection between auction and contract theory, focusing on the auctioning of incentive contracts (see e.g., McAfee and McMillan (1986), Laffont and Tirole (1987)) and of incomplete contracts (see e.g., McAfee and McMillan (1987), Bajari and Tadelis (2001)).

While the theoretical disciplines provide useful frameworks to analyze many central issues in public procurement, the great practical relevance of the topic also calls for an empirical and more quantitative assessment of the determinants of procurement performance. Accordingly, another discipline which has been extensively adopted for the study of public procurement is *empirical analysis*. Indeed, many of the themes listed above have been analyzed empirically as well. This is the case for issues like the impact of auction and contract design on moral hazard in the contract execution (see e.g., Lewis and Bajari (2011), Lewis and Bajari (2014)), the impact on procurement performance of corruption (see e.g., Coviello and Gagliarducci (2010), Goldman et al. (2013)) and collusion (see e.g., Porter and Zona (1993), Lee and Hahn (2002), Bajari and Ye (2003)), relational contracting and reputation (Corts and Singh (2004), Banerjee and Duflo (2000)), procurement of incomplete contracts (Bajari et al. (2009), Bajari et al. (2014), Crocker and Reynolds (1993), Levin and Tadelis (2010)), entry (Branzoli and Decarolis (2015)).

The aim of this dissertation is to contribute to the literature with three pieces of original research on relevant issues in public procurement which have been so far neglected, and to do so in an interdisciplinary fashion. Therefore, each of the three following chapters will focus on a different aspect of procurement and adopt one of the three methodologies referenced above, namely auction theory, contract theory and empirical analysis. In particular, Chapter 2 contributes to the auction-theoretical research on procurement, while Chapter 3 and Chapter 4 respectively focus on contract-theoretical and empirical analysis of procurement.

The rest of this introductory chapter gives a brief description of the research problems addressed in the three following chapters, as well as an essential review of the main findings.

Chapter 2 provides a preliminary auction-theoretical analysis of "Pre-commercial Procurement"(PCP), which is an innovative practice recently introduced in the EU for the public procurement of R&D. PCP is organized as a competitive step-wise process where a number of potential suppliers start developing alternative solutions and are sequentially eliminated through the different R&D phases. In particular, PCP is modeled as an elimination contest (i.e., a multi-stage contest where at each stage a number of contestants is eliminated) with budget-constrained players and *non-sunk bids*. The non-sunk feature constitutes a novelty in the modelization of elimination contests and relies on the consideration that when budget-constrained players initially strategize on how much to bid in each stage, they do not regard bids spent in earlier stages as strategically irrelevant in the decision of how much to bid in subsequent stages. This is so because they face a basic trade-off when allocating scarce resources over stages: the more they spend earlier the less they have to spend later, and the more they plan to spend later the less they have to spend earlier. In a simple two-stage all-pay framework with complete information and asymmetric players, it is found that, notwithstanding the above mentioned trade-off, ex-ante budgets of players are relatively more important - in determining the outcome of the game - than their strategic ability in allocating limited resources over the contest. Due to the dynamic nature of the game and to the information structure, the ex-ante strongest player is always able to deter other players from submitting a positive bid in the first stage, guaranteeing herself shortlisting with the smallest outlay in order to save resources for the second stage, where mixed-strategies are played. This implies the result that the two-stage all-pay contest has a lower performance, in terms of expected revenue, than the single-stage one, due to the fact that the first-stage yields almost no revenue and that shortlisting to the second-stage is inefficient. According to these results, PCP does not seem to be a very advantageous practice for the procurement of R&D. The contribution of this work to the literature is two-fold. First, it provides some theoretical modeling of PCP, which has not yet received attention from the literature, despite its potentially great relevance. Second, it contributes to the auction literature, in providing a first characterization of the equilibria of the two-stage elimination all-pay contest with non-sunk bids.

Chapter 3 provides a contract-theoretical framework to explain the occurrence of the embezzlement of public money by the contracting firm in the execution of public contracts (i.e., *cost-padding*). It is argued that the phenomenon can be explained as an agency problem where the room for the contracting firm's moral hazard is created by the opportunism of its principal - a possibly corrupt top-tier politician. Differently from existing literature, which mainly focuses on corruption at the award stage of procurement and mostly on bureaucratic corruption, the model considers that in real-world cases corruption can interest as well the execution stage and have a *political* nature, i.e., involve top-level politicians, who may as well have to gain from large-scale corruption. In particular, the Chapter extends the contract-theoretic model of cost-padding in Laffont and Tirole (1993) to allow for the political principal to be partially selfish - i.e., he is no longer a benevolent regulator but he rather maximizes a weighted average between social welfare and his private utility - and for both the auditing technology and the stakes of corruption to be endogenous and dependent on the selfishness of the politician. The model shows that while a moderately opportunist politician (by choosing a relatively aggressive auditing technology) prevents the firm from engaging in cost-padding, an enough opportunist politician (by choosing a relatively weak auditing technology) creates an incentive for cost-padding

in optimal contracts, in order to ask for a share of embezzled money conditional upon detection. An additional finding is that an improvement in the efficiency of the fiscal system, by lowering the social cost of cost-padding, makes cost-padding easier to occur, since also less opportunist politicians are tempted to engage in corruption.
Chapter 4 investigates empirically the relationship between the degree of centralization of a procurement system and its performance. While practitioners suggest that the advantages of centralization (in terms of savings on purchase and process costs brought by economies of scale), outweigh its costs (in terms of missed flexibility toward local needs and protection of SMEs), it is the case that public procurement around the world is largely decentralized. It is therefore convenient to ask whether and to what extent such a prevailing decentralization trend is justifiable on empirical grounds. Chapter 4 addresses exactly this research question, which has been only marginally considered in the literature, despite its great practical relevance, and without conclusive evidence. In particular, the TED dataset is exploited to provide preliminary evidence on the relationship between procurement decentralization and performance for Italy. The Italian case is appropriate and interesting to focus on in this context since all levels of government (central and sub-central) plus a number of other public institutions are involved in procurement, and are largely subjected to the same rules. Using winning rebate as a measure of procurement performance, it is found that small decentralized units - in particular municipalities and public enterprises - are less efficient than more central purchasers, despite they currently award most procurement contracts. This result holds even after controlling for important determinants of rebate, such as the award mechanism, the size of the purchasing unit and local characteristics, suggesting that performance is affected by some other unobservable characteristics which vary between classes of contracting authorities. It is argued that these characteristics much likely amount to the set of professional competences and incentives of the purchasing unit's procurement staff, which are needed to efficiently administrate procurement and achieve best value for money. Differently from (more) central purchasers, small decentralized units cannot afford

specialized technical offices and hence are likely to perform relatively badly. It is therefore concluded that the current system seems to be too decentralized and that policy makers should consider re-organizing procurement on a more centralized basis in order to address the general performance mismatch.

Chapter 2

Pre-commercial Procurement as an Elimination Contest with Non-sunk Bids

2.1 Introduction

Governments all over the world are faced with continuously changing and continuously emerging societal challenges. These include coping with the impact of demographic aging (e.g., via ensuring high-quality and cost-effective health care and elderly care) and pursuing environmental sustainability (e.g., via improving energy efficiency of buildings and public transport).

Often these needs are so technologically demanding and in advance of what the market can offer that radically innovative R&D is required. Therefore, the public sector needs to develop procurement strategies that allow to stimulate the required innovation in a cost-effective way [1].

[1] Notice that procuring innovative goods may be more problematic than procuring standard goods, mainly because the "public good" nature of innovative knowledge combined with the high multifarious uncertainty peculiar to the R&D process, results in firms under-

As it is well known, public procurement has a huge economic relevance, insofar it accounts for a significant percentage of GDP (about 15-20% in OECD countries [2]) and, most importantly, has a *direct* impact on the economy. Therefore, if R&D procurement strategies are appropriately designed and forward looking, public purchasers would not only ensure that high-quality and cost-effective solutions are delivered on time to address contingent public needs, but would also have a positive impact on the innovative performance of national industries, which in turns would enhance their productivity, competitiveness and, ultimately, growth potential [3]. Moreover, the need of sound practices for procuring innovation is more important than ever nowadays, given that societal challenges for which innovative solutions are needed are getting more and more pressing, and that public money has a high opportunity cost in an era of economic instability [4].
However, according to the European Commission, public sectors in Europe tend to severely understate the potential of public procurement as a driver of innovation, with the result that, in terms of innovative performance, Europe lags behind its major trading partners and competitors[5]. To contrast this trend, the European Commission published a Communication in 2007 (European Commission (2007)) where it called up Member States to revisit the role of public procurement as a driver of innovation, in particular by using a new procurement practice, called "Pre-

investing in innovation. See Cabral et al. (2006) for a discussion of these issues and a comparative analysis of incentive tools available to procure innovation.

[2]The average for OECD is 12% when excluding procurement by state-owned utilities. When these purchases are also accounted for, the size of procurement can increase by an additional 2 to 13 percentage points of GDP (OECD (2011)).

[3]See Aghion and Howitt (1997) for an essential reading about the impact of innovation on growth.

[4]Edler and Georghiou (2007) provide a discussion on the role of public demand as a potential major source of innovation, and Aschhoff and Sofka (2009) assess its performance as a driver of innovation with respect to other policy tools (e.g., regulation, R&D subsidies and basic research in Universities).

[5]The European Commission reports that the US are spending twenty times more than Europe in procurement of R&D ($50Bn vs $2.5Bn per year), and that this gap in procurement expenditures is responsible of approximately half of the overall R&D investment gap between the US and Europe. Although the gap is mainly due to disparities in defense/space budgets, expenditure is still four times higher in the US in non defense/space sectors, such as health, energy, education, transport and environment.

commercial Procurement", as a more effective approach to procure the R&D needed to develop solutions to public needs. Pre-commercial Procurement (PCP) concerns the R&D phase before commercialization and is based on three innovative features that potentially make it a much more advantageous approach for the procurement of innovative goods and services with respect to the practices commonly used in the EU [6].

The first distinct feature of PCP is that, unlike standard procurement approaches, it is organized as a competitive stepwise process, which is illustrated in Figure 2.1: in PCP a number of firms enter the competition and start developing alternative solutions, and after each of the R&D phases - typically solution exploration, prototyping and development of a limited volume of products in the form of a test series - intermediate quality evaluations are run, on the basis of which participating firms are sequentially eliminated. The firms who get successfully to the end of the R&D process are then awarded a contract. The stepwise nature of PCP should allow to steer the development of innovative products throughout the R&D process to best fit the public sector needs, so that a faster takeover of innovations is made possible, and to select the best potential suppliers, thereby reducing the risks and costs of working with as yet unproven technologies. Also, contracting R&D from a number of firms rather than from a firm only, would ensure a future competitive market for the innovative products, thereby allowing public purchasers to avoid being bound to a single supplier.

The second innovative feature is that in PCP risks and benefits are shared between contracting firms and public purchaser. This makes both parties interested in the publication, standardization and commercialization of results, which should contribute to speeding the uptake of inventions in the market - and hence the delivery of solutions to social needs - as well as reducing market fragmentation on the supply side. The third feature is that in PCP the tender for the R&D contract is separated from the tender for the commercialization of the innovative product. Separating the procurement of R&D from the procurement of commercial volumes enables the public purchaser to filter out the risks of the R&D phase before

[6] See the Communication for a detailed account of PCP characteristics.

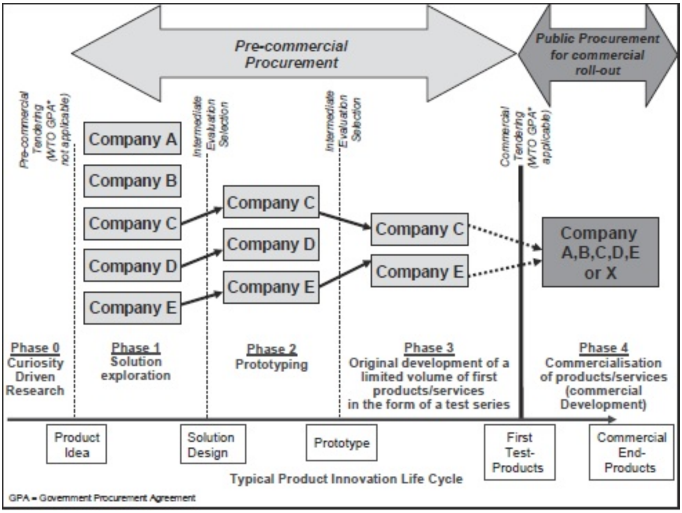

Figure 2.1: The Pre-commercial Procurement process (Source: Communication COM (2007) 799 European Commission (2007))

committing to procure large volumes.

These three characteristics contribute together to reduce the costs and risks of procuring innovation with respect to the standard procurement practices used in the EU (e.g., "Exclusive Development"). In these practices the public purchaser typically reserves all the R&D results for itself, so that the contracting firms not only ask for higher prices, which implies that the public purchaser is less likely to afford more R&D contracts in each tender, but also that firms do not have the incentive to invest in the publication, standardization and commercialization of results, with the consequence that the uptake of the new inventions in the market will be slower. Also, in standard procurement practices, the public purchaser does not follow the entire R&D process, and the procurement of R&D is not separated from commercialization, so that the purchaser bear all the risk that after committing to procure commercial volumes, the innovative product turns out to be unsuitable for the target market. As a consequence, public purchasers tend to focus on near-to-market innovations, which are less risky, rather than on radical, but likely riskier innovations,

which are the most needed.
Therefore PCP seems very promising as an alternative practice to the procurement of R&D. However, there is still little experience in the EU with this approach, so it is difficult and premature to pass judgments or predict the extent to which PCP could indeed be better than practices commonly used [7].
Moreover, PCP has not yet received the attention of economic literature. To the best of our knowledge the only exception is a work by Che et al. (2014) where it is investigated the extent to which the pure unbundling between R&D and commercial phases of procurement, as it is called for in PCP, can be justified on contract-theoretical grounds. The authors find that pure unbundling is never optimal, since the choice of the commercial contractor should depend at least to some extent on the values of the projects competing in the R&D tender[8]. Indeed, the development of some more theoretical work would help to get a better understanding of all the economic issues underlying PCP, and hence to rationalize the use of PCP as a policy tool.
This work intends to take a step in this direction. In this essay we implement an auction-theoretic analysis of PCP. In particular, given the stepwise nature of the shortlisting process at the basis of PCP, and the fact that all participants incur a cost regardless of them winning (or being selected through stages) or not, we find it convenient to model PCP as a an elimination all-pay contest, namely a multi-stage contest where (i) at each stage a subset of contestants is selected to go to the subsequent stage - while the others are eliminated, (ii) shortlisting is determined by a multi-unit all-pay auction, i.e., at each stage only a given number of highest bidders is shortlisted but *all* contestants forfeit their own bid and (iii) the contestants who are shortlisted in all stages, i.e., complete the R&D process, are awarded a contract[9]. All-pay auctions have been com-

[7] A review of the EU funded PCP projects which are currently being implemented is available at the European Commission web page on PCP.

[8] Also, there is some work about the legal aspects of PCP (e.g., see Apostol (2012)).

[9] The all-pay auction is a limit case of the Tullock's contest. Tullock (1980) assumes that a contestant's probability of winning the contest equals the ratio between her own effort and the sum of other contestants' efforts, in order to capture the notion, common to many contests in practice, that random factors, or "noise", can play a role in determining the

monly used in the literature to model R&D contests and races, as well as other competitive scenarios where both losers and winners forfeit their own bid or "effort", such as sport competitions, lobbying, political campaigns, job promotions, litigation and wars[10].

Modeling PCP as an elimination all-pay contest allows to capture a fundamental feature of the competition between firms, namely the strategic nature of their behavior in allocating limited resources between R&D phases. The presence of a constraint on resources implies that firms face a *trade off* when allocating resources between early and later stages: a firm that spends little money on early stages in order to save resources for later stages, is likely to conduct a low quality basic R&D, thereby risking to be eliminated early, but if it manages to get to later stages it has a high probability of winning in the end. On the other hand, a firm that spends most resources in early stages, is more likely to get successfully to later stages, but may risk to run out of resources before the completion of the product development and consequently to miss the contract. In this case the potential supplier will "lose everything" in the sense that she will never be able to recover the resources she invested up to that point. The presence of such a trade off has two fundamental implications in our model, which have been neglected by the literature. The first implication is that when a player strategizes on how much she will bid at each given stage she will be allowed to play, she will not regard the total of the bids she has planned to spent until that stage as sunk, since they are *not* strategically irrelevant in her decision of how much to bid in the following stages. This is due to the interplay between stages explained above: the more a contestant spends early the less she has to spend later, the more she plans to spend later, the less she has to spend earlier. The

outcome of a contest. The all-pay auction is a fully discriminatory contest, that is the limit case where there is no noise at all and the outcome is completely determined by the effort exerted by players.

[10] All-pay auctions have been studied both under complete and incomplete information. Basic references in the former strand are Hillman and Samet (1987), Hillman and Riley (1989), Baye et al. (1993),Baye et al. (1996), Che and Gale (2003) and Siegel (2009). Basic references to the latter are Hillman and Riley (1989), Amann and Leininger (1996), Krishna and Morgan (1997), Moldovanu and Sela (2001), Moldovanu and Sela (2006) and Moldovanu et al. (2012).

second implication is that the winner of the game may not be the player with the biggest budget, but rather the player who is the ablest in allocating resources between stages.

In a simple two-stage framework with complete information and asymmetric players we find that, notwithstanding the presence of the trade-off, relative ex-ante strengths of players are more important than their relative abilities - in determining the equilibrium outcome of the game, which is also proven to be unique. Due to the information structure, the strongest player is always able to deter the other players from submitting a positive bid in the first stage, guaranteeing herself shortlisting with the smallest outlay in order to save most resources for the second stage, where mixed strategies are played. This leads to the result that the two-stage all-pay contest yields a lower expected revenue than the single-stage one, due to the fact that the first stage yields almost no revenue and that shortlisting to the second stage is inefficient.

On the basis of these results PCP does not seem to be a very advantageous practice for the procurement of R&D. However, the current version of our model has adopted some simplifying assumptions so that more work is needed to fully assess PCP on theoretical grounds.

Moreover, in modeling PCP as an all-pay elimination contest, we have excluded from the analysis some other important features of PCP - such as the role of intermediate quality evaluations in the selection process (unless one assumes that higher effort leads unequivocally to higher quality), and risk-benefit sharing between the contracting firm and the public purchaser. These aspects could inspire future work about alternative modelizations of PCP.

Our work serves a twofold purpose. First, to introduce some theoretical work about PCP, which has not yet received the attention of the economic literature, despite its potentially great relevance. Second, to fill a gap in the all-pay auction and elimination contest literature, since to the best of our knowledge this is the first attempt to characterize the equilibria of an elimination all-pay contest with non-sunk bids.

This essay is structured as follows: Section 2.2 discusses the relation to the literature; Section 2.3 presents the model; Section 2.4 characterizes the equilibria; Section 2.5 concludes. All proofs are in the Appendix A.1.

2.2 Relation to the literature

The body of literature on elimination contests, to which this work contributes, is large and various. The aim of this section is to briefly review this literature, with a particular attention to explain how and to what extent our work departs from the bulk of contributions with respect to three main features, i.e., (i) the approach of the analysis, whether normative or positive, (ii) the way of modeling the shortlisting process, and (iii) the inclusion in the model of a constraint on resources.
Most contributions in the literature study contests from a normative point of view, adopting an *optimal contest design* perspective, that is they are aimed at identifying the set of "rules" which lead to the most-favorable outcomes for the contest designer, i.e., most importantly, total effort maximization. In particular, studies belonging to this research agenda, initiated by Rosen (1986) address three main questions, i.e., (i) which is the optimal prize structure in contests (see e.g., Rosen (1986), Fu and Lu (2012)), (ii) which is the optimal seeding of players, i.e., the best way to match players in sub-contests on the basis of ability rankings - typically to avoid that the strongest competitors eliminate each other in early rounds (see e.g., Rosen (1986), Groh et al. (2012)), and (iii) which is the optimal structure of contests, i.e., the number of stages and the number of contestants remaining at each stage (see e.g., Gradstein and Konrad (1999), Moldovanu and Sela (2006), Fu and Lu (2012)).
An interesting investigation for the all-pay case is provided by Groh et al. (2012), who consider a two-stage elimination tournament with asymmetric players where players compete in pair-wise matches modeled as all-pay auctions, and characterize the optimal seedings which are needed to achieve the maximization of, respectively, the total tournament effort, the probability of a final between the two strongest players, and the winning probability of the strongest player.
Also, Gradstein and Konrad (1999), studying a Tullock contest with symmetric players, ask under which conditions it is better for the designer to

choose a multi-stage format rather than a single-stage one, thereby endogenizing the choice of the contest structure. They find that a single-stage contest is preferable only when the contest rules are discriminatory enough, i.e., when the effort exerted by contestants is relatively more important than random factors in determining the outcome of the contest, like in an all-pay auction[11].

A particular sub-strand in the literature about the optimal contest structure is the *efficient entry* literature. Works belonging to this agenda typically investigate two-stage contests where a *shortlisting stage* (or *entry stage*) is introduced by the designer before the proper contest stage, with the aim of inducing *efficient entry* in the contest, i.e., selecting the players with the highest valuations to participate in the contest. In particular, Fullerton and McAfee (1999) analyze a research tournament where an auction is used to shortlist potential contestants for entry in the tournament, and show that for a large class of contests the optimal number of finalists is two, and that while neither a first-price nor second-price format can generally induce efficient entry, an all-pay auction amended to award a prize to all the entrants can[12].

Another strand in the normative literature analyzes the role of information revelation in settings with incomplete information where players can signal and strategically misrepresent their preferences (see e.g., Lai and Matros (2006), Zhang (2008) and Zhang and Wang (2009)). When important information is revealed in the interim stages of a game, the incentives of players in earlier stages are altered, so that whether and to what extent it is optimal to reveal information about players' ability at a given stage of the game, is a fundamental aspect of contest design, which is also relevant to many contests in practice[13].

[11] Moldovanu and Sela (2006) implement a similar analysis but in an incomplete information setting.

[12] In the context of indicative bidding, Ye (2007) analyzes a very similar game and reaches the same conclusions. Other contributions to this research are Higgins et al. (1985) and Baye et al. (1993).

[13] Another strand of literature that could be somehow related to our work analyze multi-stage sequential all-pay auctions. In this research agenda, initiated by Leininger (1991), multi-stage all-pay auctions are modeled as dynamic games where contestants enter the game sequentially (rather than simultaneously), as it is the case in many real contests where

Differently from all the works mentioned so far, we do not adopt a normative perspective but rather a positive one. If in the aforementioned papers either the multi-stage or the all-pay features, or both, are introduced to achieve efficient shortlisting, in our model both features are rather a natural description of a stepwise competition where all players forfeit their outlay. Our aim is not to provide an optimal design of the PCP practice, but rather to give an essential modeling of the strategic behavior of budget-constrained contestants in a dynamic setting such as the PCP one.

Whereas a normative analysis would be as well useful and relevant in our context, given that a priority in the design of all procurement practices should be to ensure the most cost-effective use of public money, a positive analysis allows to detect the determinants of bidders' behavior when they are not constrained by the designer's maximization problem.

A second point of divergence from our work and most contributions in the literature is the way in which the shortlisting process is modeled. Most of the contributions that we have mentioned typically adopt a "multi-battle" kind of shortlisting, where at each stage the remaining contestants are divided into groups where sub-contests or pairwise battles are run, and then the winners of these sub-contests compete again against each other in later stages (e.g., this is how shortlisting works in most team sport tournaments). On the other hand, we adopt an "all-against-all" kind of shortlisting, where at each stage remaining contestants do not meet just a subset of remaining competitors, but they rather confront all the other survivors (e.g., this is how shortlisting works in R&D races). Just a few papers in the elimination contests literature adopt this kind of shortlisting. To the best of our knowledge this method is only adopted in the *efficient entry* literature mentioned above and in Fu and Lu (2012).

A third feature which is shared by most works in the literature is that the role of a constraint on resources is typically not considered, despite of

contestants perform one after the other. Other contributions to this strand are Konrad and Leininger (2007) and two very recent contributions by Segev and Sela (2011) and Segev and Sela (2012).

its relevance in most real world contests [14]. Just a handful of papers embed it explicitly in the analysis. Amegashie (2002) analyzes a two-stage elimination contest and finds that when contestants face a symmetric cap on total effort between stages, full "burning out" can happen in equilibrium, i.e., all active players may find it optimal to spend all resources in the first-stage and be left with nothing in the second stage. Stein and Rapoport (2005) introduce a budget constraint in a two-stage contest and find that as the rent increases, the ratio between second stage and first stage expenditures is constant if the budget constraint is not binding, while it decreases non linearly in the value of the rent if the constraint is binding[15].

Similarly to these works, we do consider the fact that players face a constraint on resources, but do not introduce explicitly a budget constraint. We rather consider that if players are to behave rationally, as is it customarily assumed in economic models, they will never let the sum of the outlays made through stages exceed their valuation, i.e. they will consider the reservation value they assign to winning the good as an implicit, natural cap on their total spending[16].

The important point that we share with this limited literature, however, is that when contestants are (artificially or rationally) budget-constrained, a fundamental trade-off exists when allocating resources over stages: the more resources a player spends in a particular stage the higher the chance to get shortlisted to the next stage, but the lower the chance to get shortlisted in later stages and eventually win.

However, strangely enough, the aforementioned works did not realize that the very presence of this trade-off implies that when a player strategizes on how much she will bid at each given stage she will be allowed

[14]For the role of effort caps in single-stage contests see Che and Gale (2003), where it is shown that if contestants are asymmetric it is optimal to handicap the most efficient one, and Gavious et al. (2002) who endogenize the choice of imposing a bid cap.

[15]See also Matros (2006), who studies optimal seeding in an elimination tournament where players face a fixed common budget constraint and the success function in each round is stochastic.

[16]We are planning to work at a version of the model where the budget constraint is modeled explicitly, which will allow to consider also the case where the budget constraint is lower than the valuation (while the present analysis amounts to the case where the budget constraint is greater or equal than the valuation).

to bid, she does not regard the total of the bids she has planned to spent until that stage as sunk, since they are *not* strategically irrelevant in her decision of how much to bid in the following stages. When there is a constraint on resources, expenditures made in earlier stages limit expenditures that can be done in later stages: the more a contestant spends early the less she has to spend later, the more she plans to spend later, the less she has to spend earlier. Therefore bids are sunk only when a contestant actually spends the money, but when she initially strategizes they are not sunk.

To the best of our knowledge the present work is the first one in the literature to make this simple but relevant point. The only paper that somehow considered that outlays in early stages may play a role in later stages, though with much different reasons and in a much different context, is Baik and Lee (2000). Motivated by those real world cases where efforts made in early stages affect the outcomes of later stages (e.g., sport games where scores in qualification stages are carried over to the final stage and added to the final-stage score), they study a two-stage Tullock contest with symmetric players and "multi-battle" shortlisting, and consider the effects on rent dissipation of allowing first-stage efforts to be partially "carried over" to the second stage, i.e., first-stage efforts are (partially) taken into account in second-stage decision making.

2.3 The model

Consider that N risk-neutral players participate to an *all-pay elimination contest* with K stages and "all-against-all" shortlisting, that is a multi-stage contest organized as K consecutive all-pay auctions where at each stage a given number of highest bidders is shortlisted to go to subsequent stages - but *all* players forfeit their own bid - and the players who are shortlisted in all stages are awarded a prize.

Let us define the set of players $\mathcal{N} = \{1, 2, ..., i, ..., N\}$ and the set of stages $\mathcal{K} = \{a, b, ..., k, ..., K\}$, with $\mathcal{N}, \mathcal{K} \subset \mathbb{N}_+$ [17]. We assume players to be risk-

[17] In the following, the subscript indices will refer to players and the superscripts will refer to stages.

neutral and asymmetric, i.e., players' valuations for winning a prize are $v_1 \geq v_2 \geq ... \geq v_N > 0$, where v_i is the valuation of the i-th player, with $v_i \in \mathbb{R}_+, \forall i \in \mathcal{N}$.

Also, we assume complete information, i.e., players know each other's valuations.

We indicate with q^k the number of players to be shortlisted at stage k, with $k \in \mathcal{K}$, $q^k \in \mathbb{N}_+$, so that q^K is the number of final winners, i.e., players that are awarded a prize. We assume that q^k can vary between stages - since the contest sponsor has discretion over that - and that it is exogenous, i.e., is determined and announced ex-ante by the sponsor.

Technically, the stage-auction at each intermediate stage k is a multi-unit all-pay auction where q^k "shortlisting tickets" are auctioned, while the final-stage auction is a multi-unit all-pay auction where q^K "final prizes" are auctioned [18]. In each stage each bidder demands one unit only. Each bidder allowed to play at k offers a non-negative bid (effort) $x_i^k \in \mathbb{R}_+ \cup \{0\}$ (the vector $x^k \in \mathbb{R}_+^{q^k} \cup \{\mathbf{0}\}$ being the *profile* of actions taken by the players who can play at k) and the q^k highest bidders are awarded the q^k shortlisting tickets to stage $k+1$, but all players pay their own bid.

We further define as the *marginal bid at stage k*, and indicate it with $x^k_{(q^k)}$, the q^k-highest bid, i.e., the stage-k bid of the last - or "weakest" - player who manages to get a ticket to stage $k+1$, so that shortlisted players have bids: $x^k_{(1)} \geq x^k_{(2)} \geq ... \geq x^k_{(q^k)}$. The bidder i such that $x_i^k = x^k_{(q^k)}$ is the *marginal bidder at stage k* [19]. The bidders who bid below the marginal bid at stage k are eliminated, while if a player bid exactly the marginal bid, two cases can occur:

"More tickets than marginal bidders" case: either there are no ties at the marginal bid or the number of players tying at the marginal bid is lower or equal than the number of shortlisting tickets remaining after that players who have bid higher than the marginal bid have already been shortlisted. In this case no tie-breaking is needed: all

[18] We borrow the tickets analogy from previous works: Lai and Matros (2006) talk about "entry tickets" and Fu and Lu (2012) about "tickets to the next stage".

[19] We borrow this definition from Fullerton and McAfee (1999), with a slight difference: in their work "marginal bidder" indicates the "first rejected bidder" while in our case it indicates the "last accepted" one.

the players who tie at the marginal bid will get shortlisted with certainty.

"More marginal bidders than tickets" case: the number of players tying at the marginal bid is higher than the number of remaining shortlisting tickets. In this case tie-breaking is needed and ties are broken uniformly at random so that player i has $\frac{\text{\# rem. tickets}}{m^k}$ probability of getting shortlisted to stage $k+1$, where m^k is the number of players (included i) who tie at the marginal bid in stage k.

Obviously, the same two cases can occur at the final stage K, with the only difference that players bid for prizes rather than for shortlisting tickets.
The shortlisting process is depicted in Figure 2.2, where for each player bidding at a given stage, it is indicated the bid which allowed her to get shortlisted to that stage.

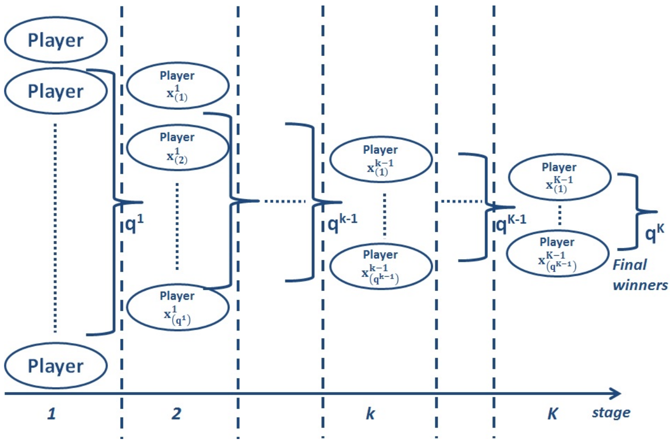

Figure 2.2: The shortlisting process in the elimination contest

For the sake of clarity, consider the following simple example. Suppose that there are 6 players allowed to bid at a given stage and that a total of 4 shortlisting tickets are available for the next stage. In this case

the marginal bid is the fourth highest bid. Suppose that two players bid higher than the marginal bid, one player bids lower and 3 players tie at the marginal bid. The high-bid players get with certainty the ticket to the next stage, and the low-bid player is eliminated. The number of tickets left is 2, but there are 3 players tying at the marginal bid, so that we are in the "more marginal bidders than tickets" case. Tie-breaking is needed: the 3 players at the tie have $\frac{2}{3}$ probability each to get a ticket. Suppose instead that there are just two players tying at the marginal bid, and two players bidding lower. In this case we are in the "more tickets than marginal bidders" case and there is no need of tie-breaking: both players at the tie get the ticket with certainty.
We define as the *net valuation* of player i who is shortlisted at stage k, and indicate it with NV_i^k, player i's valuation net of the sum of the bids she has made until stage k, i.e.,

$$NV_i^k \triangleq v_i - \sum_{l=1}^{k} x_i^l \quad \text{with} \quad NV_i^k \in \mathbb{R} \quad \forall i \in \mathcal{N}, k \in \mathcal{K} \tag{2.1}$$

Importantly, we assume that players' spending is implicitly capped by their own valuation: as discussed in the previous sections, a player's valuation, which represents the maximum amount of resources the player is *rationally* willing to spend for winning the prize, represents a "natural" cap on the total effort each player can exert as a whole in the competition[20].
Therefore, player i faces the following *implicit budget (or effort) constraint*:

$$\sum_{k=1}^{K} x_i^k \leq v_i \tag{2.2}$$

Notice that the maximum amount a player can spend at a given stage k is her net valuation at stage $k-1$, so that, relative to each stage k, we could rewrite the budget constraint of Equation 2.2 as:

$$x_i^k \leq NV_i^{k-1} \tag{2.3}$$

[20]See footnote 16.

Obviously, if player i spends exactly her net valuation, $x_i^k = NV_i^{k-1}$, she will have no resources left to spend from stage $k+1$ onward. This implies that other shortlisted players at stage $k+1$ would be able to beat player i with an infinitesimal amount, making her losing the entire budget. Therefore it is clear that in each stage where a player is allowed to play, the total of the bids she has planned to spend until that stage are not sunk, since they are not strategically irrelevant in her decision of how much to bid in following stages.
The consideration above implies that the preferences of player i, as represented by the payoff function at the final stage K are as follows[21]:

$$\Pi_i(h^K) = \begin{cases} v_i - \sum_{k=1}^{K} x_i^k, & \text{if } \{x_i^K > x_{(q^K)}^K\} or \{x_i^K = x_{(q^K)}^K and \text{ rem. prizes} > \text{ties}\} \\ \frac{v_i}{m^K} - \sum_{k=1}^{K} x_i^k, & \text{if } \{i \text{ ties at } x_{(q^K)}^K and \text{ ties} > \text{rem. prizes}\} \\ - \sum_{k=1}^{r} x_i^k \quad (r \leq K), & \text{otherwise} \end{cases} \tag{2.4}$$

The payoff function tells us that player i can end up in three situations: (i) if she makes it to the final stage and offers a bid higher than the marginal bidder (which, at this stage, is the last player who is awarded a prize), she "wins" (i.e., she is awarded a prize) with certainty. This also happens if player i is the marginal bidder but either she does not tie with anyone, or the number of ties is lower than the number of prizes left after the shortlisting of highest bidders ("more tickets than marginal bidders" case). In both cases she gets a payoff equal to her valuation net of the sum of all the bids she has made until the final stage; (ii) if player i ties with some other player(s) at the marginal bid in the final stage and the number of ties is higher than the number of prizes left ("more marginal bidders than tickets" case), she is awarded a prize only if she is selected by the uniformly random tie-breaking mechanism, but the sum of the bids she made is a *certain* outlay; (iii) if player i is eliminated before the final stage, or if she makes it but bids below the marginal bid, she incurs a loss equal to the sum of the bids she has made until the last stage she has been shortlisted in. Notice that the losses are greater the further the player is shortlisted through the stages.

[21]See Appendix A.1.1 for the complete and rigorous definition of the elimination all-pay auction in game theoretic terms.

It is plausible to think that if player i expects to get either a negative or a zero payoff in the game, she has no incentive to bid positive in any of the stages she will have a chance to bid in. In particular, we impose the two following assumptions to hold in the model:

Assumption 2.1 *Players who bid zero in a given stage are allowed to be short-listed to the next stage.*

In fact, it can be the case that the marginal bid is zero so that players bidding (with or without ties) at zero have a positive probability to get shortlisted. Therefore, unlike similar models, bidding zero is not equivalent to stay out of the contest. This implies that it also makes sense to assume that

Assumption 2.2 *Players who expect to get either a negative or a zero expected payoff always enter the game and bid zero in the first stage, as if they were not indifferent between staying out from the contest and entering, even if expected payoffs are the same.*

The first assumption could seem strong, however other works adopt similar ones. For example Fu and Lu (2012) assume that if all contestants who participate in a round make zero effort, the winner of that round is selected at random. We have used Assumption 2.1 in the current version of the model for simplicity, but we are currently working to amend the model so that zero bidders are no longer allowed to get shortlisted. However, we do not expect our results to change significantly.
At this stage of work we consider the basic case were $\mathcal{N} = \{1, 2, 3\}$, $\mathcal{K} = \{a, b\}$, $q^a = 2$ and $q^b = 1$. That is, there are three players and two stages, at the first stage two players are shortlisted and at the end only one player wins (i.e., one prize only is awarded). The model can be extended to the general case described above, and we plan to do that.
We analyze the case where players are asymmetric, i.e., have different valuations for the prize, $v_1 > v_2 > v_3 > 0$.

2.4 Characterization of equilibria

We solve the game by backward induction, looking for the complete set of Subgame Perfect Nash Equilibria (SPNE), i.e., of triples of strategies $(x_i^{a*}, x_i^{b*}) \quad \forall i \in \{1, 2, 3\}$. Therefore, we first look for the Nash Equilibria of the generic subgame after any possible (length-1) history h^a, namely the Stage-b all pay auction, and then, on the basis of continuation payoffs, we analyze the bidding in Stage-a [22].

2.4.1 Stage-b all-pay auction

In Stage-b the two players who got shortlisted from Stage-a, that is players $i, j : x_i^a, x_j^a \in \{x_{(1)}^a, x_{(2)}^a\}$, bid again to win the single final prize. Notice that since we are working backward, we do not know the identity of these players, so that we indicate them generically with i, j. The Stage-b (i.e., final) payoff function of player i (analogously for j) is as follows:

$$\Pi_i(h^b) = \begin{cases} v_i - x_i^a - x_i^b, & \text{if} \quad x_i^b > x_j^b \\ \frac{v_i}{2} - x_i^a - x_i^b, & \text{if} \quad x_i^b = x_j^b \\ -(x_i^a + x_i^b), & \text{if} \quad x_i^b < x_j^b \end{cases} \tag{2.5}$$

The payoff function above is obviously a particular case of the expression in Equation (2.4), and tells that: (i) if shortlisted player i bids higher than the other shortlisted player, she wins the prize with certainty and gets a payoff equal to her valuation net of the sum of the bids she has made in the two stages, i.e., equal to her *net valuation at Stage-b* $NV_i^b = v_i - (x_i^a + x_i^b)$, or, more meaningfully, equal to her *net valuation at Stage-a minus her Stage-b bid*, i.e., $NV_i^a - x_i^b$ where $NV_i^a = v_i - x_i^a$; (ii) if i ties with the other player, the winner of the prize is selected randomly but the sum of the bids is a certain outlay for both; (iii) if i bids lower than her opponent, she incurs a loss equal to the sum of the bids.

We observe here that differently from similar models (e.g., Groh et al. (2012), Fullerton and McAfee (1999)), we do not need to assume that players who make it to the final stage are all given a positive payment -

[22] For each $h^a \in \mathbb{R}_+^3$ there is a subgame, so that there are infinite possible subgames.

like a prize for finalists - independent from their performance in the final stage. This technicality is required in models where any player who bids zero in the first stage is *always* eliminated, since in that context ensuring that all players have a positive expected payoff from being shortlisted to the final stage is a necessary condition for the existence of an equilibrium in the first stage. Instead, as it will be clear in the following, our Assumption 2.1 implies that the case that some players have a zero expected payoff from being shortlisted to Stage-b does not create problems for the existence of an equilibrium in Stage-a.

Notice that the Stage-a bid must be present in the Stage-b payoff since, as said, we do not consider them as sunk. The Stage-a bid caps the maximum amount player i can spend in Stage-b, which is equal to her net valuation at Stage-a, i.e., $x_i^b \leq NV_i^a$.

Therefore, Stage-a net valuations represent the "updated" reservation value that each player assigns to winning the game when he has to decide how much to bid in Stage-b: this value takes into account that she has already spent part of her resources to get shortlisted to Stage-b. Therefore Stage-a net valuations play in the Stage-b all-pay auction the same role that ex-ante valuations play in a standard all-pay auction. This implies that the Stage-b subgame is analogous to a standard one-stage two-player all-pay auction with complete information. It is well known that this kind of auction does not have a Nash equilibrium in pure strategies, neither in the case where players are asymmetric nor in the case with symmetric players, but, in both cases, it does have a Nash equilibrium in mixed strategies (e.g., see Hillman and Samet (1987) for the symmetric case and Hillman and Riley (1989) and Baye et al. (1996) for the asymmetric case.)

Notice that even if players are ex-ante asymmetric, i.e., they have different valuations, after bidding in Stage-a they can become symmetric, in the sense that they can get the same net valuation. Therefore, we should consider two different cases:

ex-ante asymmetric - ex-post asymmetric players ("asym-asym" case):
: shortlisted players have different net valuations: in this case we will denote by H the player who is shortlisted to the Stage-b sub-

game with the *higher net valuation*, $NV_H = v_H - x_H^a$, and by L the player who is shortlisted to Stage-b with the *lower net valuation*, $NV_L = v_L - x_L^a$, with $H, L \in \{i, j\}$ and $NV_H > NV_L \geq 0$[23].

ex-ante asymmetric - ex-post symmetric players ("asym-sym" case): shortlisted players have the *same net valuations*, $NV_i = NV_j \geq 0$: in this case we will denote them by S and use the notation $NV_S = v_S - x_S^a$, with $S \in \{i, j\}$. Notice that this case can only happen if the ex-ante stronger between the shortlisted players made in Stage-a a higher bid than the ex-ante weaker player. However, as we will see, the "asym-sym" case will never occur in the SPNE.

The two following propositions characterize the equilibrium of the Stage-b game:

Proposition 2.1 (Existence of mixed strategy Nash equilibrium in the Stage-b all-pay auction)

1.1 *No pure strategy equilibrium can exist in the subgame, neither in the "asym-asym" case nor in the "asym-sym" case.*

1.2 *The equilibrium bid of each shortlisted player i in the Stage-b subgame is a random variable with cumulative distribution function (CDF) $F_i(x_i^b)$ which is continuous over $(0, \infty)$.*

1.3 *The support of the equilibrium CDF is the same $\forall i$ and is $[0, NV_L]$ in the "asym-asym" case and $[0, NV_S]$ in the "asym-sym" case.*

1.4 *In equilibrium at most one agent bids zero with strictly positive probability.*

Proof. In the Appendix A.1.2.

Proposition 2.2 (Nash equilibrium of the Stage-b all-pay auction) *The Stage-b all-pay auction has one of two possible different asymmetric Nash equilibria in mixed strategies, depending on which case occurs:*

2.1 "asym-asym" case: *If players got shortlisted with different net valuations, there is an unique equilibrium where the player who got shortlisted with the higher net valuation (player H) randomizes continuously over $(0, NV_L]$*

[23]Superscript of net valuations NV_i are omitted since the only net valuations we will refer to are those at Stage-a.

according to the mixed strategy $F_H(x_H^b) = (x_L^a + x_H^b)/v_L$, *and the player who got shortlisted with the lower net valuation (player L) randomizes continuously over* $(0, NV_L]$ *according to the mixed strategy* $F_L(x_L^b) = (NV_H - NV_L)/v_H + (x_H^a + x_L^b)/v_H$. *Players' equilibrium payoffs are respectively* $u_H^* = NV_H - NV_L = v_H - x_H^a - v_L + x_L^a > 0$ *and* $u_L^* = 0$.

2.2 "asym-sym" case: *If players got shortlisted with the same net valuation, there is an unique equilibrium where both players* i *and* j *randomize continuously over* $(0, NV_S]$ *according, respectively, to mixed strategies* $F_i(x_i^b) = (x_j^a + x_i^b)/v_j$ *and* $F_j(x_j^b) = (x_i^a + x_j^b)/v_i$, *and both get an equilibrium payoff of zero,* $u_S^* = 0$ *with* $S \in \{i, j\}$.

Proof. In the Appendix A.1.3.

Notice that an interesting asymmetric external effect arises in the equilibrium of the "asym-asym" case: player L has a positive external effect on player H through her past action x_L^a ($\frac{\partial F_H}{\partial x_L^a} > 0$, $\frac{\partial u_H^*}{\partial x_L^a} > 0$), the insight being that the more player L has spent in the first stage, the less aggressively player H will need to bid in the second stage to outbid L, and hence the higher will be her expected second-stage payoff. Conversely, player H does not have external effects on L (by reducing, $F_L(x_L^b) = (v_H - v_L)/v_H + x_L^a/v_H + x_L^b/v_H$). Morevoer, player H does not take into account his *own* Stage-a bid in his Stage-b equilibrium strategy (despite it is not-sunk), while player L does, and such that $\frac{\partial F_L}{\partial x_L^a} > 0$, meaning that the higher her bid in the first stage the less aggressively she will be able to spend in the second stage.
On the other hand, the equilibrium of the "asym-sym" case displays symmetric external effects: each player's equilibrium CDF contains the Stage-a bid of the opponent (but not her own). Despite more work is needed to fully understand these external effects and the intuition behind them, it seems that they do not have much in common with the effects studied in the literature on contests with externalities (see e.g., Klose and Kovenock (2015)), where typically players care (ex ante, not only in equilibrium) about the allocation of the prize in the event they lose[24].

[24]For a survey on contributions on externalities in winner-pay auctions see Jehiel and Moldovanu (2006).

Except for the presence of the Stage-a bids, the equilibrium strategies of the "asym-asym" case are identical to the ones of the one-stage all-pay auction with asymmetric players (see Theorem 3 in Baye et al. (1996)). On the other hand, the equilibrium of the "asym-sym" case resembles somehow the one of the one-stage all-pay auction with symmetric players (see Proposition 3 in Hillman and Samet (1987)), insofar both players get a zero expected payoff; however, differently from the one-stage game, equilibrium strategies embed the Stage-a bids and also display player-specific valuations at the denominator (obviously, given the ex-ante asymmetry between players).

Notice that *equilibrium payoffs are expressed in terms of net valuations, so that they take into account Stage-a bids*. Interpretation is that player L (in the "asym-asym" case) and player S (in the "asym-sym" case), who get a zero expected continuation payoff, sometimes win and sometimes lose, and are on average able to exactly cover the sum of their outlays, whereas player H (in the "asym-asym" case) is winning more often than losing, so that, on average, she is able to more than cover the sum of her outlays. Moreover, notice that we cannot check yet whether the equilibrium strategies respect requirement [1.4] in Proposition 2.1, since at this stage we do not know the equilibrium values of Stage-a bids. As we shall see, such requirement is met in the SPNE strategies.

Proposition 2.2 tells us something interesting: when players are ex-post asymmetric ("asym-asym" case) *the winner is, on average, the player who got shortlisted to Stage-b with the higher net valuation*, rather than the player with the original higher valuation (i.e., the ex-ante strongest player), as it was the case in the equilibrium of the one-stage game. The intuition behind this result is that *when players have limited resources to allocate between stages, winning depends crucially not only on the relative strengths of players, but also on how players allocate resources between the two stages*. However, we will see in the following that, due to the asymmetry between players, the strongest player (i.e., player 1) has an advantage over the other players, so that in equilibrium she will always be the player who gets shortlisted with the higher net valuation, and, consequently, will have better chances to be the final winner. Instead, when players are ex-post symmetric ("asym-sym" case), no player has an advantage, so that they have symmetric chances to be the final winner.

2.4.2 Stage-a all-pay auction

Now we go backward: given the continuation payoffs in Proposition 2.2, we ask what are the optimal choices of players at Stage-a, i.e., after history h^0.

The Stage-a all-pay auction is a multi-unit all-pay auction where two shortlisting tickets are auctioned.

Notice that $x^a_{(2)}$ is the marginal bid at Stage-a, so that player i (with $i = \{1,2,3\}$) will get shortlisted with certainty only if her Stage-a bid is greater than the marginal bid, or if she bids the marginal bid but we are in the "more tickets than marginal bidders" case, which in this case means that either $x^a_i = x^a_j > x^a_k$ or $x^a_j > x^a_i > x^a_k$. Instead, if i ties with other players at the marginal bid but we are in the "more marginal bidders than tickets" case, which in this case means that either $x^a_j > x^a_i = x^a_k$ (i.e., $m^a = 2$) or $x^a_i = x^a_j = x^a_k$ (i.e., $m^a = 3$), ties will be uniformly broken at random.

Formally, the Stage-a payoff function of player i is as follows [25]:

$$\Pi_i(h^a) = \begin{cases} u^*_i, & \text{if } \{x^a_i > x^a_{(2)}\} or \{x^a_i = x^a_j > x^a_k\} or \{x^a_j > x^a_i > x^a_k\} \\ \frac{\underline{\text{\# rem. tickets}}}{m^a} u^*_i, & \text{if } \{x^a_j > x^a_i = x^a_k\} or \{x^a_i = x^a_j = x^a_k\} \\ -x^a_i, & \text{otherwise} \end{cases} \tag{2.6}$$

where u^*_i is the continuation payoff of player i in case she is shortlisted, such that:

$$u^*_i = \begin{cases} 0, & \text{if} \quad i = \{L, S\} \\ NV_H - NV_L, & \text{if} \quad i = H \end{cases} \tag{2.7}$$

[25]Notice that each possible history of length-1 is a profile of actions, so that $h^a = x^a$, with $x^a \in \mathbb{R}^3_+$

Therefore, player i knows that: (1) if she is not shortlisted, she will incur a certain loss equal to her Stage-a bid; (2) if she is shortlisted with NV_L or NV_S, she will get a zero expected payoff, i.e., on average she will not be the final winner, while (3) if she is shortlisted with NV_H, she will get a positive expected payoff, i.e, on average she will be the final winner.

From Assumption 2.2 we have that players who expect to end up either in (1) or in (2) always enter the game and bid zero in Stage-a, and from Assumption 2.1 we have that players who bid zero in Stage-a have a chance to be shortlisted to Stage-b. On the other hand, if player i expects to end up in (3), she will bid in Stage-a the lowest possible amount that allows her to get shortlisted. From the discussion above it is clear that each player i's optimal choice in Stage-a is to make such a bid that allows her to get shortlisted with NV_H. However, the presence of an ex-ante asymmetry between bidders implies the following:

Proposition 2.3 (Advantage for ex-ante stronger players) *A player with a higher valuation has an "advantage" over a weaker player: if she underbids (at limit, overlaps to) a bidder with a lower valuation, she will get shortlisted with NV_H with certainty, provided that her bid allows her to get shortlisted. Formally:*

$$\forall x_i^a, x_j^a \in \{x_{(1)}^a, x_{(2)}^a\} \quad \textit{with} \quad x_i^a \leq x_j^a, \quad \textit{if} \quad v_i > v_j \quad \textit{then} \quad v_i - x_i^a > v_j - x_j^a \tag{2.8}$$

This result implies that *due to complete information*, an ex-ante weaker player that anticipates to be shortlisted with an ex-ante stronger player has no incentive to bid positive in Stage-a. This implies that in the equilibrium of the Stage-a game players 2 and 3 optimally bid zero and player 1 bids a very small positive amount. While in the Appendix A.1.4 we provide a complete proof of this result, consider the following heuristic reasoning to get an intuition of why this is the case: for any couple of *positive* bids she expects from her rivals, $x_i^a > x_j^a > 0$ with $i, j \in \{2, 3\}$, player 1's optimal choice is to "bid in between" i.e., such that $x_i^a > x_1^a > x_j^a$, since this always ensures that she is shortlisted with NV_H. Notice that

the case $x_2^a = x_3^a > 0$ will not occur in equilibrium insofar player 3 has no incentive to overlap with a strictly positive bid to stronger players, since in case she manages to get shortlisted, she will always get NV_L and hence a zero continuation payoff. But anticipating that this way they will never be able to get shortlisted with NV_H, players 2 and 3 have no incentive to bid positive in Stage-a. One could think therefore that player 1's optimal response, anticipating that player 2 and 3 will bid zero, might be to overlap and bid zero as well. However, notice that this way she would risk not to get shortlisted at all. For this reason she might rather prefer to bid an arbitrarily small positive amount, $\epsilon > 0$.
We prove that in fact this is exactly the case and that the following result holds:

Proposition 2.4 (Equilibrium of the Stage-a all-pay auction) *Given continuation payoffs in Equation 2.7, the Stage-a all-pay auction has a unique equilibrium in pure strategies, which is $x^{a*} = \{x_1^{a*} = \epsilon, x_2^{a*} = 0, x_3^{a*} = 0\}$. In this equilibrium only player 1 bids a positive amount, which is undetermined but very close to zero. Also, only the "asym-asym" case occurs in equilibrium, so that player 1 is always shortlisted with NV_H.*

Proof. In the Appendix A.1.4.

Proposition 2.5 (Equilibrium of the Stage-a all-pay auction - continued) *The Stage-a all-pay auction has no equilibria in mixed strategies, so that the pure-strategy equilibrium is the unique equilibrium of Stage-a.*

Proof. In the Appendix A.1.5.

2.4.3 SPNE of the two-stage all-pay auction

From Propositions 1-5 we get the following result:

Proposition 2.6 (SPNE of the two-stage all-pay auction) *When players have valuations $v_1 > v_2 > v_3 > 0$, the two-stage all-pay auction has a unique SPNE which is as follows:*

$$\begin{cases} \left(x_1^{a*} = \epsilon \simeq 0, \quad F_1(x_1^b) = \frac{x_1^b}{v_j} \quad \forall x_1^b \in [0, v_j]\right) \\ \left(x_j^{a*} = 0, \quad F_j(x_j^b) = \frac{v_1 - v_j}{v_1} + \frac{x_j^b}{v_1} \quad \forall x_j^b \in [0, v_j]\right) \end{cases} \tag{2.9}$$

with $j \in \{2,3\}$. Equilibrium payoffs are $u_1^* = NV_1 - NV_j = v_1 - \epsilon - v_j > 0$ and $u_j^* = 0$.

In this equilibrium only player 1, i.e., the ex-ante strongest player, bids positive in Stage-a. Consequently, she gets always shortlisted and always with NV_H. Player 2 and 3 bid zero, and one of them gets shortlisted at random, and always with NV_L[26]. In Stage-b shortlisted players randomize over a common support, whose upper bound is ex-ante undetermined and equal to $NV_j = v_j$ (since $x_j^{a*} = 0$). Player 1 gets a positive expected payoff, i.e., on average she wins the game, while the other shortlisted player gets a zero expected payoff, i.e., on average she makes no losses, and the player who is not shortlisted gets an actual zero payoff.

Therefore, even if the subgame result tells us that the player who will win on average the game is not the ex-ante strongest player, but rather the player who is able to allocate the resources such that she manages to get shortlisted with the higher net valuation, however the SPNE result tells us that *in fact, this player is always player 1, so that it seems that players' relative ex-ante strengths are more important, in determining the outcome of the game, than their relative abilities to allocate optimally limited resources over stages*.

The intuition for this result is that since there is complete information and the game is dynamic, players can use information about continuation payoffs and rivals' valuations to bid optimally in Stage-a. By Proposition 2.3, a player who anticipates that in the second-stage she will meet a stronger player, does not want to bid positive in the first stage. Because of Assumption 2.1, she can still be shortlisted but on average she will make no loss in the end. The information structure allows the strongest player to deter other players from bidding positive in the first stage, so that she can ensure to get shortlisted with a very small outlay and save most resources for the second stage. Therefore, even if the information structure in our model is different, we get a result similar to the literature about the effect of signaling in elimination contests with informa-

[26]Notice that the SPNE strategies meet the requirement 1.4 of Proposition 2.1.

tion revelation (e.g.,Lai and Matros (2006)): too much information does not necessarily lead to "good" outcomes. In both cases efficient shortlisting of players is prevented: in their case this is due to misrepresentation of preferences, whereas in our case it is due to the predatory behavior of the strongest player. Unsurprisingly, this is detrimental for total revenue (effort) extraction, as illustrated by the following proposition:

Proposition 2.7 (Expected Revenue) *The two-stage all-pay auction yields a lower expected revenue than the one-stage all-pay. The first stage yields virtually no revenue, whereas the second stage yields a lower expected revenue than the two-player all-pay due to inefficient shortlisting, that is the fact that the weakest player (i.e., player 3), has a positive chance to get shortlisted and to win eventually.*

Proof. In the Appendix A.1.6.

This result is consistent with the prediction in Gradstein and Konrad (1999) that when the contest rules are discriminatory enough, a one-stage contest yields a higher total effort than its multi-stage counterpart. In our case this is due to the fact that the multi-stage contest implies a positive probability that the second strongest player does not reach the final stage, so that shortlisting is inefficient.
Therefore, what emerges from our analysis is that a multi-stage all-pay auction does not seem to have very appealing features. However, it is reasonable to think that our results may depend on the simplicity of our analysis. In the next section we discuss some possible work developments aimed at enhancing the descriptive power of the model.

2.5 Conclusion

In this essay we have provided an auction-theoretic analysis of an innovative practice recently introduced in the EU for the procurement of R&D, i.e., Pre-commercial Procurement (PCP). Given the stepwise nature of PCP and the fact that all firms participating to the tender sustain a cost regardless of them winning or not, we have modeled PCP as an elimination all-pay contest with budget-constrained asymmetric players

and non-sunk bids.
The non-sunk feature is a fundamental novel feature brought by our modelization and relies on the consideration that when players are budget-constrained, they face a trade off when deciding how to allocate resources between earlier and later R&D phases: the more a player spends early the less she has to spend later, the more she plans to spend later, the less she has to spend earlier. This interplay between stages implies that when a player initially strategizes on how much to bid at each stage she might be called to play, she does not regard the total of the bids she has planned to bid until that stage as sunk, since they are not strategically irrelevant in subsequent stages. To the best of our knowledge, the present work is the first one in the literature to make this simple but relevant point. A second implication of the presence of the trade-off is that the winner may not be the player with the biggest budget, but rather the player who is the most able in allocating limited resources over stages.
However, focusing on a simple two-stage framework with complete information, we find that the relative strengths of players are more important than their relative abilities, in determining the (unique) equilibrium outcome of the game. This result stems from the fact that since the game is dynamic and there is complete information, players can use information about continuation payoffs and rivals' valuations to bid optimally in the first stage: a player who anticipates that in the second-stage will meet a stronger player, does not want to spend resources in the first stage. The information structure allows the strongest player to always deter other players from bidding positive in the first stage, so that she can ensure to get shortlisted with a very small outlay and save most resources for the second stage (where mixed strategies are played). This leads to the result that the two-stage all-pay contest yields a lower expected revenue than the single-stage one, since the first stage yields basically no revenue (due to the strongest player exerting a minimal effort in the first stage) and shortlisting is inefficient (since the weakest player has a positive chance to get shortlisted and eventually win).
On the basis of our results, PCP does not seem to be an advantageous practice to procure innovative goods, so that procurement officials should

not stick to such kind of practice. However, results are preliminary and more work is needed to fully assess PCP on theoretical grounds. Therefore, we are currently working at the implementation of a number of steps aimed at enhancing the descriptive power of the model. First, we are modifying the model so to no longer allow that players who bid zero in the first stage have a chance to get shortlisted, and to allow for a more realistic information structure. Also, we plan to assume players to be risk-averse. This, combined with embedding in the analysis of some modelization of the risk-sharing feature of PCP, will let us assess the positive impact - on players incentives - of the presence of a risk-sharing element in PCP with respect to other procurement practices which do not feature risk-sharing. All together, these steps will enable us to check whether our current results are in fact to some extent underestimating the potential performance of PCP.

To our knowledge this work represents the first attempt to provide a formal economic analysis of PCP. Assessing procurement practices on theoretical grounds (of both descriptive and normative nature) can complement the know-how of procurement practitioners in rationalizing their use as policy tools. This is particularly relevant given the huge impact that public procurement in general has on the whole economy, and in particular the critical potential of the procurement of innovation for enhancing the innovative performance and competitiveness of national industries. With this work we have hopefully initiated a fruitful research agenda on the theoretical analysis of PCP. An example of further work in this agenda could be to implement an optimal contest design study of PCP, which would help make the most of its potential. Also, the present work provided a contribution to the all-pay auction and elimination contest literature, since to the best of our knowledge this is the first attempt to characterize (under complete information) the equilibria of the elimination all-pay contest with non-sunk bids[27].

[27]The only step left to complete the characterization of the two-stage elimination all-pay contest is to analyze the case with ex-ante symmetric players. We also plan to extend the analysis to the general case with N players and K stages.

Chapter 3

Political Corruption in the Execution of Public Contracts: a Principal-Agent Analysis

3.1 Introduction

In June 2014 a huge corruption scandal burst in Italy concerning the public works for the MOSE, the ambitious project of underwater barriers designed to protect Venice from flooding. The inquiry led to the arrest of 35 people among entrepreneurs, bureaucrats and politicians (including the mayor of Venice and the former governor of Veneto), and to the investigation of other 100 people, with the charges of fiscal fraud, corruption, extortion and money laundering. The inquiry unveiled a well-established system where contracting and sub-contracting firms in the consortium of firms in charge of the MOSE works, systematically embezzled public funds, mainly via inflated and false billings. The embezzled money was then allocated to managers' private use and to buy the favoritism of national-level politicians (e.g., to unblock extra funding to the project) and the connivance of the authorities in charge of the monitoring of works[1]. Authorities reported that the money embezzled since the beginning of works in 2003 amounts to 1 billion euros, i.e. 20 percent of the current cost of the MOSE works (i.e., 5,6 billions euros at the 80 percent of completion).

The MOSE case, as well as other similar episodes, highlights two fundamental aspects about the relation between public procurement and corruption that have been neglected by the literature.

First, although it is well acknowledged that corruption may be a major source of cost-overruns in public procurement (see e.g., Auriol (2006), OECD (2007), TransparencyInternational (2006)), most contributions focus on corruption at the award stage (see e.g., Laffont and Tirole (1991), Celentani and Ganuza (2002), Burguet and Che (2004), Compte et al. (2005), Lengwiler and Wolfstetter (2006), Burguet and Perry (2007), Arozamena and Weinschelbaum (2009)), while the most severe overruns may rather follow from corruption at the implementation stage of the contract (see e.g., Piga (2011), Boehm and Olaya (2006)). Cases of corruption at the post-tendering stage are widespread and significant (e.g., see Søreide (2005) and Ware et al. (2007)). There are many forms in which post-tender corruption can occur in procurement. Most notably, the contracting firm can, with the connivance of some corrupt public official in charge of monitoring the execution of the contract, engage in cost-padding, namely accounting manipulations that allow it to inflate reimbursable costs and

[1] Authorities reported that the consortium paid real "annual wages"- ranging from 100.000 to 1 million euros per person per year - to regional and national level top politicians (both right and left-wing and also as electoral funding), as well as to regional officers, judges, intelligence officers, one high official of the Italian Financial Police and one judge of the Court of Accounts. In addition to monetary "wages", substantial favors were paid in in-kind utilities such as "renovation of villas, stays in grand hotel in Venice and Cortina, private flights, holidays in Tuscany, offers of unnecessary job positions in the consortium to sons and daughters of magistrates and officers, unnecessary consultancy contracts and hydro-geological studies which were not even read"(our translation from http://www.repubblica.it/cronaca/2014/06/07/news/mose_tangenti_e_sprechi_per_un_miliardo-88272959/?ref=search). The president of the consortium, which was also nicknamed by people in the system as the "Doge", used diverted money to increase his own salary by one million per year, to benefit relatives and even to build an image of himself as a philanthropist of Venice - creating job positions, funding university, sponsoring public events and even funding for 5 million the Italy stage of the America's cup (our translation from "Nonno Mose: trent'anni di tangenti a prescindere", il Venerdi di Repubblica, June 20-27, 2014).

divert public money to private uses (as in the MOSE case)[2][3].

However, despite the practical relevance of corruption at the execution stage of public contracts, to the best of our knowledge only two works have provided a theoretical analysis of this issue. The former is a paper by Laffont and Tirole (1993) (Ch.12), who analyze cost-padding in an extension of the standard regulatory problem with unobserved firm's productivity (see Laffont and Tirole (1986)), and allow for the possibility that the firm bribes the supervisor - a bureaucrat who audits the firm on behalf of a benevolent regulator - in order to consider the effect of corruption on optimal procurement contracts. More recently, Iossa and Martimort (2013) have studied how the procurement contract (and in particular the allocation of risk between parties) should be designed in order to minimize the scope for post-tender corruption, finding that the solution depends on a country's quality of auditing institutions and levels of corruption.

In the works above, the only kind of corruption which is allowed for is bureaucratic corruption, namely the contracting firm bribes the bureaucrat in charge of the monitoring of contract execution, since it needs its connivance to engage in illegal activities. The very first economic models of corruption focused on this problem, namely corruption is an agency problem where the bureaucrat is a corruptible agent of the government, which is instead regarded as a benevolent regulator (see e.g., Becker and Stigler (1974), Banfield (1975), Rose-Ackerman (1975) and Klitgaard (1988))[4].

However, big corruption scandals like the MOSE, show that corruption

[2]There are many ways contracting firms can pad costs, among which increasing expense claims for materials and supplies (via over-billing), charging advertising and other unallowable expenses to project costs, increasing managerial compensation, not reporting cost-reducing improvements (see e.g., Ware et al. (2007)).

[3]Notice that not all causes of cost overruns are driven by the firm's opportunistic behavior. For example, inadequate planning (due to complexity and uncertainty), and honest mistakes may be sources of severe cost-overruns but are driven by unintentional behavior of either the contracting firm or the purchasing authority. Another source of cost overruns that is not necessarily opportunism-driven is the political bias in choosing "wrong" projects and underestimating costs (like in the case of "white elephant" projects) (e.g., see Flyvbjerg (2007)).

[4]See Aidt (2003) for a survey on economic models of corruption.

may not be limited to minor bureaucratic levels, but rather involve higher levels of the political hierarchy, namely top-level politicians, who may as well have to gain from large-scale corruption[5]. Therefore, a second main aspect of the relationship between procurement and corruption that was neglected by the literature is that beside bureaucratic corruption, also *political* corruption can arise: when the potential gains from a corrupt deal are large, bureaucratic malfeasance can be often sustained by dishonesty at the top-level of the political hierarchy. While the general issue that all levels of government are rent-seeking and hence corruptible has a long-standing tradition in the "Public Choice" and political economy research agendas (see e.g., Buchanan and Tullock (1962), Barro (1973), Ferejohn (1986), Shleifer and Vishny (1993), Grossman and Helpman (2002), Besley (2007)), the problem has not been analyzed for public procurement in particular. To the best of our knowledge, the only exceptions are two recent empirical studies. The former is a work by Coviello and Gagliarducci (2010), who investigate the relationship between the time politicians stay in office and the functioning of procurement, finding that more time in office is associated with a worsening of procurement performance. The latter is by Goldman et al. (2013) who analyze the effect of political connections of publicly traded corporations in the US on the allocation of procurement contracts, and find that companies that are connected to the winning (losing) party are significantly more likely to experience an increase (decrease) in procurement contracts.

On the basis of the considerations above, in this work we want to provide a *political corruption* explanation of why cost-padding in the execution of public contracts is so widespread and substantial. We argue that the occurrence of cost-padding is not only due to the opportunism of the contracting firm, which takes advantage of the informational asymmetry which naturally arises in contract execution, but also to the opportunism

[5]Other examples, beside the MOSE case, are the Italian corruption scandals concerning the Milan world's fair EXPO 2015 (see e.g., (in italian) `http://www.repubblica.it/argomenti/tangenti_expo`), and the recent case "Sistema Incalza"(see e.g., (in italian) `http://espresso.repubblica.it/plus/articoli/2015/03/20/news/grandi-opere-i-nomi-del-sistema-ercole-incalza-1.205042`). In both cases corruption was found to involve top level politicians and former politicians.

of its political principal, who can be self-interested and corruptible and have a gain from designing perverse incentive schemes in order to induce the firm to embezzle money.
In particular, our model is an extension of the contract-theoretic cost-padding model in Laffont and Tirole (1993), where we allow both for the principal to be partially selfish - i.e., he maximizes a weighted average between social welfare and his own personal benefit - and for the auditing technology and the stakes of corruption to be endogenous and depending on the motives of the politician[6]: in our model the politician (principal) himself audits the firm (agent) and, depending on his degree of selfishness, decides both the level of auditing technology and, in case evidence of cost-padding is found, whether to enter a corrupt transaction with the firm, i.e., hide evidence in exchange of a share of the money embezzled by the firm[7]. This framework allows to develop a theory of endogenous political corruption: while in Laffont and Tirole (1993) cost-padding could emerge in optimal contracts only due to asymmetric information, in this model cost-padding and, consequently, corruption, are ultimately choices of the politician, which depend on his degree of selfishness.
We find that while a moderate politician (by choosing a relatively aggressive auditing technology) prevents the firm from engaging in cost-padding, an enough opportunist politician (via choosing a relatively weak auditing technology) leaves an incentive to pad costs in optimal contracts and, conditional upon detection, enters in a corrupt transaction with the firm. Moreover, an improvement in the efficiency of the fiscal system makes cost-padding easier to occur: this happens since a decrease in the social cost of cost-padding (in terms of less distortionary taxation) implies that also less opportunist politicians will be tempted to engage in

[6]The "mixed"view of the government was introduced by Grossman and Helpman (1994) in the context of lobbying and special interest politics, and can be found in other research agendas as well, e.g., in law enforcement and economics of crime (e.g., Garoupa and Klerman (2002) and Dittmann (2006)). The latter literature also use the endogenization of the detection technology.

[7]Dhami and Al-Nowaihi (2007) also have an agency problem where the principal (a politician) can be partially self-interested and audit himself the agent (a corruptible bureaucrat). However, the auditing technology is exogenous in their case.

corruption. This result can be also interpreted in light of the recent debate on State capacity (Besley and Persson (2010), Acemoglu (2010) Acemoglu et al. (2011)): by increasing the gains from staying in power, a more efficient fiscal system increases the politician's incentive to misuse public office. Therefore, without a coincident increase in political accountability, an increase in State capacity can be detrimental.
The rest of the essay is structured as follows: Section 3.2 presents the model; Section 3.3 analyzes the auditing subgame; Section 3.4 characterizes optimal contracts; Section 3.5 analyzes the optimal choice of auditing technology for the politician; Section 3.6 concludes. All proofs are gathered in the Appendix A.2.

3.2 The Model

3.2.1 Setting

A politician (principal) wants to contract the realization of a single and indivisible project of public utility from a monopolistic firm (agent)[8].
The politician is partially selfish, i.e. rather than being a purely benevolent social welfare maximizer as in Laffont and Tirole (1993) (Ch. 12, LT in the following), he maximizes a weighted average between social welfare (SW) and some measure of private utility (PU), which will be both defined shortly. Therefore, his objective function has the form:

$$U = SW + \mu PU \tag{3.1}$$

where $\mu \in [0, \infty)$ is a *selfishness parameter* measuring the weight placed by the politician on private utility relative to social welfare (see e.g., Dhami and Al-Nowaihi (2007)[9]). According to the value of μ, politicians

[8] The firm might be the winner of a procurement tender or a concessionaire for that project (like in the MOSE case).

[9] This modelization of the politician's preferences was first introduced by Grossman and Helpman (1994). A possible alternative modelization (see e.g., Dittmann (2006)) makes use of a convex combination i.e.,

$$U = (1 - \alpha)SW + \alpha PU \tag{3.2}$$

with $\alpha \in [0, 1]$, where the limit cases are $\alpha = 0$ (purely benevolent) and $\alpha = 1$ (purely can be categorized as follows:

Definition 3.1 *If $\mu > 1$ the politician is "opportunist", i.e., he cares relatively more about his private utility; if $\mu \leq 1$ the politician is "moderate", i.e., he cares relatively more about social welfare.*

The LT purely benevolent politician and the "Public Choice" purely selfish politician are limit cases of this modelization, where, respectively, $\mu = 0$ and $\mu \to \infty$.
As in LT, the firm's technology is represented by the following linear cost function

$$C(\beta, e, a) = \beta - e + a \tag{3.3}$$

where β is a parameter which measures the technological efficiency (or "intrinsic productivity") of the firm, with $C_\beta > 0$ (a high β corresponds to an inefficient technology), e is the level of cost-reducing effort ($C_e < 0$) and a is the level of cost-padding, i.e., money embezzlement ($C_a > 0$). The realized cost of the project is equal to actual cost $(\beta - e)$ plus cost-padding[10].
The efficiency parameter β is private information to the firm. The politician only knows that there are two possible types of firms, a low-cost (efficient) type L, and a high-cost (inefficient) type H, i.e., $\beta \in \{\beta_L, \beta_H\}$, with $\beta_L < \beta_H$, and has a prior distribution over the two types i.e., $\nu = P(\beta = \beta_L) \in (0, 1)$. Cost-reducing effort e and cost-padding activity a are post-contractual choice variables which are both unobservable for the politician. Only the realized cost C is observable and verifiable by the politician. Therefore, this is an extension of the standard regulatory problem in Laffont and Tirole (1986) where the moral-hazard problem becomes two-dimensional: the firm can try to inflate observed costs (and hence the reimbursement it receives from the regulator) not only by exerting a suboptimal level of effort, but also by embezzling money[11].
Notice that despite both adverse selection and moral-hazard are present

selfish).

[10]If the firm exerts effort level e it reduces realized cost by e, and if it engages in a level of cost-padding of a it increases realized cost by a.

[11]Two other cost-padding models that build on Laffont and Tirole (1986) are

in this model, the key dimension of analysis is adverse selection (on the efficiency parameter) since both moral-hazard variables (i.e., cost-reducing effort and cost-padding) result deterministically in a level of cost realization C[12].

Moreover, exerting a cost-reducing effort level e brings disutility (expressed in monetary terms) of $\psi(e)$ to the firm. The disutility increases with effort $\psi_e > 0$ for $e > 0$, it is convex $\psi_{ee} > 0$, and satisfies $\psi(0) = 0$ and $\lim_{e \to \beta} \psi(e) = +\infty$. Following LT, for simplicity we assume that equilibrium effort is always positive.

Also, we adopt the accounting convention that the politician reimburses C to the firm, and compensates it by a net monetary transfer t in addition to the reimbursement of the cost (it is assumed that otherwise the firm does not accept the project). We impose the limited-liability constraint $t \geq 0$.

A contract between the politician and the firm can be based on observables C and t, and specifies a cost-transfer pair (C, t). If the firm does not accept the contract, it gets its reservation utility, which is normalized to zero.

The project has constant value $S > 0$ for consumers. To finance the realization of the project, that costs $(C + t)$ (where C of course includes embezzled money), the politician levies distortionary taxation: for each dollar raised by taxation, consumers bear disutility $\$(1 + \lambda)$, with $\lambda > 0$, where λ denotes the shadow cost of public funds.

We also assume that for the politician it is worth realizing the project even with an inefficient firm ($\beta = \beta_H$)[13]. All agents (i.e., politician, firm and consumers) are assumed to be risk-neutral.

Also, we rule out any issue of political accountability or of contractual renegotiation. In particular, we assume that there is an implicit mechanism that enforces all legal and illegal contracts and ensures credibility

Chu and Sappington (2007) and Bougheas and Worrall (2012). However, these models do not introduce a second moral-hazard variable, arguing that cost-padding can be simply interpreted as *negative effort*. Also in neither of these models there is auditing or collusion.

[12] Therefore, the contracting problem we analyze is technically one of screening, as is standard in agency models of regulation already mentioned.

[13] LT also allow for the possibility of shut-down of the firm and find that it is worth to keep the inefficient type active as long as S is sufficiently high.

of announcements[14].

3.2.2 Audit of Cost-padding and Corruption

We assume that after the contract has been implemented, i.e., the firm has chosen its levels of effort and cost-padding, the politician audits the firm about cost-padding[15].

In this model the politician audits himself the firm rather than resorting to a supervisor, so that the agency problem has a two-tier structure rather than a three-tier one as in LT and in many other models of auditing and regulation (see e.g., Tirole (1992), Laffont and Tirole (1993), Mookherjee and Png (1995) and Kofman and Lawarree (1996)). We introduce this simplification on the basis that the role of a corruptible supervisor in a model where the principal is himself corruptible seems redundant[16].

We assume that the auditing technology simply amounts to a level of detection probability, $\rho \in [0, 1]$, and is *endogenous* and dependent on the degree of selfishness of the politician, $\rho(\mu)$. The politician chooses strategically the level of detection probability, and announces it before offering contracts to the firm. Therefore, we assume that at the moment of auditing the firm, the politician will simply audit the firm according to the predetermined auditing technology[17].

The auditing technology is costless and produces hard-information, namely for a given level of cost-padding $a \geq 0$, the politician will detect the true (and verifiable) level of cost-padding ($\hat{a} = a$) with probability $\rho(\mu)$ and nothing ($\hat{a} = \emptyset$) with probability $1 - \rho(\mu)$ [18].

If no hard evidence of cost-padding is found, the firm keeps the en-

[14]We acknowledge that this assumption is strong and we are planning to relax it in an extension of this work.

[15]We borrow this modelization of auditing from Dhami and Al-Nowaihi (2007), albeit in their case the auditing technology is exogenous.

[16]However, this is less justifiable on practical grounds, since the politician typically use bureaucrats to audit the firm, and would likely need the intermediation of the bureaucrat to enter corrupt deals. See Section 3.6 for a discussion on possible extensions of the model.

[17]This is admissible insofar we have ruled out issues of commitment credibility. More on this in Subsection 3.2.4.

[18]Dhami and Al-Nowaihi (2007) also adopt hard information auditing technology. LT instead assume a different auditing technology which produces soft-information i.e., the signals of the true level of cost-padding are always imperfect and errors can occur.

tire amount of diverted money[19]; if instead hard evidence is found, the politician can either confiscate the money and return it to consumers as a lump-sum transfer, or can offer to suppress evidence in return of a share of the embezzled money[20]. This decision is *endogenous* and depends on the degree of selfishness of the politician. If the firm accepts the sharing offer, they divide the money and nothing is returned to consumers. If instead the firm does not agree to share the money, the amount of diverted money is confiscated and returned back to consumers[21]. Therefore, the stakes of corruption, which amount to the level of money embezzled by firm, are endogenous in this model and depend on the politician's behavior. The optimal sharing between the firm and the politician is determined by the Nash-bargaining solution[22]. We believe that this is the appropriate modelization in our context, since what we have in mind is the world of big projects where the gains from cost-padding are potentially large and contractors are likely to have substantial bargaining power relative to corrupt politicians (as it was indeed the case in the MOSE scandal).
The timing of the game is summarized in Figure 3.1.

3.2.3 Agents' Preferences

On the basis of the setting described above, we can now define agents' preferences.

[19] Differently from LT, we assume that there is no deadweight loss associated with the diversion of funds that is, the firm derives utility \$1 from padding cost by \$1. On the other hand LT consider that accounting manipulations may be costly in expertise, time and need of secrecy and hence create a deadweight loss.

[20] Differently from LT, we assume that the money diverted by cost-padding can be fully recouped by the politician in case of detection, whereas LT assume that cost-padding is fully consumed by the firm before the audit. The fact that successful auditing can end up in a refund to consumers is also present in Baron and Besanko (1984).

[21] However, it could seem also plausible that in case of unsuccessful bargaining the politician instead keeps all the money for himself. A possible explanation could be that the politician then fears that the firm may report something to the police, while he is safe if he returns money back to consumers. Hence, the politician tries to pocket money only in case an agreement with the firm is reached. For more on the modelization of a judicial authority, see Section 3.6.

[22] This also is borrowed by Dhami and Al-Nowaihi (2007).

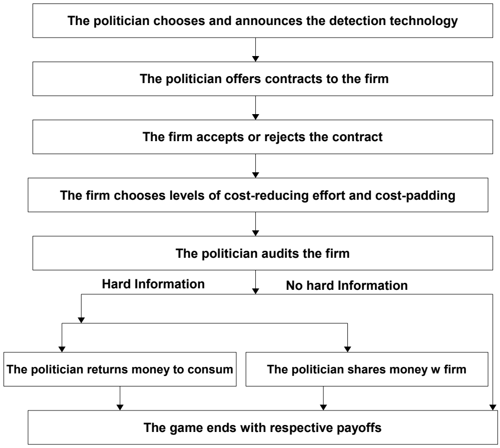

Figure 3.1: The timing of the game

Firm

The profit of a firm of type β who accepts contract (C, t) and engages in a level of cost-padding $a \geq 0$ is:

$$\Pi(\mu) = \begin{cases} t + a - \psi(\beta - C + a), & \text{if } \hat{a} = \emptyset \\ t + a^F(\mu) - \psi(\beta - C + a), & \text{if } \hat{a} = a \end{cases} \tag{3.4}$$

That is, in case hard evidence of cost-padding is not found ($\hat{a} = \emptyset$) the firm keeps the full amount of embezzled money a. If instead hard evidence of cost-padding is found ($\hat{a} = a$), the share of embezzled money accruing to the firm, a^F, will depend on whether the politician will be willing to enter Nash-bargaining with the firm, which, as said, is an endogenous decision dependent on his selfishness μ. Notice that a represents both the level of cost-padding chosen by the firm and the gains from cost-padding, and hence also amounts to the endogenous stakes of corruption.

Also, due to the linearity of the cost function, when the firm commits

to a contractual cost level C, choosing a level of cost-padding a will imply that the level of cost-reducing effort e it needs to exert is determined residually, $e = \beta - C + a$. Further, differently from LT, we assume that the transfer t paid by the politician is not dependent on the outcome of the auditing: the firm is not punished above the confiscation of the diverted money[23].
The expected profit of the firm can therefore be written as:

$$\mathbb{E}[\Pi(\mu)] = t + \mathbb{E}[a^F(\mu)] - \psi(\beta - C + a) \tag{3.5}$$

where $0 \leq \mathbb{E}[a^F(\mu)] \leq a$.

Consumers

Analogously, the expected welfare of consumers when the contracting firm is of type β, accepts contract (C, t) and engages in cost-padding level $a \geq 0$ is:

$$\mathbb{E}[W(\mu)] = S + \mathbb{E}[a^C(\mu)] - (1 + \lambda)(C + t) \tag{3.6}$$

where $C = \beta - e + a$ and $\mathbb{E}[a^C(\mu)]$ is the expected amount of embezzled money that will be returned back to the consumers as a lump-sum transfer.

Politician

In this model the private utility of the politician will merely amount to the share of embezzled money accruing to the politician, a^P. Therefore, the objective function of a politician with self interest μ when the contracting firm is of type β, accepts contract (C, t) and engages in cost-padding level $a \geq 0$ is:

$$\mathbb{E}[U(\mu)] = \mathbb{E}[SW(\mu)] + \mu\mathbb{E}[a^P(\mu)] \tag{3.7}$$

[23]In LT, who assume that cost-padding cannot be confiscated because it is consumed by the firm before auditing, the penalty in case of detection is the retention of transfer ($t_a = 0$).

Now we turn to defining social welfare SW in our model[24]. While some authors in the literature (see e.g., Dhami and Al-Nowaihi (2007), Garoupa and Klerman (2002)) argue that including profits in social welfare is questionable because of the inclusion of proceeds of corruption (and so they adopt consumer surplus as the measure of social welfare), we rather believe that the utilitarian view, as adopted by LT, is more realistic, insofar real world regulators need to take into account the interest of the private sector even if it may engage in illegal activities. However, we go a step further with respect to LT. Since the self-interest of the politician does not interfere with the social-welfare component of the objective function, we assume that conditional upon detection, the politician will, *regardless of his type*, include in social welfare only the "socially efficient" level of profits, Π_{SW}, i.e., profit net of the firm's gain from cost-padding (which after detection is observable and measurable)[25]. More formally,

Assumption 3.1 *If* $\hat{a} = a$, $\Pi_{SW}(\mu) \equiv t - \psi(\beta - C + a) \quad \forall \mu$.

Accordingly, we will distinguish between the expected profit of the firm $\mathbb{E}[\Pi(\mu)]$, which was defined in (3.5) and using Assumption 3.1 can be written as

$$\mathbb{E}[\Pi(\mu)] = \Pi_{SW} + \mathbb{E}[a^F(\mu)] \tag{3.8}$$

and the part of expected profit to be included in social welfare,

$$\mathbb{E}[\Pi_{SW}(\mu)] = \Pi_{SW} + \mathbb{E}[a^F_{SW}(\mu)] \tag{3.9}$$

where $\mathbb{E}[a^F_{SW}(\mu)] = [1 - \rho(\mu)]a$ is the fraction of expected firm's share of embezzled money to be included in the social welfare, such that $\mathbb{E}[a^F_{SW}(\mu)] \leq \mathbb{E}[a^F(\mu)]$.

Therefore, the politician's objective function will be $\mathbb{E}[U(\mu)] = \mathbb{E}[W(\mu)] + \mathbb{E}[\Pi_{SW}(\mu)] + \mu\mathbb{E}[a^P(\mu)]$, or extensively

$$\mathbb{E}[U(\mu)] = S + \mathbb{E}[a^C(\mu)] - (1+\lambda)(C+t) + t + \mathbb{E}[a^F_{SW}(\mu)] - \psi(\beta - C + a) + \mu\mathbb{E}[a^P(\mu)] \tag{3.10}$$

[24] SW is to be interpreted in monetary terms in order for the weighted average to be meaningful.

[25] The increased disutility in effort remains the same since effort has already been exerted.

Using the fact that $\mathbb{E}[\Pi_{SW}(\mu)] = \mathbb{E}[\Pi(\mu)] + \mathbb{E}[a^F_{SW}(\mu)] - \mathbb{E}[a^F(\mu)]$ we can obtain a more meaningful expression for the social welfare component of the objective function, namely

$$\mathbb{E}[SW(\mu)] = S + \mathbb{E}[a^C(\mu)] + \lambda(\Delta\mathbb{E}[a^F(\mu)]) - (1+\lambda)(C - \mathbb{E}[a^F_{SW}(\mu)] + \psi(\beta - C + a)) - \lambda\mathbb{E}[\Pi(\mu)] \tag{3.11}$$

which tells us that social welfare is the difference between the consumer surplus attached to the project S (increased by the expected transfer to consumers $\mathbb{E}[a^C(\mu)]$ and by the social gain from not including cost-padding in the profits conditional upon detection $\lambda\Delta\mathbb{E}[a^F(\mu)]$, where $\Delta\mathbb{E}[a^F(\mu)] \equiv \mathbb{E}[a^F(\mu)] - \mathbb{E}[a^F_{SW}(\mu)]$) and the sum of (i) the total cost of the project as perceived by taxpayers $(1+\lambda)(C - \mathbb{E}[a^F_{SW}(\mu)] + \psi(\beta - C + a))$ and (ii) the social cost of giving the firm a rent above its reservation utility $\lambda\mathbb{E}[\Pi(\mu)]$.
This expression also shows that, due to distortionary taxation, the politician dislikes leaving a rent to the firm.

3.2.4 Equilibrium Concept and Information Revelation

The relevant equilibrium concept is Perfect Bayesian Equilibrium (PBE), since the politician both chooses the auditing technology and offers contract under uncertainty about the type of firm he is facing (he just has a prior belief). Notice that while the politician will update his beliefs after the firm has chosen a contract (since the firm may reveal some information about its type through the contract choice), however he will not use this information in the following of the game (i.e., in the auditing subgame), since we assumed that he can credibly commit to the announcement about the level of auditing made at the first stage: in this model the politician is a "blind executor" at the auditing stage[26]. Also, notice that a

[26]Our conjecture is that nothing substantial would change in equilibrium in case he had the possibility to change the level of auditing, at least as long as auditing is costless. We will get back on this in Section 3.6.

successful audit does not add any new information about the firm's type which has not already been revealed by the firm's contract choice.
The game is to be solved by backward induction, therefore we will first characterize the equilibrium of the auditing subgame and derive the equilibrium expected shares of embezzled money $\mathbb{E}[a^{F*}(\mu)]$, $\mathbb{E}[a^{P*}(\mu)]$ and $\mathbb{E}[a^{C*}(\mu)]$; then, on the basis of continuation payoffs we will analyze optimal contracts for the politician $(C^*(\mu), t^*(\mu))_i \quad, i \in \{L, H\}$ (which, since the politician as usual acts as a Stackelberg leader, take into account the firm's optimal choices of cost-padding and cost-reducing effort); last, on the basis of optimal contracts, we will analyze the optimal choice of detection probability for the politician, $\rho^*(\mu)$. Notice that until the last stage (Section 3.5), the detection probability is considered as a parameter, $\rho \in [0, 1]$.

3.3 The auditing subgame

If the politician does not discover hard evidence of cost-padding ($\hat{a} = \emptyset$) the equilibrium shares of embezzled money are trivially $a^{F*}(\mu) = a$, $a^{P*}(\mu) = 0$ and $a^{C*}(\mu) = 0 \quad \forall \mu$.
Instead, if the politician discovers hard evidence of cost-padding ($\hat{a} = a$) he will choose the most profitable between the two options of entering Nash-bargaining with the firm or returning money to consumers. This decision will depend on the Nash-bargaining solution, which we now derive.
If we let $a^P \in [0, a]$ be the politician's share of the embezzled money, we have that if the politician and the firm manage to reach an agreement on the sharing of the cake, their respective payoffs are[27]:

$$U_A = S - (1 + \lambda)(t + C) + \Pi_{SW} + \mu a^P \tag{3.12}$$

[27]Notice that without Assumption 3.1 we would have a problem in implementing Nash-bargaining, since the utility of one bargaining party- the politician - would have included the utility of the other bargaining party - the firm. The interpretation of Assumption 3.1 is that the politician *temporarily* confiscates the money and invites the firm to Nash-bargain over it.

$$\Pi_A = \Pi_{SW} + (a - a^P) \tag{3.13}$$

If instead they do not manage to reach an agreement, the politician returns money to consumers as a lump-sum transfer. Therefore, the disagreement payoffs are:

$$U_D = S + a - (1 + \lambda)(t + C) + \Pi_{SW} \tag{3.14}$$

$$\Pi_D = \Pi_{SW} \tag{3.15}$$

The equilibrium shares will be given by the solution to the following problem:

$$\max_{a^P:(U_A,\Pi_A)\geq(U_D,\Pi_D)} (U_A - U_D)(\Pi_A - \Pi_D) \tag{3.16}$$

It is immediate to check that $U_A \geq U_D$ can hold only if the politician is opportunist, i.e., $\mu > 1$ (while the firm always find it profitable to enter bargaining). As we expected, we have that Nash Bargaining will occur only if the politician is selfish enough. Otherwise ($\mu \leq 1$), he will return money to consumers. Importantly, notice that the politician does not need to be fully benevolent (i.e., $\mu = 0$) to decide not to enter the corrupt deal. This is an interesting aspect of this result, since it allows for the realistic interpretation that a politician may well be self-interested but not enough to engage in corruption.

Therefore, if the politician is opportunist (indicated with subscript O) the optimal shares of embezzled money will be: $a_O^{P*} = \frac{1+\mu}{2\mu}a$, $a_O^{F*} = \frac{\mu-1}{2\mu}a$, $a_O^{C*} = 0$, where a^{P*} and a^{F*} are given by the bargaining solution. Notice that $\frac{\partial a_O^{P*}}{\partial \mu} < 0$[28]. Interpretation is that a more eager politician is easier to bribe: like impatience, selfishness reduces bargaining power.

Instead, if the politician is moderate (indicated with subscript M) the optimal shares are: $a_M^{P*} = 0$, $a_M^{F*} = 0$, $a_M^{C*} = a$[29].

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[28] Also, notice that $\lim_{\mu\to\infty} \frac{1+\mu}{2\mu}a = \frac{a}{2}$, $\quad \lim_{\mu\to 1+} \frac{1+\mu}{2\mu}a = a$.

[29] There is a discontinuity at $\mu = 1$: $\lim_{\mu\to 1+} a^{P*} = a$ but for $\mu \leq 1$ $a^{P*} = 0$.

From the results above we can derive the optimal expected shares of embezzled money (which take into account the case that hard evidence is not found) and state the following result:

Proposition 3.1 (Expected equilibrium shares of a) *The expected equilibrium shares of embezzled money depend on the type of politician and are as follows:*

$$\mathbb{E}[a_j^{P*}] = \begin{cases} 0, & j = M \\ \rho \frac{1+\mu}{2\mu} a, & j = O \end{cases} \tag{3.17}$$

$$\mathbb{E}[a_j^{F*}] = \begin{cases} (1-\rho)a, & j = M \\ (1-\rho \frac{1+\mu}{2\mu})a, & j = O \end{cases} \tag{3.18}$$

$$\mathbb{E}[a_j^{C*}] = \begin{cases} \rho a, & j = M \\ 0, & j = O \end{cases} \tag{3.19}$$

The expected continuation payoffs for the politician and the firm from the auditing subgame are simply the expressions in (3.7) and (3.8) where money shares are at their equilibrium levels i.e.,

$$\mathbb{E}[U_j^*] = \mathbb{E}[SW_j^*] + \mu\mathbb{E}[a_j^{P*}], \quad \mathbb{E}[\Pi_j^*] = \Pi_{SW} + \mathbb{E}[a_j^{F*}] \quad j \in \{M, O\} \tag{3.20}$$

Notice that so far we have just determined the optimal *shares* of embezzled money, but the optimal level of cost-padding is yet to be determined and will be an optimal choice of the firm.

3.4 Optimal Contracts

3.4.1 Firm's Optimal Cost-padding Choice

After accepting contract (C, t) the firm decides its optimal level of cost-padding a by solving the problem

$$\max_{\{a \geq 0\}} \quad \mathbb{E}[\Pi_j^*] = t + \mathbb{E}[a_j^{F*}] - \psi(\beta - C + a) \quad j \in \{M, O\} \tag{3.21}$$

Remember that due to the linearity of the cost function, when the firm commits to a contractual cost level C, choosing a level of cost-padding

a will imply that the level of cost-reducing effort e it needs to exert is determined residually, $e = \beta - C + a$. In particular, for a given C, an increase in a needs to be counterbalanced by an equal increase e. This suggests that, since the marginal disutility of increasing effort is lower for the efficient type ($\psi_{e\beta} > 0$), for a given cost level a more efficient type will engage in more cost-padding than a less efficient type[30]. This result is proved to be true and is stated as follows,

Proposition 3.2 (Proposition 1 LT) *If for a given cost level C a_L^* and a_H^* are the optimal levels of cost-padding for, respectively, β_L and β_H, then it must be the case that $a_L^* \geq a_H^*$.*

Proof. In the Appendix (A.2.1).

It is important to remark that Proposition 3.2 asserts that the more efficient type engages in more cost-padding than the less efficient type *for a given cost level*, not that the more efficient type will engage in more cost padding *in equilibrium*, since in general different types will produce at different costs.

In order to derive optimal contracts, we will analyze the simple case where cost-padding can take only two levels $a \in \{0, \alpha\}$ ($\alpha > 0$) that is, following LT, we stylize the firm's cost-padding decision to a dichotomic choice.Therefore, the optimal choice of cost-padding for the firm reduces to the following: after accepting contract (C, t), the firm will engage in cost-padding (i.e., $a = \alpha$) iff $\mathbb{E}[\Pi_j^*(a = \alpha)] \geq \mathbb{E}[\Pi_j^*(a = 0)]$, which implies

$$\mathbb{E}[\alpha_j^{F*}] \geq \psi(\beta - C + \alpha) - \psi(\beta - C) \tag{3.22}$$

where $\mathbb{E}[\alpha_j^{F*}]$ with $j \in \{M, O\}$ is the firm's equilibrium share of cost-padding from Proposition 3.1[31]. This condition simply tells that the firm

[30]Condition $\psi_{e\beta} > 0$ amounts to the Spence-Mirrlees Single-crossing condition in our case, which will ensure the sustainability of a separating equilibrium in optimal contracts (see e.g., Bolton and Dewatripont (2005)). Notice that $\psi_{\beta} > 0$ also holds, namely the efficient type has a lower disutility from effort.

[31]In the following optimal contract analysis we will use the generic notation for the subgame equilibrium shares of cost-padding $\mathbb{E}[\alpha_j^{F*}]$, $\mathbb{E}[\alpha_j^{P*}]$ $\mathbb{E}[\alpha_j^{C*}]$, and will make them explicit only later when needed. Also, we will omit the star superscript.

will engage in cost-padding iff the gain from engaging in cost-padding (i.e., the firm's expected share of embezzled money) outweighs its cost (i.e., the extra disutility of effort due to cost-padding).

3.4.2 Benchmark: No Cost-padding

As a benchmark, we first consider the case where cost-padding is unfeasible.
First, notice that in this case there is no possibility for the politician to pursue his personal interest, since in our model this is uniquely represented by his share of embezzled money. Therefore, regardless of his type, the politician's objective function reduces to social welfare $U_j = SW \quad \forall j \in \{M, O\}$ *as if* he were benevolent[32]. Also, the cost function of the firm in this case is $C(\beta, e) = \beta - e$.
In this case the model is identical to the basic regulatory model in Laffont and Tirole (1986), which is a standard model in contract theory[33]. While referring to this work for the complete analysis, here we just briefly summarize (in our notation) relevant results and intuitions.

Complete information

Under complete information, i.e. when the principal knows β and observes the cost-reducing effort e, the firm cannot misrepresent its type and the politician can directly contract on the level of effort to be taken by each type of firm[34]. The politician will offer contracts (e_i, t_i) (or equivalently, (e_i, Π_i)) that maximize SW under Individual Rationality constraints i.e., $\Pi_i = t_i - \psi(e_i) \geq 0 \quad i \in \{L, H\}$.
The solution of this problem (indicated with superscript BC) is

[32] Also notice that in absence of cost-padding $\mathbb{E}[\Pi_{SW,j}] = t - \psi(\beta - C) \quad \forall j \in \{M, O\}$, so that the regulator is purely utilitarian.

[33] More exactly, is identical to the model in Ch.1 of Laffont and Tirole (1993), which is the two-type version of Laffont and Tirole (1986).

[34] This is the definition of complete information in Laffont and Tirole (1993)(Ch 1). However, notice that in this case the principal does not need to observe effort, since, knowing β, he can infer its level from observing costs $e = \beta - C$.

$$e_i^{BC} = e^{FB} : \psi'(e^{FB}) = 1; \quad \Pi_i^{BC} = 0 : t_i^{BC} = \psi(e^{FB}) \quad i \in \{L, H\} \tag{3.23}$$

namely, for both types: (i) the optimal level of effort is the first best one, namely the one which equates marginal social cost (i.e., marginal disutility of effort) and marginal social benefit (i.e., marginal cost savings), and (ii) the firm receives no rent, since distortionary taxation is socially costly. Therefore, the complete information solution is the socially optimal one and corresponds to the politician offering both types a fixed-price contract, such as e.g., $t(C_i) = k-(C_i-C_i^{FB})$, where $C_i^{FB} = \beta_i - e^{FB}$ and $k = \psi(e^{FB}), \quad i \in \{L, H\}$ [35]. Notice that this first best outcome requires the same effort level for both types, since the disutility of effort function $\psi(.)$ and the marginal productivity of effort are identical for both types. Accordingly, they receive the same transfer but the inefficient type is allowed to produce at a higher realized cost, $C_H^{BC} > C_L^{BC}$.
The value function of the politician in this case, which amounts to social welfare under complete information, is

$$U^{BC} = S - (1+\lambda)(\beta_i - e^{FB} + \psi(e^{FB})) \tag{3.24}$$

Incomplete information

Under incomplete information the politician can still observe the realized cost C but does not know the true value of the efficiency parameter β and does not observe the effort level e. In this case we have a standard screening problem where the principal offers a menu of type-contingent contracts based on contractibles (C_i, t_i) (or equivalently, (C_i, Π_i)) which maximize *expected* SW under Individual Rationality (IR) and Incentive Compatibility (IC) constraints: $IR_i : t_i - \psi(\beta_i - C_i) \geq 0$, $IC_i : t_i - \psi(\beta_i - C_i) \geq t_k - \psi(\beta_i - C_k), \quad i \neq k, \quad i,k \in \{L, H\}$. This problem has the following well-known solution (indicated with superscript BI):

[35]It is straightforward to check that level of effort that maximizes the firm's utility $\{k - (\beta_i - e_i - C_i^{FB}) - \psi(e_i)\}$ is exactly e^{FB}.

$$e_L^{BI} = e^{FB}, \quad e_H^{BI} < e^{FB} : (1-\nu)(1+\lambda)[1-\psi'(e_H^{BI})] = \nu\lambda\Phi'(e_H)$$
$$\Pi_L^{BI} = \Phi(e_H^{BI}) : t_L^{BI} = \psi(e_L^{BI}) + \Phi(e_H^{BI}), \quad \Pi_H^{BI} = 0 : t_H^{BI} = \psi(e_H^{BI}) \tag{3.25}$$

where $\Phi(e_H) = \psi(e_H) - \psi(e_H - \Delta\beta)$, $\Phi'(e_H) > 0$ and $\Delta\beta = \beta_H - \beta_L$.

The interpretation is as standard in these kind of screening problems. The efficient type can profitably mimic the inefficient type (since thanks to its higher efficiency he enjoys a rent in economy of disutility of effort), so the principal needs to give him a positive rent if he wants to have both types active. This rent is an increasing function of the effort level required from the inefficient type, so that the principal reduces the rent by distorting downward the effort required from the inefficient type, while still requiring the first-best effort from the efficient type ("efficiency at the top" is preserved). The optimal value of e_H balances the trade-off between the two regulatory goals of efficiency, which calls for high-powered incentive schemes (i.e., fixed-price contracts), and rent extraction, which calls for low-powered incentive schemes (i.e., cost-sharing contracts)[36]. The value function of the politician in this case, which amounts to social welfare under incomplete information, is:

$$\begin{aligned} U^{BI} &= \nu[S - (1+\lambda)(\beta_L - e^{FB} + \psi(e^{FB})) - \lambda\Phi(e_H^{BI})] + \\ &+ (1-\nu)[S - (1+\lambda)(\beta_H - e_H^{BI} + \psi(e_H^{BI}))] \end{aligned} \tag{3.26}$$

3.4.3 Optimal contracts under cost-padding

Now we let the firm engage in cost-padding, so that the the cost function of the firm is $C(\beta, e, a) = \beta - e + a$.
We analyze first the case with complete information and then the case with informational asymmetries.

[36] A marginal decrease e_H has a marginal cost in terms of an increase by $1-\psi'(e_H)$ in the production cost of type H, but also a marginal benefit in terms of a decrease by $\Phi'(e_H)$ of the rent we need to give to type L. As shown by the FOC, the optimal level of e_H equates expected marginal cost $(1-\nu)(1+\lambda)[1-\psi'(e_H)]$ and expected marginal benefit $\nu\lambda\Phi'(e_H)$.

Complete information

Knowing the true value of the efficiency parameter β and observing the level of effort e, the politician can offer type-contingent contracts (t_i, e_i) or - in our notation - (Π_i, e_i). Notice that given the observability of C, the politician can infer the level of cost-padding, $a = C - \beta + e$, as if auditing technology were perfect, i.e., $\rho = 1$: the politician will always detect cost-padding when the firm does it[37]. While in LT this obviously implies that the politician, who is benevolent, requires $a = 0$ (so that the problem trivially backs to the case where cost-padding is unfeasible), here we need to distinguish between the two types of politician, since the decision depends on his selfishness. From the auditing subgame in Section 3.3 we know that upon detection a moderate politician will confiscate the money, $a^F_M = 0$. Therefore under a moderate politician the firm will never engage in cost-padding, since condition (3.22) will never hold $\forall \alpha > 0$, and the solution is the same as when cost-padding is unfeasible (Equation (3.23))[38]. Instead, if the politician is opportunist he will share embezzled money with the firm according to Proposition 3.1, so that his maximization problem is:

$$\begin{aligned} \max_{\Pi_i, e_i} \quad & \{S - (1+\lambda)[\beta_i - e_i + a_i + \psi(e_i)] - \lambda \Pi_i + \lambda a^F_{iO} + \mu a^P_{iO}\} \\ \text{s.t.} \quad & IR_i : \Pi_i = t_i + a^F_{iO} - \psi(e_i) \geq 0 \quad i \in \{L, H\} \end{aligned} \tag{3.27}$$

As usual, the individual rationality constraints IR_i will be binding in equilibrium[39]. Notice that the objective function of the politician differs from the objective function in the case where cost padding is unfeasible only through the term $\{-(1+\lambda)a_i + \lambda a^F_{iO} + \mu a^P_{iO}\}$ which is a constant in

[37]Notice that in this case the expectation operator disappears, and $\mathbb{E}[a^F_{SW,ij}] = 0$ and $\Delta\mathbb{E}[a^F_{ij}] = a^F_{ij} \quad \forall i, j$.

[38]Remember that $\psi'(.) > 0$.

[39]The fact that in the auditing subgame both the firm and the politician have bargaining power while in contracting all the bargaining power is in the hands of the politician (i.e., he offers a take-it-or-leave-it offer to the firm) may seem an incongruence, but can be meaningfully justified as follows: in legal transactions (such as contracting) the politician, as a regulator, has all the bargaining power; in illegal transactions instead (such as taking bribes) he needs to bargain to obtain a good deal.

the maximization problem. Therefore even in the case of an opportunist politician, the solution (indicated with superscript CC) is identical to the solution in the benchmark case (Equation (3.23)), namely each type is offered a fixed-price contract [40]. Since the fixed-price contract makes the firm residual claimant for its cost-savings, no type will engage in cost-padding, i.e., $a_L^{CC} = a_H^{CC} = 0$: the effort level induced from a fixed-price contract implies a marginal disutility of effort equal to 1 ($\psi'(e^{FB}) = 1$), so that each dollar diverted through cost-padding costs the firm 1 dollar of monetary disutility from the required extra-effort. Paying the entirety of diverted money, the firm has no incentive to pad costs.
Due to the ex-post absence of cost-padding, the value of the politician's objective function is the same as in (3.24). Therefore, regardless of the type of the politician, the solution is *ex-post* identical to that in LT, as if the politician were purely benevolent. This result does not seem much plausible, since one would rather expect that if the politician is particularly opportunist (μ is very high), which means he values much more private utility than social welfare, then he should let the firm engage in cost-padding, since this is the only way he can obtain private gains. This sort of inconsistency in our model is due to the linearity of the cost function, which reduces the level of cost-padding - i.e., the only determinant of the personal utility of the politician - to a *parameter* in his maximization problem. We are planning to work to a more sophisticated modelization of costs, which should eliminate this inconsistency[41].
We summarize the results in the following proposition:

Proposition 3.3 (Optimal contracts under complete information) *Under complete information the contracting solution is first-best with no cost-padding, and the selfishness of the politician is irrelevant.*

[40]The politician can offer the fixed-price contract $t(C) = k - (C_i - C_i^{FB})$ where $k = \psi(e^{FB})$, $C_i = \beta_i - e_i + a_i$ and $C^{FB} = \beta_i - e^{FB}$.

[41]Another possibility is that in this case the individual rationality constraint may not be binding at the optimum.

Incomplete information

We suppose now that the politician does not know β and does not observe e, but only observes C[42]. In this case the politician would in principle want to proceed as in the benchmark case, namely choose type-contingent contracts (C_i, t_i) (or, $(C_i, \mathbb{E}[\Pi_i])$) to maximize her expected utility $\mathbb{E}[U_j]$ under individual rationality constraints IR_i, and incentive compatibility constraints IC_i, with $i \in \{L, H\}, \quad j \in \{M, O\}$. However, differently from the standard screening problem, here IC_i are more problematic to characterize, since we do not know which level of cost-padding will a type choose *when mimicking the other type*, so that the rents from mimicking are undetermined.
In order to obviate this problem LT consider different possible solutions, and then check for which conditions on parameters can each of these optima be an equilibrium. We follow the same approach, and consider that depending on which are the optimal levels of cost-padding for each type of firm, in principle four types of optima are possible:

Type1 Only the inefficient type engages in cost-padding: $a_H^* = \alpha$, $a_L^* = 0$;

Type2 Only the efficient type engages in cost-padding: $a_H^* = 0$, $a_L^* = \alpha$;

Type3 Both types engage in cost-padding: $a_H^* = \alpha$, $a_L^* = \alpha$;

Type4 Neither type engages in cost-padding: $a_H^* = 0$, $a_L^* = 0$.

We do not need to analyze all four types of equilibria, since the following holds:

Proposition 3.4 (Lemma 6 LT) *In each type of optimum, the efficient type is always offered a fixed-price contract, so that $a_L^* = 0$. Therefore, only the inefficient type can do cost-padding in equilibrium.*

Proof. In the Appendix (A.2.2).

Proposition 3.4 implies that we can restrict attention to Type1 and Type4 optima. In all the section it is exploited the fact that constraints

[42] This is the definition on incomplete information in LT. The intermediate cases where only one of the two variables is unobservable are not considered.

IR_L and IC_H can be ignored since the former is implied by IC_L and IR_H, and the latter holds at the solution (See Appendix A.2.6).

Type1 optima: cost-padding by the inefficient type

Suppose the case $a_H^* = \alpha, a_L^* = 0$ is an optimum. The cost level of the inefficient type is then $C_H = \beta_H - e_H + \alpha$. Let us denote with a_L^m the optimal level of cost-padding for the efficient type when it mimics the inefficient type (i.e., chooses contract (C_H, t_H)). Then, we know by Proposition 3.2 that $a_L^m = \alpha$[43]. Therefore, relevant constraints IC_L and IR_H are respectively:

$$\mathbb{E}[\Pi_L] = t_L - \psi(\beta_L - C_L) \geq t_H + \mathbb{E}[\alpha_j^F] - \psi(\beta_L - C_H + \alpha) \tag{3.28}$$

$$\mathbb{E}[\Pi_H] = t_H + \mathbb{E}[\alpha_j^F] - \psi(\beta_H - C_H + \alpha) \geq 0 \tag{3.29}$$

Using the fact the these constraints will be binding at the optimum, which implies that $\mathbb{E}[\Pi_H] = 0$ and $\mathbb{E}[\Pi_L] = \psi(e_H) - \psi(e_H - \Delta\beta) = \Phi(e_H)$ we can reduce the maximization problem of politician j's to the following unconstrained problem in e_i,:

$$\begin{aligned} \max_{e_H, e_L} \quad & \{\nu[S - (1+\lambda)[\beta_L - e_L + \psi(e_L)] - \lambda\Phi(e_H)] + \\ & (1-\nu)[S - (1+\lambda)[\beta_H - e_H + \psi(e_H)] + (1-\nu)G(\alpha_j)\} \end{aligned} \tag{3.30}$$

where $G(\alpha_j) = \mathbb{E}[\alpha_j^C] - (1+\lambda)\mathbb{E}[\alpha - \alpha_{SW,j}^F] + \lambda\Delta\mathbb{E}[\alpha_j^F] + \mu\mathbb{E}[\alpha_j^P]$ is a constant which adds to expected social welfare insofar the inefficient type engages in cost-padding. Importantly, notice that the value of the constant depends on the type of the politician.
Since $G(\alpha_j)$ is a constant in the maximization problem, the contracting solution (in terms of optimal effort and rent levels) is the same as in the benchmark case, as stated in the following result:

[43]Notice that $a_H^* = a_L^m = \alpha$ respects Proposition 3.2: for a given cost $C = C_H$, $a_L^m \geq a_H^*$.

Proposition 3.5 (Type1 Optima: Cost-padding by type H) *We define the "Cost-padding Regime" as the contracting solution where the inefficient type engages in cost-padding. This solution (indicated with superscript CP) is the same as in the benchmark case (Equation 3.25)*[44].

The value function of the politician will however be different since the inefficient type engages in cost-padding:

$$U_j^{CP} = U^{BI} + (1-\nu)G(\alpha_j) \tag{3.31}$$

The incentive for the inefficient type to pad costs is due to the fact that it is offered a cost-sharing contract, which implies $\psi'(e_H) < 1$ so that, unlike in the fixed-price contract, the gain from diverting 1 dollar through cost-padding outweighs its cost (in terms of marginal disutility). Therefore, under cost-sharing the firm does not pay the entirety of diverted money so that, unlike the efficient type, it has an incentive to pad costs. Notice that, regardless of the type of the politician, cost-padding would never arise if rent extraction were not a regulatory concern, since the politician would always offer the fixed-price contract to both types[45]. Moreover, the lower the optimal power of incentives (i.e., the lower the effort required from the inefficient type), the higher it would be the incentive to pad costs for the inefficient type.
The Cost-padding Regime occurs in equilibrium when the inefficient type *wants* to engage in cost-padding (i.e., he does not want to deviate to no cost-padding) given optimal effort e_H^{CP}, therefore - using condition (3.22) and $\beta_H - C_H + \alpha = e_H$ - iff

$$\mathbb{E}[\alpha_j^F] \geq \psi(e_H^{CP}) - \psi(e_H^{CP} - \alpha) \tag{3.32}$$

Expliciting condition (3.32) with respect to the detection technology ρ, yields the following result:

Proposition 3.6 (Occurrence of the Cost-padding Regime) *Under either type of politician $j \in \{M, O\}$, the cost-padding regime occurs when $\rho \leq \underline{\rho}_j$, where*

[44] The only difference is that type H is given a zero *expected* - rather than actual - rent: $\mathbb{E}[\Pi_H^{CP}] = 0$ (or equivalently, a transfer $t_H^{CP} = \psi(\beta_H - C_H + \alpha) - \mathbb{E}[\alpha_j^F]$.)

[45] Again, this is due to the assumption of linear costs. The more sophisticated modelization we are planning to go for is likely to allow for the result that under an opportunist politician cost-padding occurs even in absence of adverse selection (see Dhami and Al-Nowaihi (2007)).

$$\underline{\rho}_j = \begin{cases} \frac{\alpha - [\psi(e_H^{CP}) - \psi(e_H^{CP} - \alpha)]}{\alpha}, & \text{if } j = M \\ \frac{\alpha - [\psi(e_H^{CP}) - \psi(e_H^{CP} - \alpha)]}{\alpha} \left(\frac{2\mu}{\mu+1}\right), & \text{if } j = O \end{cases} \tag{3.33}$$

The intuition is that the firm has a relatively high incentive to engage in cost-padding if the probability of being discovered is relatively *low*, i.e., cost-padding is difficult to detect. Furthermore, the following results hold: (i) when the gains from cost padding increase it is easier for the cost-padding regime to occur ($\frac{\partial \underline{\rho}_j}{\partial \alpha} > 0$, $j \in \{M, O\}$); (ii) when the politician is opportunist, it is more likely that the cost-padding regime occurs i.e., $\underline{\rho}_O > \underline{\rho}_M$, and (iii) the more opportunist is the politician the more likely is the cost-padding regime to occur ($\frac{\partial \underline{\rho}_O}{\partial \mu} > 0$). These results are plausible, since an opportunist politician is more eager to receive a share of the cost-padding gains, which occur only in this regime[46].

Proof. In the Appendix (A.2.3).

Type4 optima: no cost-padding

Suppose now that the case $a_H^* = 0$, $a_L^* = 0$ is an optimum. The cost level of the inefficient type therefore would be $C_H = \beta_H - e_H$.
In this case, if type L chooses contract (C_H, t_H), both $a_L^m = 0$ and $a_L^m = \alpha$ are admissible by Proposition 3.2. Therefore, the IC_L is less trivial to define than before, insofar we want that the rent of the efficient type is such that he does not want to mimic the inefficient type neither without engaging in cost-padding:

$$IC_L(a_L^m = 0) : \mathbb{E}[\Pi_L] \geq t_H - \psi(\beta_L - C_H) \tag{3.34}$$

nor with engaging in cost-padding

$$IC_L(a_L^m = \alpha) : \mathbb{E}[\Pi_L] \geq t_H + \mathbb{E}[\alpha_j^F] - \psi(\beta_L - C_H + \alpha) \tag{3.35}$$

By using the fact that constraint IR_H will bind at the optimum as usual i.e., $\mathbb{E}[\Pi_H] = t_H - \psi(e_H) = 0$, we can rewrite (3.34) and (3.35) respectively as

[46]It would be also possible to explicit condition (3.32) with respect to α, which is the other relevant parameter, but ρ is the parameter of interest in our analysis and we checked that the condition with respect to α is in fact driven by the behavior of ρ (i.e., we need conditions on ρ to say something about α).

$$\mathbb{E}[\Pi_L] \geq \Phi(e_H) \tag{3.36}$$

and

$$\mathbb{E}[\Pi_L] \geq \Gamma(e_H) \tag{3.37}$$

where $\Gamma(e_H) \equiv \psi(e_H) - \psi(e_H - \Delta\beta + \alpha) + \mathbb{E}[\alpha_j^F]$.
Depending on which of the constraints (3.36) and (3.37) binds at the optimum, different regimes can emerge.
To consider all possibilities we set the following maximization problem, where use is made of Proposition 3.4 (so that $e_L^* = e^{FB}$ and $a_L^* = 0$), and of $\mathbb{E}[\Pi_H^*] = 0$:

$$\begin{aligned} \max_{e_H, \mathbb{E}[\Pi_L]} \quad & U(e_H, \mathbb{E}[\Pi_L]) = \nu[S - (1+\lambda)[\beta_L - e^{FB} + \psi(e^{FB})] + \\ & - \lambda\mathbb{E}[\Pi_L]] + (1-\nu)[S - (1+\lambda)[\beta_H - e_H + \psi(e_H)]] \\ \text{s.t.} & (3.36), (3.37) \end{aligned} \tag{3.38}$$

which yields the following result:

Proposition 3.7 (Type4 Optima: No Cost-padding) *When type H does not engage in cost-padding two contracting solutions can occur. We define the solution where $a_L^m = 0$ (i.e., when (3.36) is binding and (3.37) is not binding) as the "Classical Regime"(indicated by superscript CL), while the solution where $a_L^m = \alpha$ (i.e., when (3.37) is binding and (3.36) is not binding) as the "Repressed Cost-padding Regime"(indicated by superscript RC)*[47].
Under the Classical Regime the contracting optimum is the same as in the benchmark case (Equation (3.25)) i.e. $e_H^{CL} = e_H^{BI}, \Pi_L^{CL} = \Phi(e_H^{BI})$, and $U^{CL} = U^{BI}$.
Under the Repressed Cost-padding Regime the optimum is $e_H^{RC} > e^{BI}$, $\Pi_L^{RC} = \Gamma(e_H^{RC}) > \Phi(e_H^{BI})$ (or $t_L^{RC} = \psi(e_L^{RC}) + \Gamma(e_H^{RC})$), where $e_H^{RC} : \psi'(e_H^{RC}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\Gamma'(e_H^{RC})$.
The two contracting solutions are mutually exclusive. Further, given the concavity of the maximization problem in (3.38) the objective function $U(e_H, \mathbb{E}[\Pi_L])$ has a unique global maximum, so that $U^{CL} = U^{RC} = U^{BI}$.

Proof. In the Appendix (A.2.4).

Proposition 3.7 states that the optimal power of incentives is higher in the Repressed Cost-padding Regime than in the other solutions, and

[47] In LT the Repressed Cost-padding regime is the case where both constraints are binding, which does not admit solutions in our case. See Appendix (A.2.4).

in particular with respect to the benchmark solution where cost-padding is unfeasible ($e_H^{FB} > e_H^{RC} > e_H^{CL} = e_H^{CP} = e_H^{BI}$). This implies that also the rent to be given to the efficient type is higher ($\Pi_L^{RC} > \Pi_L^{CL} = \Pi_L^{CP} = \Pi_L^{BI} > \Pi_L^{FB}$).
This is the main result in LT, who give the following intuition. Increasing e_H is more attractive in the Repressed Cost-padding regime, i.e., when the efficient type would like to engage in cost-padding when mimicking the inefficient type, sue to the fact that cost-padding increases the marginal disutility $\psi'(e_H - \Delta\beta + \alpha)$ of the efficient type of mimicking the inefficient type with respect to the case without cost-padding, $\psi'(e_H - \Delta\beta)$. This implies that a marginal increase in e_H increases the rent of the efficient type by less than when the efficient type does not want to pad costs ($\Gamma'(e_H) < \Phi'(e_H)$)[48].
The Classical Regime occurs in equilibrium iff the efficient type does not want to engage in cost-padding when mimicking the inefficient type, i.e., iff $\Phi(e_H^{CL}) \geq \Gamma(e_H^{CL})$, or:

$$\mathbb{E}[\alpha_j^F] \leq \psi(e_H^{CL} - \Delta\beta + \alpha) - \psi(e_H^{CL} - \Delta\beta) \tag{3.39}$$

that is, when the cost of engaging in cost-padding (in terms of the increase in disutility) outweighs the benefit from cost-padding. Notice that this condition is necessary and sufficient for the emergence of the Classical Regime, since we know from Proposition 3.2 that if the efficient type does not engage in cost-padding for a given cost (C_H in this case), then the inefficient type will not deviate to cost-padding.
Expliciting condition (3.39) with respect to ρ we obtain the following result:

Proposition 3.8 (Occurrence of Classical Regime) *Under either type of politician $j \in \{M, O\}$, the Classical Regime occurs when $\rho \geq \overline{\rho}_j$, where*

$$\overline{\rho}_j = \begin{cases} \frac{\alpha - [\psi(e_H^{CL} - \Delta\beta + \alpha) - \psi(e_H^{CL} - \Delta\beta)]}{\alpha} & \text{if } j = M \\ \frac{\alpha - [\psi(e_H^{CL} - \Delta\beta + \alpha) - \psi(e_H^{CL} - \Delta\beta)]}{\alpha} \left(\frac{2\mu}{\mu+1}\right) & \text{if } j = O \end{cases} \tag{3.40}$$

The intuition is that the firm has a relatively low incentive to engage in cost-padding if the probability of being discovered is relatively *high* (i.e.,

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[48]The optimal level of e_H is the one that equates the expected marginal benefit of increasing e_H, in terms of a reduction by $[1 - \psi'(e_H)]$ in the production cost of type H, and the expected marginal cost, in terms of an increase by $\Gamma'(e_H)$ of the rent for type L: $(1-\nu)(1+\lambda)[1 - \psi'(e_H^{RC})] = \nu\lambda\Gamma'(e_H^{RC})$, which corresponds to the F.O.C.

cost-padding is likely to be detected). Furthermore, the following results hold: (i) when the politician is opportunist, it is less likely that the Classical Regime occurs, since $\overline{\rho}_O > \overline{\rho}_M$; (ii) the more opportunist is the politician the less likely is the Classical Regime to occur ($\frac{\partial \overline{\rho}_O}{\partial \mu} > 0$); (iii) when the efficiency differential increases, the cost of cost-padding (in terms of extra-disutility) drops, so that it is less likely for the Classical Regime to occur ($\frac{\partial \overline{\rho}_j}{\partial \Delta\beta} > 0$); (iv)when the gains from cost padding increase it is *more* likely for the Classical Regime to occur ($\frac{\partial \overline{\rho}_j}{\partial \alpha} < 0$).

Proof. In the Appendix (A.2.5).

Result (iv) seems less intuitive but can be explained by remembering that in our model α represents not only the gain from cost-padding but also the level of cost-padding activity: while the marginal gain from cost-padding is constant with respect to the level of cost-padding, the marginal cost in terms of disutility is increasing, so that for an high enough level of cost-padding, the cost outweighs the benefit.

On the other hand, the Cost-padding Regime occurs in equilibrium iff the efficient type does want to engage in cost-padding when mimicking the inefficient type, i.e., $\Gamma(e_H^{RC}) \geq \Phi(e_H^{RC})$ *and* the inefficient type does not want to engage in cost-padding i.e., the reverse of condition (3.22) holds (Proposition 3.2 does not help in this case). Therefore the following double-condition must hold

$$\psi(e_H^{RC}) - \psi(e_H^{RC} - \alpha) > \mathbb{E}[\alpha_j^F] \geq \psi(e_H^{RC} - \Delta\beta + \alpha) - \psi(e_H^{RC} - \Delta\beta) \quad (3.41)$$

Notice that (3.41) implies that the Repressed Cost-padding Regime can occur only if

$$\psi((e_H^{RC})) - \psi((e_H^{RC}) - \alpha) > \psi((e_H^{RC}) - \Delta\beta + \alpha) - \psi((e_H^{RC}) - \Delta\beta) \quad (3.42)$$

This condition is verified *with certainty* only if $\Delta\beta > 2\alpha$. In remaining cases i.e., $\Delta\beta \leq \alpha$ and $\alpha < \Delta\beta < 2\alpha$ it can be checked (by use of the Mean Theorem) that it is impossible to determine unambiguously which side of (3.42) is greater (apart for the limit case $\Delta\beta = 0$, for which (3.42) never holds). Therefore, to avoid such ambiguities, we will assume in the following that

Assumption 3.2 *The Repressed Cost-padding Regime can occur only if* $\Delta\beta > 2\alpha$.

Proposition 3.9 (Occurrence of the Repressed Cost-padding Regime) *Under both types of politician, the Repressed Cost-padding Regime occurs for intermediate values of detection technology i.e.,* $\underset{\sim}{\rho}_j < \rho \leq \tilde{\rho}_j$*,* $j \in \{M, O\}$ *where the expression for* $\underset{\sim}{\rho}_j$ *is identical to the one in (3.33) with* e^{RC} *in place of* e^{CP}*, and the expression for* $\tilde{\rho}_j$ *is identical to the one in (3.40) with* e^{RC} *in place of* e^{CL}*.*
The facts that $\psi(.)$ *is increasing and that* $e_H^{RC} > e_H^{CP} = e_H^{CL}$ *imply that* $\underset{\sim}{\rho} < \underline{\rho}$ *and* $\tilde{\rho} < \overline{\rho}$*.*

Combining the results obtained in Proposition 3.6 and Proposition 3.8, we have the following results about the range of values of ρ that sustain the Repressed Cost-padding Regime: (i) an increase in α shrinks the range from both sides; (ii) the range under an opportunist politician is shifted to right with respect to a moderate one, and the more he is opportunist the more is shifted; (iii) an increase in the efficiency differential shrinks the range from right.
We are know able to gather results of this section in the following proposition

Proposition 3.10 (Optimal contracts under incomplete information) *Under incomplete information, three different regimes can occur, depending on the value of the detection probability* ρ*: (i) for* $0 < \rho \leq \underset{\sim}{\rho}_j$*: only the Cost-padding Regime occurs; (ii) for* $\underset{\sim}{\rho}_j < \rho \leq \underline{\rho}_j$ *either the Cost-padding or the Repressed Cost-padding can occur; (iii) for* $\underline{\rho}_j < \rho \leq \tilde{\rho}_j$ *only the Repressed Cost-padding can occur; (iv) for* $\tilde{\rho}_j < \rho \leq \overline{\rho_j}$ *no regime can occur; (v) for* $\overline{\rho}_j \leq \rho < 1$ *only the Classical Regime can occur.*
In all regimes the efficient type is offered a fixed-price contract, which ensures that he never engages in cost-padding in equilibrium. On the other hand, the inefficient type is offered cost-sharing contracts which may leave an incentive to pad costs. Cost-padding occurs in equilibrium only in the Cost-padding Regime.

Proposition 3.10 is represented in Figure 3.2 below, which shows that the transition to one regime to the other at the increase of ρ it is not smooth as it would be at the limit case where $e^{RC} = e^{CP} = e^{CL}$, which would imply $\underset{\sim}{\rho} = \underline{\rho}$ and $\tilde{\rho} = \overline{\rho}$. Instead, there is an overlapping of Cost-padding and Repressed Cost-padding regimes in the range $(\underset{\sim}{\rho}, \underline{\rho}]$ and a

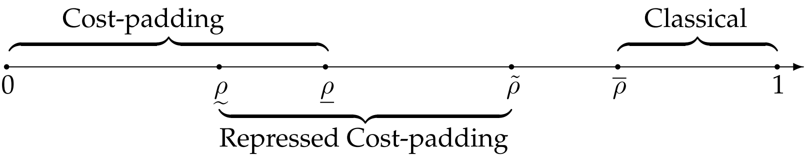

Figure 3.2: Regime Transition

gap in the range $(\tilde{\rho}, \overline{\rho}]$ where no regime can occur. Both the overlapping range and the gap shrink as $e^{RC} \to e^{CP}$.
However, the relevant interpretation of results does not change with respect to the case with smooth transition (see LT pag. 527): when the probability of detecting cost-padding is low type H wants to engage in cost-padding (as would type L if it were to mimic the type H), which gives rise to the Cost-padding Regime. The power of incentives is the same as when cost-padding is unfeasible; when the detection probability increases a bit, the type H no longer has incentive to engage in cost-padding, whereas the type L would still have incentive to do pad costs if it were mimicking, which gives rise to the Repressed Cost-padding Regime. In order to make such mimicking costly, the effort level of type H is raised, which increases the marginal disutility of mimicking for type L; when the probability of detecting cost-padding becomes even higher, then neither type L has incentive to engage in cost-padding: we are in the Classical Regime, and the effort required from type H return to the level of the case where cost-padding is unfeasible.

3.5 The politician's optimal choice

The last step is to analyze the politician's optimal choice of detection probability ρ on the basis of optimal contracts derived in last section. Therefore, while in the previous sections the detection probability ρ was regarded as a parameter, in this section we endogenize it.

3.5.1 Optimal auditing technology

The politician will choose the detection probability that ensures that he ends up in the regime that gives him the highest continuation payoff

(i.e., the highest value of the objective function), which will depend on his type.
From Proposition 3.7 we know that the two cost-padding free solutions, i.e., the Repressed Cost-padding Regime and the Classical Regime yield the same value to the politician, which in turn is identical to the value that the politician can obtain in the benchmark solution, $U^{CL} = U^{RC} = U^{BI}$ where U^{BI} is given in (3.26). The only solution where the politician gets a different value function is in the Cost-padding Regime, where U_j^{CP} is given in (3.31) and depends on the type of politician.
Therefore, the politician's choice is reduced to compare U^{BI} and U^{CP}, i.e., to decide whether or not he wants to allow for cost-padding in equilibrium. It is straightforward from (3.31) that the difference between U^{CP} and U^{IU} is given by the constant $G(\alpha_j)$, so that the choice of the politician will merely depend on the *sign* of this expression.
By straightforward calculation we get that $G(\alpha_j) > 0$ if and only if $\mu \geq 1 + \lambda$, which leads to our main result:

Proposition 3.11 (Politician's preferred regime) *a) A moderate politician ($\mu \leq 1$) never chooses the Cost-padding Regime, while he is indifferent between Repressed Cost-padding and Classical regimes; b) An opportunist politician chooses the Cost-padding Regime iff he is opportunist enough i.e., iff $\mu \geq (1+\lambda)$ (while if $1 < \mu < 1 + \lambda$ he behaves as a moderate one). In particular, it must be the case that the weight he puts on his personal utility is higher than the disutility that consumers bear from distortionary taxation.*

Our result is consistent with the "mixed"nature of the politician, who cares both about social welfare and private utility: since cost-padding implies a higher cost in terms of distortionary taxation, only a politician who is eager enough will be willing to allow cost-padding. This result is nice insofar it captures in a simple and clear way the realistic case that a politician can well be partially selfish, but only particularly corrupt - the ones who let private cause substantially exceed public interest - will damage the public.
On the basis of Proposition 3.10 and Proposition 3.11 we can now easily conclude about the optimal detection probability for each type of politician.
First notice that case (iv) in Proposition 3.10 (i.e., the "gap") can be trivially disregarded $\rho_j^* \notin (\tilde{\rho}_j, \overline{\rho}_j] \quad \forall j \in \{M, O\}$, while case (ii) (i.e., the "overlapping") can be ruled out for the moderately opportunist politician, since he has a strict preference for the cost-padding free solutions

over the Cost-padding Regime, so that $\rho^*_M \notin [\underset{\sim}{\rho}_M, \underline{\rho}_M)$. On the other hand the very opportunist politician might allow for the overlapping.
We can now state our final result:

Proposition 3.12 (Politician's optimal choice of detection probability) *Moderately opportunist politicians (indicated with superscript MO) ($\mu < (1+\lambda)$) will optimally choose any value of ρ in the interval $M = (\underline{\rho}_j, \tilde{\rho}_j] \bigcup [\overline{\rho}_j, 1)$, where $j = \begin{cases} M, & \text{if } \mu \leq 1 \\ O, & \text{if } 1 < \mu < (1+\lambda) \end{cases}$. Therefore, $\rho^*_{MO} = \forall \rho \in M$.*
Very opportunist politicians (indicated with superscript VO) ($\mu \geq 1+\lambda$) will choose $\rho^*_{VO} = \underline{\rho}_O = \underset{\rho \in (0, \underline{\rho}_O]}{\arg\max} \quad U^{CP}_O(\rho)$.

Notice that while U^{BI} is constant with respect to ρ, so that the moderately opportunist politician is indifferent between any value that sustains any of the cost-padding free solutions, on the other hand U^{CP}_O depends on ρ and hence the politician further maximize with respect to it.
The intuition beyond the optimal choice of the very opportunist politician is that he faces a *trade-off* when choosing the detection technology: on one hand a higher detection probability would allow him to detect cost-padding more often, which increases its expected share of embezzled money; on the other hand a higher detection probability deters the firm from engaging in cost-padding (i.e., makes Cost-padding regime relatively less likely to occur), which decreases its expected share of money[49]. Therefore he optimally chooses the highest level of detection probability such that the agent still finds it profitable to engage in cost-padding, namely $\rho^*_{VO} = \underline{\rho}_O$.
Propositions 3.11 and 3.12 summarize the result we wanted to show, namely that the presence of cost-padding in public projects can be given a *political corruption* explanation. While in LT - where the politician is benevolent and the auditing technology is exogenous - cost-padding can emerge in optimal contracts only due to incomplete information (i.e., when preventing cost-padding is too costly in terms of the extra-rents the politicians need to pay), and (bureaucratic) corruption can never occur in equilibrium (since the principal always makes a take-it-or-leave-it

[49] A similar trade-off occurs in Dittmann (2006), where an increase in detection probability can have opposite effects on the revenue from fines: the proportion of criminals that are detected and fined increases, which raises the revenues from fines, but more individuals are deterred from committing crime, which decreases revenue.

offer to the corruptible bureaucrat), in this model, due to the endogenization of the detection technology, cost-padding and (political) corruption can occur in equilibrium and are ultimately choices of the politician. Particularly opportunist politicians, who are eager to get a share of the gains from illegal activity, will misuse public office to allow for its occurrence (via choosing a relatively low detection probability and hence leaving an incentive to pad costs in optimal contracts) and enter in corrupt transaction when they have the chance to do so.

3.5.2 A State Capacity interpretation

Closer inspection of condition $\mu \geq 1+\lambda$ yields two additional interesting results.
First, we have that an improvement in the efficiency of taxation (i.e., a decrease in λ) makes the cost-padding regime easier to occur, insofar a lower degree of selfishness is needed for the politician to go for the Cost-padding Regime. In the limit case of a perfectly efficient fiscal system (i.e., $\lambda = 0$) *all* opportunist politicians (i.e., $\forall \mu > 1$) will allow cost-padding to occur. The intuition is that a decrease in the distortion of taxation reduces the social cost of cost-padding, which implies that also moderately opportunist politicians will have an incentive to let cost-padding occur.
Also, notice that the extent to which the politician is able to pursue his private agenda rather than social welfare depends on the effectiveness of the political system, in terms of the political accountability it manages to create. Therefore μ can be interpreted as a measure of political accountability: the more efficient is the political system, i.e., the more accountable are politicians, the lower is μ (see e.g., Shapiro and Willig (1990)). If we do so, we also have a second result, namely that a decrease in λ must be more than counterbalanced by a decrease in μ in order to make cost-padding less easier to occur. This result can be explained in the light of the Acemoglu (2010) discussion about State capacity[50]. A reduction in the distortion of taxation has ambiguous effects on welfare: on one hand it has a direct positive effect insofar it improves redistribution and allocation of resources. On the other hand however, it has an indirect negative effect insofar it increases the potential benefits of ruling the state, so that pursuing personal interest becomes more attractive for the politician: the higher the improvement in efficiency the lower degree

[50] Also see Acemoglu et al. (2011)

of selfishness is needed to find it convenient for the politician to prefer the cost-padding regime[51].

Therefore, our results confirm Acemoglu (2010) insight that an improvement in State capacity (like a more efficient fiscal system) is not good per se (as instead argued by Besley and Persson (2010) - who neglected the impact that an increase in State capacity has on political equilibrium) but it is beneficial only if it comes from or is coincident to an increase in the political accountability of politicians.

3.6 Conclusion

In this essay we have provided a contract-theoretical framework to explain why cost-padding and corruption are so widespread in the execution of public contracts.

To do so, we have extended the contract-theoretic cost-padding model in Laffont and Tirole (1993), to allow for the principal to be partially selfish and for the auditing technology to be endogenous. In our model the principal (a top-level politician) audits himself the firm and, depending on his degree of selfishness, he decides both the level of auditing technology and whether to enter (upon detection) a corrupt bargaining with the firm to share embezzled money. The stakes of corruption are hence endogenous and depend on the politician's motives.

This framework enabled us to develop a theory of endogenous *political* corruption and to argue that the occurrence of cost-padding can be given a *political* explanation: opportunist politicians can gain a personal benefit from allowing contracting firms to embezzle public money. While in Laffont and Tirole (1993) cost-padding and, consequently, (bureaucratic) corruption, could emerge in optimal contracts only due to asymmetric information, in this model cost-padding and corruption are ultimately choices of the politician, which depend on his degree of selfishness.

We found that while a moderate politician (by choosing a relatively aggressive auditing technology) prevents the firm from engaging in cost-padding, a very opportunist politician (via choosing a relatively weak auditing technology) leaves in optimal contracts an incentive to pad costs and, upon detection, share embezzled money with the firm. Moreover, an improvement in the efficiency of the fiscal system makes cost-padding easier to occur, due to the fact that since the social cost of cost-padding

[51] In Acemoglu (2010) an increase in the potential benefits of controlling the state intensifies the political conflict aimed at capturing this control.

is lower, also less opportunist politicians will be tempted to engage in corruption. This result can be also interpreted in light of the recent debate on State capacity (see Besley and Persson (2010)), Acemoglu (2010), Acemoglu et al. (2011)): by increasing the gains from staying in power, a more efficient fiscal system increases the incentive for misusing public office. Therefore, without a coincident increase in political accountability, an increase in State capacity can be detrimental for welfare.

Despite its relative simplicity, our model is able to produce interesting results. Still, there are a number of dimensions along which this work could be further developed. First, it would be interesting to relax the assumption of automatic enforcement of contracts and announcements to see how issues of contract renegotiation and credibility problems add up to our results. In particular, this would allow for the information revelation issues to have more bite in the model, and to analyze the problem of credibility underlying the politician's auditing choice.

Second, it would be interesting to assume that auditing is costly. This would make the modelization of the auditing technology more realistic and may enrich the results about the politician's optimal choice. In particular, the optimal choice of the level of auditing will no longer only depend only on the trade-off between favoring cost-padding (which calls for weak auditing) and detecting cost-padding (which calls for strong auditing), but also on the fact that auditing is costly. This would also likely produce interesting implications in combination with the issue of time-consistency highlighted above [52].

To further enhance the descriptive power of the modelization of auditing, it would be possible to separate the roles of the politician and of the supervising bureaucrat. This could be done by adopting the three-tier agency structure of classical auditing models, but still allowing for both the bureaucrat and the politician to be corruptible.

Third, it would be interesting to open the "black box" of the politician's self-interest μ. There are two main ways this step could be implemented. The first is "institutional" and amounts to incorporating a more realistic modelization of power in the model. This could be implemented either by introducing a judicial system which could detect and punish corrupt politicians, or introducing voting so to allow for a constituency to keep the politician accountable. In either case, however, the problem should be not be degenerated to a new agency problem where the

[52] For example, after the firm reveals its type through the choice of the contract, the politician may decide not to audit an efficient firm since it would never engage in cost-padding.

political principal becomes the judicial system or the Constituency and the non-benevolent politician acts as the supervisor or regulator of the firm (as in Laffont and Tirole (1993), Section VI)). Instead, one should develop a model where the politician remains the political principal, i.e., a social-welfare maximizer, albeit partially selfish, and a clever way of incorporating some element of separation of powers. A simple possibility of that kind is to introduce the judicial system as a pair of parameters, the former defining an exogenous probability of detection of the corrupt deal between the firm and the politician, and the latter defining the punishment they should incur upon detection. A more sophisticated modelization of the institutions could also allow to endogenize the efficiency of the fiscal system λ.

The second way to open the black box of self-interest would be "motivational"and would consider the role of psychological and social factors on the intrinsic motivation and self-regulation of the politician. This alternative way may refer to the recent literature about more sophisticated behavior of economic agents (see e.g., Bénabou and Tirole (2002), Bénabou and Tirole (2003) and Bénabou and Tirole (2006)).

Chapter 4

Decentralization and Procurement Performance: Some New Empirical Evidence from Italy

4.1 Introduction

Public procurement accounts for a large share of the economic activity in developed economies (15-20% of GDP, OECD average[1]).
Therefore, it is essential that governments design and implement sound public procurement policies and practices to achieve best value for money when purchasing goods and services needed to address public needs. This is particularly urgent nowadays, in an era of economic instability and crisis, where a key concern for governments is achieving savings in order to consolidate public finances and clear fiscal space for other necessary policies.
A central issue in the debate on how to improve the performance of public procurement spending, is how much public procurement should be centralized i.e., whether procurement should be mostly administered by

[1] The average for OECD countries is 12% when excluding procurement by state-owned enterprises. When these purchases are also accounted for, the size of procurement can increases by an additional 2 to 13 percentage points of GDP (OECD (2011)).

central governments (or agencies) or rather delegated to sub-central levels of authority.
In practice, despite in recent years many countries have increased their degree of procurement centralization, often with the institution of a central procurement agency which concludes procurement agreements on behalf of other public purchasers, public procurement is largely decentralized[2]. Figure 4.1 clearly shows how in many OECD countries local governments account for substantial percentages of procurement spending (on average 48% in OECD), with Italy (80%), Finland (72%), Denmark (69%), Japan (69%) and Sweden (69%) displaying the highest degrees of decentralization[3].

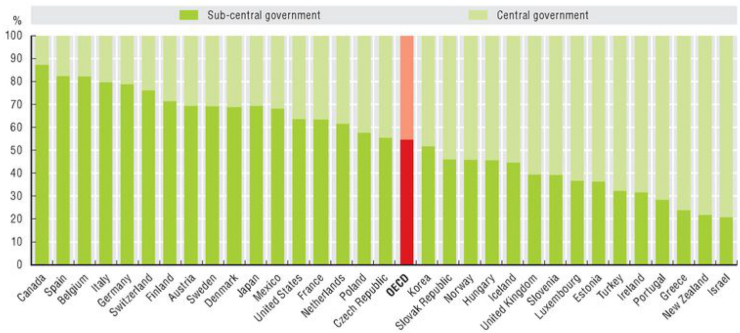

Figure 4.1: Share of government procurement by level of government (2011). Source: OECD (2013). Percentages exclude procurement by social security funds and public enterprises.

What then is natural and convenient to ask is whether such a prevailing decentralization trend in procurement systems is justifiable on economic grounds or whether public purchasing should be rather more centralized, and to what extent.

[2]Centralization usually occurs in the form of the stipulation of so called "framework agreements" signed by central procurement agencies on behalf of public purchasers. Framework agreements are agreements between one or more contracting authorities and one or more economic operators, the purpose of which is to establish the terms governing contracts to be awarded during a given period, in particular with regard to price and, where appropriate, quantity (see Dimitri et al. (2006a)).

[3]See McCue and Pitzer (2000) for an overview on recent trends on centralization in public procurement.

Procurement practitioners argue that at the heart of the issue is the trade-off between the potential savings created by purchasing aggregation, which call for centralization, and the need of responding to local specific needs, which calls for decentralization. This can be seen as an expression of the more general trade-off underlying the provision of public goods, which is at the core of the long-standing debate in the fiscal federalism literature (see e.g., Oates (1985), Besley and Coate (2003) and Oates (2005)).
More specifically, the main arguments in favor of centralization are the following[4]. First, the aggregation of purchases enables public purchasers to obtain a better per-unit price (since suppliers exploit economies of scale), and to increase their bargaining power, which both result in savings on purchase costs. Second, aggregation allows for savings on duplication of (potentially substantial) process costs, such as advertisement and organization of tenders, and litigation. Moreover, centralization helps to afford and concentrate qualified and specialized human resources, i.e., procurement professionals recruited and trained to optimize procurement design and implementation. On the other hand, hiring and training experts can be prohibitively expensive for small decentralized units.
Such gains from centralization, however, are possible mostly when products are relatively standardized (e.g., ICT equipment, IT servers, stationary and paper, fuel, natural gas, meal coupons etc.[5]). When products are less standardized, local authorities may have better information about local needs and local markets, so that decentralization may be preferable. However, local authorities might also be more prone to favoritism and corruption than central ones, due to invested political interests and lobbying of local suppliers (e.g., see Vagstad (2000), Fisman and Gatti (2002), Faguet (2004), Bordignon et al. (2008) and Coviello and Gagliarducci (2010).). Also, the application of ICT technologies to procurement (so called "e-procurement"), may both streamline information from the periphery to the center - hence reducing the information-gathering costs that the latter would incur - and further save on administrative costs. This would again call for centralization, since, due to the economies of scale created by ICT investments, the larger volumes of transactions are affected, the larger the potential savings.
However, a (potentially large) drawback of centralization is that it may disadvantage small and medium enterprises (SMEs) which, due to lower

[4]For an extensive analysis of relative advantages and disadvantages of procurement centralization see Dimitri et al. (2006a).

[5]In fact, these products are usually procured by central purchasing agencies in several countries (Dimitri et al. (2006a)).

production volumes and profit margins, may find it difficult to compete in big tenders. This would both have a negative impact on the competition level in procurement, possibly facilitating collusion between big firms, and deplete the industrial fabric of the economy.
All considered, practical evidence seems to be in favor of a rather centralized procurement, albeit some degree of decentralization should be allowed to ensure flexibility and protection of SMEs. However, albeit much informative, the arguments summarized above are of qualitative nature, whereas it would be indeed useful to assess the relationship between procurement decentralization and performance on a more quantitative basis, and in a framework which allows to control for other determinants of performance.
The aim of this work is exactly to give such kind of contribution. In particular, we exploit the TED dataset, based on mandatory contract award notices in the EU, to provide a preliminary empirical assessment of the relationship between procurement decentralization and procurement performance in Italy. The Italian case is appropriate and interesting in this context since all levels of government (central and sub-central) plus a number of other public institutions (e.g., local health authorities, universities, state-owned enterprises) are involved in the procurement of goods, services and works, and are largely subjected to the same rules, at least as far as EU-relevant procurement is concerned.
Using winning rebate as a measure of procurement performance, we find that small decentralized units are generally less efficient than (more) central authorities in procuring goods and services. In particular, municipalities are the least efficient purchasers. This is particularly relevant since municipalities are the level of government that award most procurement contracts (24.7% in our data, against 8.5% awarded by central government, 3% by regions and 2.2% by provinces). According to our main estimates, if a tender awarded by a municipality were instead awarded by central government, the winning rebate would on average increase by 6.6%, which would result - according to a back on the envelope calculation - in an average per-tender saving of 132.000 euros[6]. The same kind of conclusion seems to be true as well for public enterprises, which also turn out to have a relatively low performance, despite being the institutional class that award in absolute the greatest number

[6]This calculation is computed using the OLS estimate of the effect of the contracting authority being the central government rather than municipality (which is used as reference) on the winning rebate, for a public contract with an average starting value/reserve price of about 2 million euros.

of contracts (27% in our data). Importantly, these findings hold even after controlling for other important determinants of rebate, such as the award mechanism, the size of the purchasing unit, and local characteristics, suggesting that performance is affected by some other unobservable characteristics which varies between different classes of public purchasers. We argue that these unobservables much likely amount to the endowment of professional competences and incentives of the procurement staff in purchasing units. Differently from (more) centralized purchasers, municipalities and other small decentralized units are likely to lack the trained, competent and motivated human resources which are needed to properly implement procurement procedures and achieve best value for money.

What our results suggest therefore, is first, that there is a general performance mismatch in the Italian system of public procurement, in the sense that the classes of contracting authorities that are responsible for the largest volumes of procurement, are also the least efficient; second, incompetence is likely to have a crucial role in explaining this performance gap. The latter confirms the striking finding of Bandiera et al. (2009), namely that waste in procurement in Italy is largely due to bureaucratic incompetence (rather than to corruption).

With the reservations that our analysis is preliminary and results cannot be readily interpreted in causal terms, a policy implication that seems to emerge is that the Italian procurement system should be re-organized on a more centralized basis in order to improve on the general performance gap.

Previous empirical works focusing on the relationship between the degree of centralization and procurement performance in Italy are limited, and empirical evidence is conflicting.

The paper closest to ours is Guccio et al. (2014), who assess the time performance in the execution of public works by different levels of governments in Italy. Similarly, they obtain that local governments (and municipalities in particular) are less efficient (i.e., incur higher cost-overruns) than central government in the procurement of public works. In contrast with these result, Bandiera et al. (2009), focusing on purchases of standardized goods by different classes of Italian public purchasers, find that the least efficient class is central government (although they do not give an explanation or intuition of why this should be the case), while the average municipality is the second most efficient class after semi-autonomous bodies (e.g., local health authorities and universities).

Moreover, there are other papers that albeit not mainly focusing on the performance differential between different levels of government, provide some marginal evidence on that issue. D'Alpaos et al. (2013), for example, in a study about the opportunistic use of time overruns in public works, also find that municipalities, although awarding the largest number of contracts, show higher cost-overruns than the average of the dataset; Decarolis (2014), also has that municipalities are typically associated with higher cost-overruns (with respect to provinces); Guccio et al. (2012) in a study about determinants of cost-overruns in public works, find, like Bandiera et al. (2009), that all institutional levels of purchasers tend to have lower adaptation costs than central government, while the evidence about local governments is not significant[7]. They argue that this result can be explained on the grounds that central government should have higher political incentives in underestimating costs. All of these papers, as virtually all recent empirical studies on procurement for Italy, use data on public works contracts[8]. On the other hand we focus on supplies and services, which both in terms on number and value of contracts, account for the greatest share of the procurement market[9].

The rest of the essay is organized as follows. In Section 4.2 we describe the Italian institutional background for public procurement, and in Section 4.3 the data. In Section 4.4 we present the empirical model and estimation results, and discuss some robustness checks. We conclude with Section 4.5. Tables and figures are relegated in the Appendix A.3.

[7]However, this may be due to the fact that they put all levels of sub-central government (i.e., regions, provinces and municipalities) in the same category, which in our opinion is a too loose classification. Bandiera et al. (2009) put provinces and municipalities in the same category.

[8]In fact, the mentioned works all use the same dataset, which was provided by the Italian Authority for the Surveillance of Public Procurement (Autorit per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture, A.V.C.P.), before it was terminated in 2014 (and merged with the Italian Anti-Corruption Authority). These data, which are no longer available, had the advantage to contain information on the execution of public work contracts, so that they allowed to build ex-post performance measures such as cost-overruns and time-overruns. Other works based on these data, beside the mentioned ones are Coviello and Gagliarducci (2010), Bucciol et al. (2013), Coviello et al. (2013), Coviello and Mariniello (2014), Decarolis and Giorgiantonio (2014), Moretti and Valbonesi (2015), Branzoli and Decarolis (2015).

[9] Of all public tenders called in 2012, 36% were for services contracts, 34,3% for supplies and 29,7% for works. As for contract values, services accounted for the 45,4% of value, supplies for 27,8% and works for 26,8% (Autorità di Vigilanza sui Contratti Pubblici di Lavori (2013)).

4.2 Institutional Background

Italy is an interesting case study for analyzing variation of procurement performance at different degrees of procurement decentralization, because all levels of government, plus a variety of other public institutions, are involved in the procurement of goods, services and works, and are mostly subjected to the same rules. This is particularly the case for larger contracts which are of EU relevance[10]: in this case the Italian national Parliament must establish procurement rules according to the principles of the relevant EU legislation, and sub-central governments have limited power to implement changes to the national legislation[11]. The main implication is that all public purchasers in Italy procure largely according to the same rules. Hence the differences in performance are not to be attributed to differences in the rules, but rather to specific characteristics of different categories of public purchasers (see Guccio et al. (2014)).
In particular, since 2006 the public procurement of works, supplies and services of EU relevance is regulated in Italy by the Legislative Decree 12 April 2006, n. 163, so called "Code of public contracts of works, supplies and services", (henceforth, the *Code*), which is the transposition of Directives 2004/17/EC (EC (2004b)), regulating the award of contracts in the *utilities sectors* (i.e. water, energy, transport and postal services), and Directive 2004/18/EC (EC (2004a)), which regulates the award of contracts in *ordinary sectors* [12].
The *Code* updates provisions, among other things, about a) the public subjects allowed to act as contracting authorities, b) the award proce-

[10]Contracts of works, goods and services whose reserve price is higher than given thresholds are considered of EU relevance and are regulated by relevant EU Directives (see e.g., Kutlina-Dimitrova and Lakatos (2014) for more detail on this).

[11]However, Decarolis and Giorgiantonio (2014) report that due to the ambiguousness of the Italian Constitution on the allocation of legislative power between central and sub-central governments about public procurement, sub-central levels often adopt their regulations despite national regulation expressly prohibits local legislation, among other things, on award procedures and criteria. Often this hyperregulation at local level constitutes an impediment to competition, beside making legal compliance burdensome.

[12]Very recently, new Directives have been approved that update the current regulation, but still have to be transposed in Member States legislation. These are Directive 2014/24/EU (EU (2014a)), which will repel the Directive 2004/18/EC, Directive 2014/25/EU (EU (2014b)), which will repel the Directive 2004/17/EC, and Directive 2014/23/EU (EU (2014c)), which for the first time will provide a separate regulation for concessions.

dures and c) the award criteria[13].
In the matter of the subjects allowed to act as contracting authorities, it is provided (Art. 32) that such subjects are: *central government*, *local governments (i.e., regions, provinces, municipalities, mountain village councils, island councils)*, *public institutions with non-economic purpose*, *bodies of public law*, *publicly financed enterprises which realize works or produce goods or services which are non destined to free competition markets*, *concessionaires* and *other private subjects* in some limited circumstances [14].
As for the award procedures, three main options are identified (Arts. 54-62 and 220-222): *open procedure*, *restricted procedure* and *negotiated procedure*, the latter having two suboptions i.e., *negotiated with call for competition* and *negotiated without call for competition*[15]. Each procedure allows a varying degree of control over the award mechanism and of the interaction with tenderers. In the open procedure, all interested suppliers can submit a tender. In the restricted procedure there is a shortlisting stage before the tender stage, which enables the contracting authority to check in advance whether potential suppliers have the appropriate experience and resources to meet its needs. In the negotiated procedure the contracting authority instead invites a restricted number of firms with whom it negotiates the terms of the contract before the awarding. According to the EU rules, while the open and the restricted procedures can be used without restrictions, the negotiated procedure with call for competition should only be used in restricted circumstances, and the negotiated procedure without call for competition can be used only in very exceptional cases, namely when a supplier is the sole source of the good or service required, in cases of extreme urgency, or when the precise specification can only be determined by negotiation[16].
As for the award criteria, the *Code* (Arts. 81-84) states that contracts are either awarded via the *lowest price* criterion, or the criterion of the *most economically advantageous tender* (aka MET or MEAT), where some other criteria are considered beside price for the award of the tender (e.g., qual-

[13]The *Code* (in italian) is available at `http://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2006-04-12;163`.

[14]For all details see Art 32 of the *Code*.

[15]In fact, there is a fourth option, which is used very rarely, called *competitive dialogue*, which was introduced for addressing particularly complex procurement contracting situations, where contracting authority needs to "dialogue" with potential suppliers before the award phase.

[16]This holds for ordinary sectors, which account for most contracts. In the utilities sectors the negotiated procedure with call for competition can be used without restrictions, while the option without call for competition is still limited to exceptional circumstances.

ity, environmental characteristics etc). In the former case, participants simply bid the price at which they are willing to implement the contract, in the form of a percentage reduction (so called "rebate") with respect to the reserve price (i.e., the auction's initial value as announced by the contracting authority). In the latter, participants submit a complex bid composed by an economic part, based on the offered rebate, and a technical part, detailing how the contract will be implemented with respect to the other (non-price) criteria. In this case the highest rebate is not necessarily the winning rebate[17].

4.3 Data

The data we use are part of a unique dataset based on mandatory contract award notices published on Tenders Electronic Daily (TED), which is the official online version of the Supplement of the Official Journal of the European Union (OJEU)[18].
Contracting authorities are obliged to publish contract notices (i.e., calls for tenders) and award notices on TED for all contracts with reserve price exceeding the EU public procurement thresholds[19][20]. TED contains contract notices, contract award notices and many other procurement documents in electronic format. Since 2006, TED has published procurement statements on more than 700.000 tenders. The dataset is updated 5 times a week with some 1.500 public procurement notices from the European Union, the European Economic Area and beyond[21].

[17] As a matter of fact, this can happen also under the criterion of the lowest price, due to a complex mechanism implemented to prevent firms from overbidding (i.e., to offer too high a rebate, which could then jeopardize the implementation of the contract): the bids that after a preliminary trimming of the top/bottom 10% of the collected bids, exceed the average by more than the average deviation, are inspected and may be excluded, in which case the winning bid is the highest among the remaining bids (see Arts. 86-89 of the *Code*).

[18] ©European Union 1998-2015, `http://ted.europa.eu`.

[19] In many cases, however, award notices of tenders below thresholds are also reported. Reasons are that authorities are not prevented from doing so, and the fact that as a result of competition, even though the reserve price is above or at the threshold, the final award value might be below the threshold.

[20] The thresholds may vary between Directive (ordinary vs utilities), by type of contract (supplies vs services vs works), and by level of authority (central government vs subcentral entities). The current thresholds can be find at `http://ec.europa.eu/growth/single-market/public-procurement/rules/current/index_en.htm`.

[21] The TED archive contains documents for the last 5 years of tenders i.e., the time span of the archive shifts over time to cover exaclty 5 years of tenders. This amount to the archive containing at each time almost 900.000 contract notices and almost 800.000 award notices.

However, it is very difficult to build a dataset from the document-based TED archive. Luckily, OpenTED - a project started in 2012 by an independent group of researchers and developers - is converting the TED electronic format tender documents into a spreadsheet format and making them available under permission of the EU[22].

This work is based on OpenTED data for Italy. The original sample is a multi-year cross-section containing 43222 observations relative to contracts of services, supplies and works awarded in Italy from 2008 to 2014. The observation unit is the single contract award. For each observation the dataset includes the following informations: name, address, institutional category and main activity of the contracting authority; name and address of the winning firm; object of the contract according to the Common Procurement Vocabulary (CPV) coding; type of contract (supply vs service vs work); initial value of the contract (i.e., reserve price); final price of the contract (i.e., price of award/winning bid); date of award of the contract; award criterion; award procedure; number of offers received; EU directive regulating the tender; identity and address of the appeal body; number of lots if the contract was divided in lots; whether an electronic auction was used; whether the tender was covered by the Government Procurement Agreement (GPA) or related to EU funded projects; identity and details of final client if the contracting authority was operating on behalf of some other entity; other technical information (e.g., date of document dispatch).

From the original sample we extracted the sample of interest, according to the following criteria. First, since our measure of procurement performance is the winning rebate in each contract award, we kept only observations for which both reserve price and final price (as well as other fundamental entries) were not missing[23]. For the same reason, we excluded cases where it was not possible to clearly define the winning rebate, namely multi-lot contracts (where the contract is divided in parts (i.e., lots) which are awarded separately) and tenders where the winner was a temporary consortium of firms ("Associazione Temporanea d'Impresa", ATI). Also, since we were interested in building variables based on the identity of winning bidders and contracting authorities, we

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Users can freely browse the archive, search and sort procurement notices by country, year, business sector and more.

[22]For more on the OpenTED project see `http://ted.openspending.org/`.

[23]There are many missings in the data, probably due to scarce attention in the compiling of the original award notice documents. Further, there is no official data dictionary, so that the variables content is not always clearly understandable.

dropped all observations for which their names were missing[24]. Last but not least, we decided to focus only on procurement of goods and services and disregard data on public works. There are three reasons for that. First, with the exception of Bonaccorsi et al. (1999) and Bandiera et al. (2009), all empirical literature on procurement in Italy focused on public works so we wanted to clearly focus on what has been mostly neglected. Second, supplies and services account for the largest share of procurement, both in terms of quantity and value of contracts[25]. Third, while winning rebate can be a reasonably adequate performance measure for the procurement of supplies and services, the same is not true for the case of public works, since very often the final cost (as measured at the end of the execution of works) exceeds the contracted cost. Since TED data only provide information on the award of the contract, we cannot build the ex-post performance measures, such as cost overruns and time overruns, which would be more meaningful indicators in the context of public works[26].
Our final sample consist of 4805 observations on awards of services and supplies contracts, relative to 42 industrial macro-sectors (as identified by the CPV codes) and awarded between January 2011 and April 2014 by contracting authorities belonging to different institutional classes[27].
We have complemented these data with further geographical informations taken from the National Statistical Institute (ISTAT (2011)), in particular about the province and the region of the contracting authority, the province and the region of the winning firm, and the population of the municipality where the contracting authority was located[28].

4.3.1 Descriptive Statistics

Our measure of procurement performance is the winning rebate, defined as the percentage discount of the final price (i.e., the price at which the contract is awarded) over the reserve price (i.e. the price announced by the contracting authority). The winning rebate is a standard measure of

[24]Also, due to many small permutations of spellings for the same firm, we assigned by hand an univocal name to each firm.

[25]See footnote 9.

[26]As already mentioned, the AVCP dataset contained such kind of follow-up information (See footnote 8).

[27]For more details on the CPV coding see `http://ec.europa.eu/growth/single-market/public-procurement/rules/cpv/index_en.htm`.

[28]The TED/OpenTEd only contained information on the winning firm's and the contracting authority's towns and postal codes.

ex-ante performance in procurement, indicating the extent to which the functioning of the award process, as administered by the purchaser, allows the latter to achieve a discount with respect to the maximum price it would have been willing to pay [29].

More formally, rebate $= \frac{\text{reserve price} - \text{final price}}{\text{reserve price}} \text{x}100$.

As it is shown in Table A.1 in Appendix A.3, the average winning rebate is 16.33% (with a standard deviation of 18.5%)[30]. The minimum rebate is 0% and the maximum rebate is 99.95%[31].

Figure A.1 in Appendix A.3 plots the empirical distribution of rebate, (together with a Kernel density estimate), showing that the distribution is clearly skewed and has a spike at 0: a relatively high share of observations (10%) has 0% rebate. The latter seems an anomaly, which we will further investigate shortly.

Table A.1 summarizes the main features of the sample according to (i) the type and object of the awarded contract; (ii) the institutional class of the contracting authority (CA, in the following); (iii) the awarding procedure and the awarding criterion; (iv) geographic location and year of award.

Concerning the type of contract, 64.8% of the sample concerns tenders of services, while 35.2% tenders of supplies. As for the object of the contract, 83.7% of the sample regards ordinary sectors and 15.6% utilities[32]. In particular, the majority of tenders concerns sewage, refuse, cleaning and environmental services (12.5%), health and social work services (8.5%), medical equipment, pharmaceuticals and personal care products (7.8%), repair and maintenance services (7.2%) and transport equip-

[29]See e.g., Coviello and Gagliarducci (2010), Coviello et al. (2013), Decarolis and Giorgiantonio (2014), Decarolis (2014). However, notice that in case the reserve price was overestimated or badly calculated, a high rebate does not necessarily imply that the public purchaser has paid a "good"price.

[30]We dropped the bottom and top 500th percentile of the empirical distribution of rebate to exclude outliers.

[31]184 observations presented a negative rebate (i.e., the final price was higher than the reserve price). These were dropped for conservative reasons. Some of the cases were almost surely reporting errors (the final price was equal to the reserve price but multiplied by 10). Also, according to the *Code*, offers with negative rebate should be regarded as inadmissible (although this, of course, does not imply that "illegal" offers were in practice prevented from winning).

[32]The remaining 0.7% regards tenders in the sectors of defense and security, which have a special regulation according to Directive 2009/81/EC (EC (2009)).

ment and auxiliary products to transportation (7%)[33].
According to the discussion in Section 4.2, a meaningful and not cumbersome categorization of CA for Italy consists of the following categories: *central government*, *region*, *province*, *municipality*, *mountain council*, *institution*, *other institution*, *public enterprise*, and *concessionaire*"[34]. With *institution* we refer to those public bodies with budget autonomy, namely local health authorities, public hospitals and universities. The important aspect of these institutions is their semi-autonomous nature[35]. *Other institution* includes all other public bodies which are not included in *institution*[36]. *Public enterprise* includes all firms run out by (mostly) public money, such as those in charge of utilities (e.g., "Anas", "Ferrovie dello Stato", "Poste Italiane" etc.). *Concessionaire* refers to those usually private companies (e.g., those in charge of building and managing highways) which must follow the Directive prescriptions when acting as CA[37].
In our sample the majority of contracts were awarded by public enterprises (27.1%) and municipalities (24.7%), followed by other institutions (17.2%), institutions (14.8%), central government (8.5%), regions (3%), provinces (2.2%), concessionaires (1.3%) and mountain councils (1.1%).
As for the award procedures, 75.8% of the tenders were awarded with the open procedure, while the restricted procedure and the negotiated procedure without a call for competition were respectively used in 10.3% of

[33] Tenders relative to financial and insurance services have been disregarded for conservative reasons.

[34] We changed the categorization with respect to that provided in the OpenTED data (which had 9 categories: *body governed by public law*, *European institution/agency or international organization*, *ministry or any other national or federal authority*, *regional or local authority*, *regional or local agency/office*, *utilities*, *national or federal agency/office*, *other* and *not specified*). That classification was inadequate for our purposes insofar (a) there were missings and errors (i.e., sometimes the CA was classified under an objectively wrong category and sometimes the same CA was classified under different categories); (b) it was not enough precise (e.g., regions and municipalities were put in the same category). Our new categorization is similar to the one adopted in Guccio et al. (2014).

[35] This definition is similar to that used by Bandiera et al. (2009).

[36] In our sample these include, among the others: institutions for residential housing ("Istituti per l'Edilizia Residenziale Pubblica"), the Bank of Italy, Chambers of Commerce, nursing homes, research institutes, sport federations, the National Institute for the Workers Insurance (Inail), the National Institute for Social Security (Inps), the National Statistical Institute (Istat).

[37] All the tenders awarded by the Armed Forces were listed under *central government* since the Armed Forces are directly dependent from the Ministry of Defense. The same was done for prisons, "Prefetture", "Provveditorati" and "Soprintendenze" which are dependent from the Ministry of Justice. Unions of municipalities were listed under *mountain council*. We dropped municipalities with less than 500 inhabitants to avoid limiting size effects.

cases. In the remaining cases it was used the standard negotiated (with call for competition) procedure (3.7%)[38]. By looking at these figures, it is possible to detect an important anomaly in the use of award procedures. While the standard negotiated procedure was rarely used, in line with the *Code* prescription that it should be used only in particular cases (at least in ordinary sectors), the negotiated procedure without a call for competition was the second most used procedure (after open), regardless of the legal requirement that it should be used only in exceptional cases (typically, emergencies)[39]. Therefore it seems that CAs are overusing a non-transparent procedure. The abuse of the negotiated procedure without call for competition also explains the surprising frequency of observations with winning rebates of 0%: virtually all the tenders with 0% winning rebates were awarded with the negotiated without call procedure. This suggests that CAs may often lack the incentive to set competitive procedures and may instead prefer non-competitive and not transparent procedures, possibly to engage in favoritism or corrupt practices. Investigating some more on this, we found that the CA categories which used relatively the most this procedure are central government (15.1% of all awards), other institutions (14.8%) and public enterprises (14.3%). Geographically, relatively higher use of this procedure was found for Lazio (27% of all awards), Marche (14.2%) and Emilia Romagna (13.4%)[40].
As for the award criteria, 53.7% of the tenders were awarded with the most advantageous tender criterion, while the 41.3% with the lowest

[38] Again, we changed the classification with respect to the OpenTED original one, which had too many categories. The *negotiated* procedure in our classification corresponds to the merging of *negotiated procedure*, *accelerated negotiated procedure* and *competitive dialogue* in OpenTED. The *restricted* procedure corresponds to the merging of *restricted procedure* and *accelerated restricted procedure*. The *negotiated without a call* corresponds to the merging of *negotiated without a call for competition* and *award of contract without prior publication of a contract notice* (which from a double check on original tender documents in TED seem to refer both to negotiated procedures without a call for competition).

[39] Percentages are substantially the same when considering separately ordinary and utilities sectors.

[40] Almost 30% of all the tenders that were awarded in Rome, adopted the negotiated procedure without call. In most of these cases the CAs were public enterprises. Also, Rome accounts for half of all the observations of negotiated procedure without call in the dataset. These considerations might suggest some evidence of so called “Mafia Capitale”, i.e. a deep-rooted and widespread phenomenon of corruption which has been recently unveiled in Rome. According to the authorities, one of the main mechanism by which the “Mafia Capitale” system worked, was the systematic award of contracts without call for competition, on the basis on inexistent urgency reasons, in order to favor “friend” firms. The high use of this procedure in Emilia Romagna could be instead be due to genuine emergency induced by the 2012 earthquake.

price (in the remaining 5% of cases the award criterion was not specified).
The number of offers per auction ranged from a minimum of 1 offer to a maximum of 67 offers[41]. The average is 4.3 offers per auction. 27.4% of tenders received 1 offer only, 19.9% 2 offers, 14% 3 offers and 11.2% 4. The level of competition was on average very low, which of course also depends on the award procedure used: 30% of the tenders which received one tender only were awarded with the negotiated procedure without call[42].
As for the geographical location, 47.1% of the contracts were awarded in the North, 32.5% in the Center and 20.4% in the South[43].
In 28.2% of the cases the winning firm was registered in the same province as the CA, in 14.8% of cases in the same region, in 54.3% in the same country. Only in 2.7% of cases the contract was awarded to a foreign firm[44].
Finally, most of the auctions in the sample were awarded in 2012 and 2013 (respectively 46.5% and 42.6%), whereas 2011 and 2014 have fewer auction (respectively, 4% and 7%) since these are the starting and ending points of the dataset, for which only data relative to some months were extracted. Table A.2 shows some preliminary evidence about the relation between winning rebate and institutional class of the CA.
It is shown that average winning rebate is highest for private concessionaires (22%), followed by central government (19.8%) and regions (19.6%), while it is lowest for municipalities (12.2%) and mountain village councils (9.3%).
From these raw data it seems that municipalities have a relatively low procurement performance, as measured by average winning rebate. This might have relevant implications, since municipalities are the level of government that award most contracts in the dataset (and the second CA class in absolute, after public enterprises). On the other hand, central government seems to be the level of government which has the highest performance (and second in absolute among CA classes, after conces-

[41] We excluded outliers with none or more than 100 bidders.

[42] But more than half (57%) were awarded with the open procedure, which more difficult to explain.

[43] According to the Istat classifications, *North* includes the regions of Valle d'Aosta, Liguria, Lombardia, Piemonte, Emilia-Romagna, Friuli-Venezia Giulia, Veneto, Trentino-Alto Adige; *Center* includes Lazio, Umbria, Toscana, Marche and *South* Abruzzo, Basilicata, Molise, Campania, Puglia, Calabria Sicilia, Sardegna.

[44] When the winning firm is a big firm with many branches in different locations, we used the legal location (i.e., the province where the firm is registered) as location for all the observations of that firm.

sionaires), despite in the current system it awards only a modest quantity of contracts.
The figures of Table A.2 in are confirmed graphically in Figure A.2 which shows the empirical cumulative distribution function of the average winning rebate separately for the different institutional classes of CA.
This preliminary evidence is interesting, but of course a regression analysis is needed to control for other important factors which may influence the winning rebate, and hence isolate the effect of the institutional class of the CA on the rebate.

4.4 Empirical Analysis

We are interested in estimating the relationship between the institutional class of the CA and the winning rebate, used as a general measure of procurement performance. We consider award-level data, controlling for province, industrial sector and year of award. We assume that the relationship of interest can be specified by the following linear model:

$$rebate_{ipts} = \alpha + CA'\beta + X_i'\delta + \gamma_p + \eta_s + \theta_t + \epsilon_{ipts} \tag{4.1}$$

where $rebate_{ipts}$ is the winning rebate in tender i, awarded in province p and in year t, and whose object is relative to industrial sector s. CA is a vector of 9 dummies, one for each institutional class of contracting authority, namely *central government*, *concessionaire*, *institution*, *public enterprise*, *region*, *municipality*, *province*, *mountain council*, *other institution*. β is the vector of coefficients of interest. X_i is a vector of characteristics of the award i, γ_p are province fixed effects, that capture local characteristics which are constant (or slowly changing) over time, η_s are sector fixed effects, that capture sector or market specific time-invariant characteristics, θ_t are year fixed effects, and ϵ_{ipts} is the usual white noise component. The vector of auction characteristics X_i contains the following variables and sets of variables: *offers number* is the number of bids received in the auction, which controls for the actual level of competition; *open*, *restricted*, *negotiated* and *negotiated without call* are 4 award procedure dummies, which account for the different degree of competitiveness created by different award procedures; *lowest price*, *met* and *non specified* are 3 award criterion dummies. To account for heterogeneity between purchases we include *reserve price*, i.e., the starting value of the auction as announced by the CA, expressed in 1000 euros and in 2010 OECD equivalents[45]; *service* is a dummy variable indicating whether the purchase was relative to a service rather than to a supply; *ordinary*, *utilities* and *security* are 3 dummies indicating which directive rules the specific tender, which should account for differences in regulation; *behalf* is a dummy variable indicating whether the CA was purchasing on behalf of another entity. Also, to account for differences in competitiveness between industrial sectors, we add *potential bidders* i.e., the number of potential competitors as measured by the total number of suppliers observed in the database in a particular sector[46]. To control for size effects, in absence of data on annual expenditure of CAs, we included *population*, i.e., resident population (in 1000) in the municipality of the CA town. Size effects may be important, since larger towns may have more potential competitors in auctions and larger CAs, which are likely to have more qualified human resources.

Moreover, the availability of data about the identity of the CA and of the winning firm, allowed to build measures of winning firm's incumbency, CA's experience and favoritism. *incumbency* is the number of contracts awarded to the winning firm by all the CA in the dataset in the previous tenders i.e., for each observation relative to a given firm we sum the number of auctions previously won, including that of the current observation i [47]. Similarly, *CA experience* is the number of contracts awarded by each CA in the dataset in the previous tenders[48].

Also, we introduce possible measures of favoritism of the CA either toward a particular bidder or toward a particular category of bidders. As a measure of favoritism to a particular bidder, we use *repeated interact* i.e., the number of contracts awarded to each winning firm by the same CA in the previous tenders[49]. In principle, the presence of repeated interac-

[45] http://stats.oecd.org/Index.aspx?DataSetCode=MEI_PRICES

[46] Bonaccorsi et al. (1999) also use this measure of competitiveness. However, this effect could be already captured by sector fixed effects.

[47] A problem with this measure is that we do not have information on the tenders awarded before the beginning date of our dataset. However, including year fixed effects in the analysis should partially control for this potential truncation problem. Alternative measures of incumbency used in the literature are the number of contracts awarded to each firm by all the CA in the dataset (see e.g., Guccio et al. (2012)) and the maximum percentage of adjudications to the same firm per year, weighted by the number of auctions (see e.g., Coviello and Gagliarducci (2010).

[48] Also in this case there is a potential problem of truncation. Bucciol et al. (2013) use the log of this number. Branzoli and Decarolis (2015) use the number of auctions run in all the sample period.

[49] Again, year fixed effects will be needed to account for truncation. Gil and Marion

tions may simply indicate that the winning firm is the "best" on the market (which should have a positive effect on rebate). On the other hand, it could witness the presence of a repeated corrupt relationship (which should have negative impact on rebate).
Favoritism can also occur on a geographical basis, insofar the CA may prefer local firms even if they are not the best available suppliers, which could have a negative effect on rebate. On the other hand, local firms may naturally win more often since due to lower transportation and logistic costs they can afford to bid higher rebates. To check the direction of this effect we introduce 4 dummies to indicate whether the winning firm is registered in the same province of the CA (*local win*) or in the same region (but different province) (*regional win*), or in the same country (but different region), (*national win*) or if the winning firm is registered in another country (*international win*)[50].
To control for geographical effects we include *province FE*, i.e., a set of 110 dummies for Italian provinces. Importantly, by controlling for time invariant characteristics at the local level, province fixed effects should also control for the levels of social capital, corruption and other long-term institutional characteristics which are unobservable.
To control for inter-sectoral heterogeneity we include *sector FE*, i.e., a set of 42 dummies for all the macro industrial sectors as defined by the CPV coding.
Last, we introduce *year FE*, namely a set of 4 indicators for the year of award (2011-2014) to control for possible time effects.
We estimate equation 4.1 using OLS and clustering the standard errors at sector level.

4.4.1 Empirical Evidence

In Table A.3 we report the OLS results from fitting different specifications of equation 4.1 to the data.
The specification in Column 1 only includes the set of dummies for the institutional class of the CA. The omitted category is *municipality*. Estimates clearly show that *all* institutional classes perform better, in terms of the average winning rebate they are able to induce, than *municipal-*

(2009) use a similar measure of repeated interaction in the context of subcontracting in public works.

[50]Other papers in the literature use this information (i.e., whether the winning firm is registered in the same province/region of the CA) as a dependent variable (see e.g., Coviello and Gagliarducci (2010) and Decarolis and Giorgiantonio (2014).

ity (*mountain council* is the only class that seems to have a lower performance, but its coefficient is never significant). In particular, among the levels of government, the institutional class that performs best is *central government*, followed by *region* and *province*. As for the other (i.e., non-governmental) types of CA, *concessionaire* is in absolute the best performing class (better than *central government*), followed by *institution* and *other institution*. The worst non-governmental CA class is *public enterprise*. In particular, according to these first estimates, if a contract awarded by a municipality were instead awarded by central government, the average rebate would increase by 7.6%, and by 7.4% if it were awarded by a region (while the coefficient of province is not significant). As for the non-governmental CA, the average rebate would increase by as much as 9.8% if the CA were a concessionaire rather than a municipality, by 6.2% if it were a semi-autonomous institution, by 5.2% if it were some other institution and by 4.8% if it were a public enterprise.

According to this preliminary evidence, municipal authorities seem to be the least efficient among public purchasers. However, these results are not fully reliable, since the specification in Column 1 does not control for many other characteristics that are likely to influence the winning rebate. Column 2 includes in the analysis province, sector and year fixed effects. *Province FE* are jointly significant at 1% level, and the same is true for *sector FE*[51]. The introduction of the FE reduces the magnitude of many of the coefficients of the CA institutional classes, although preserving their sign and significance. This indicates that unobservable local and sectoral characteristics are important determinants of procurement performance, and omitting them would crate bias in the estimates. While the coefficient of *central government* falls just marginally, all other coefficients sensibly drop. In particular the coefficient of *concessionaire* drops by more than 2%, meaning that, once sectoral and local characteristics are accounted for, private concessionaires are not sensibly more efficient than central government in procuring supplies and services (with respect to municipalities). Also, the coefficient of *region* falls by more than 3%, meaning that the performance lead of regions with respect to municipalities is sensibly downsized when accounting for local and sectoral characteristics. Still, these estimates my suffer from omitted variable bias.

Column 3 includes the most relevant controls among those discussed in the previous sub-section. These are the award procedure, the award criterion, the number of offers, the population of the municipality of the

[51] While *year FE* are not jointly significant.

CA, and the reserve price. As expected, most of these variables have a relevant impact on average rebate, and further reduce most of the coefficients of interest. In particular, when controlling for these characteristics, *central government* turns out to be in absolute the most efficient institutional class with respect to municipalities. Moreover, the coefficients of the controls have expected sign and significance. Using a restricted or a negotiated procedure rather than an open procedure (reference category), has, ceteris paribus, a negative impact on average rebate (-2.2% in case of a restricted and even -10% in case of a negotiated without call[52]). Adopting the criterion of the lowest price rather than the most economically advantageous offer (reference category) has a positive effect on rebate (+3.7%). The coefficients of *population* and of *reserve price* are equal to 0 and not significant, possibly due to the fact that size effects may be already captured by geographical fixed effects. Also, the coefficient of *offers number*, albeit with the expected sign and significance, seems to have a quite weak effect (1 more bidder in the tender makes average rebate increase by hardly 1%). Suspecting a problem of functional misspecification, in column 4 we replace the offers number with its natural logarithm, which improves the fitting of the model[53]. This change in the functional form of *offers number* also almost halves the coefficient of *negotiated without call*, indicating that the two variables are likely correlated, which is obvious insofar the award procedure is likely to sensibly drive the participation in a tender.

In column 5 the remaining available variables are included. With the exception of *regional win* and *international win*, none of the new coefficients is significant. For most of the variables, a plausible explanation is that their effect is already captured by other regressors already included in the analysis. For example, the effect of *potential bidders* is likely to be already captured by the sectoral fixed effects. Also, the difference in regulation (*ordinary* vs *utilities* vs *security*) may have an effect on rebate only through the choice of the award procedure[54]. The same can be true for the effect of *CA experience* and *repeated interact*: a greater experience of the CA, in terms of the number of auctions it has administered before the auction under analysis, can have an impact on rebate only to the extent that a more experienced CA adopt some more appropriate (or *less*

[52]The coefficient of negotiated, albeit with the correct sign, is not significant.

[53]This can be ascertained by implementing usual diagnostic tests on linearity. Also, notice that the adjusted R^2 goes from 0.195 to 0.239.

[54]For example, as already said, the negotiated procedure can be used as a standard procedure in the utilities sectors but not in the ordinary sectors.

appropriate but *more* illegally profitable) award procedure or award criterion; similarly, the CA can choose a less competitive procedure or the MET criterion in order to manipulate the award the contract in favor of some preferred bidder[55]. As for *incumbency*, its effect is possibly already captured by the number of bidders: if a firm is incumbent in a particular market, it will be the only or among the few bidders in a tender relative to that market.
The coefficients of *international win* and *regional win* are negative, indicating that a not local winner may offer a lower rebate with respect to a local winner (reference category) due to higher transportation or logistic costs (with this effect increasing in case the winner is foreign).
Column 6 finally, includes only regressors that were found significant in the previous specifications, in order to improve on the efficiency of the estimates of interest. From this last specification, we conclude that the evidence provided by Column 1 is essentially confirmed, namely that the institutional class that has the best performance is central government (rebate +6.6% with respect to municipalities) followed by concessionaires (+ 5.5%), regions (+ 4.4%), semi-autonomous institutions (+4.2%), other institutions (+3.5%) and public enterprises (+2.5%). The only CAs which seem to behave on average worse than municipalities are mountain councils (- 1.1%) but the coefficient is never significant (like the coefficient of provinces (+ 1.8%)).
Also, the fact that the coefficients of interest have remained large and significant after controlling for other relevant determinants of rebate such as the award procedure, the award criterion and geographical and social factors, indicates that there are some intrinsic characteristics which vary between institutional classes of CA which matter in explaining the variation in procurement performance. We argue that such residual differences in CAs much likely amount to the set of professional and technical competences and incentives owned by the human resources in the CA. Specific competences as well as motivation are needed to administer properly the procurement process e.g., by estimating correctly the reserve value and selecting the most appropriate award procedure and criteria. Small CAs, such as most municipal authorities and public enterprises, naturally lack this kind of professionalism, differently from central authorities, which can often rely on big technical offices.
Therefore, an explanation of why small decentralized units seem to perform relatively badly in procurement is that they miss those competences

[55] Similar explanations can be found for *service* and *behalf*

and motivation which are needed to achieve best value for money when purchasing. This result is particularly relevant when considering that municipalities and public enterprises are the CA classes that currently award most contracts in Italy[56]. This finding confirms the result of Guccio et al. (2014), namely that municipalities, despite being the level of government which awards most contracts, are by far the least efficient in doing so. Also, our result is in line with the Bandiera et al. (2009) finding that an important source of waste of public money in procurement is the professional incompetence of the bureaucracy in charge of administering the tenders, which is not able to select the best offer available[57].

Therefore, even if our results are preliminary and cannot be automatically given a causal interpretation, there seems to be a systematic and statistically evidence that 1) there is a general performance mismatch in the Italian system of public procurement, in the sense that the CAs that are responsible for the largest procurement volumes in Italy (i.e., municipalities and public enterprises), are also the least efficient in procuring and 2) at the basis of this performance gap is much probably the fact that small decentralized units cannot achieve the efficient level of procurement competences (in terms of specialized and motivated human resources) which are needed to set up efficient procurement practices. In Section 5 we discuss some policy implications.

4.4.2 Robustness Checks

Our OLS analysis might be affected by three problems. First, regression residuals are clearly not normal. This can be ascertained both graphically from Figure A.3, where the Kernel density function of residuals is plotted against a Normal density function, and by implementing the standard Shapiro-Wilk test, which strongly rejects the null hypothesis of normality[58].

The second problem is potential sample selection bias. Our sample of interest excluded categories of auctions for which the rebate can be systematically lower (or higher) so that we might observe auctions with smaller (respectively, higher) rebate as a result of a selection bias and interpret

[56] The Italian Courts of Auditors have often highlighted criticism relative to the inefficient and corrupt management of public enterprises.

[57] Differently from our results, however, they find that the most wasteful institutional class is central government.

[58] The test was implemented for specification 6 of Table A.3, with a value of the test of 14.834 (p-value = 0.00000).

that as a less (respectively, more) virtuous behavior of the CA[59].
The third potential problem has to do with errors in variables, due to the relatively poor quality of the data. While the third problem is difficult to address, we can check the robustness of our results against the two other problems[60].
Non-normality of residuals does not pose problems of bias or inconsistency of estimates, but makes hypothesis testing not reliable, since standard errors and hence t-statistics may be wrong. The problem of non-normality of residuals in our data is most likely due to the fact that the dependent variable is a percentage, so it is bounded. When there are many observations pushed up against the bound - as it is the case in our data, where a peak is observed at 0 - residuals are typically not normal.
According to the technical literature (see e.g., Baum (2008)), a strategy for handling proportion data in which zeros and ones as well as intermediate values are plausible was proposed by Papke and Wooldridge (1996). This method accounts to a Generalized Linear Model (GLM) which uses the logit link function (i.e., the logit transformation of the response variable) and the binomial distribution, which may be a good choice of family even if the response is continuous. This technique can be used to generate predictions from the model and transform them back into the units of the response variable. This approach is preferred to that of dropping the observations with zero or unit values, which would create a truncation problem[61].
In Column 2 of Table A.4 we report the estimates of the GLM regression run on the specification in Column 6 of TableA.3. For comparability reasons, the latter is reported in Column 1 of Table A.4, with the only difference that the dependent variable rebate is expressed in decimal rather than percentage form, since the GLM method can be used only when the dependent variable is between 0 and 1. It can be seen that the sign and the significance of coefficients of interest remain unchanged, indicating that the non-normality of residuals did not affect severely the inference

[59] In particular this may concern tenders awarded to a temporary consortium of firms (ATI) and those awarded in multi-lots, which have been excluded from the analysis.

[60] Usual diagnostics checks have shown that there are no relevant problems of multicollinearity or of non-linearity. Potential influence problems were addressed by dropping outliers, while heteroscedasticity and correlation of errors were addressed by clustering errors at the sector level for all specifications.

[61] The GLM approach, while properly handling both zeros and ones, does not allow for an alternative model of behavior generating the limit values (0 and 1). However, in our context there is no reason to believe that different factors generate the observations at the limit points, so that this should not be a source of sample selection issues.

in our case.
Next we address potential sample selection bias. To do so, we run regressions over different subsamples of the original samples in order to reduce the variability and, this way, sample selection in the data (e.g., see Bucciol et al. (2013)., Decarolis (2014), Guccio et al. (2014)). If estimates obtained with subsamples are similar to those obtained with the full dataset it is suggested that sample selection is not driving the previous findings[62].
Specifications in Columns 3-5 of Table A.4 run the same model as Column 6 of Table A.3, but on different subsamples of data. In Column 3 the subsample of interest corresponds to those contracts belonging to the 5 most frequent industrial sectors in the dataset[63]. Column 4 considers only contracts awarded in the North, and Column 5 only contracts relative to ordinary sectors. Estimates confirm the robustness of our main findings.
Two further robustness checks that we have implemented are shown in column 6 and 7, in which we have respectively changed the clustering of standard errors from the sector to the province level, and changed the geographical fixed effects from the province level to the region level. Again, results confirm the robustness of findings of interest.
Overall, there is evidence about the robustness of the main result of the analysis, namely that small decentralized purchasing units, and in particular municipalities and public enterprises, are ceteris paribus less efficient than more central purchasers in administering public procurement of supplies and services.

4.5 Conclusion

In this work we used the TED data to provide some preliminary empirical evidence on the relationship between the degree of centralization of a procurement system and its performance. For this purpose, we focused on the procurement of supplies and services in Italy, which is a convenient case study, insofar all levels of governments (plus a number

[62]Notice that given the non-normality of errors, no Heckman correction methods can be applied in this case.

[63]As already said, these are "sewage, refuse, cleaning and environmental services" (12.5% of the sample), "health and social work services" (8.5%), "medical equipment, pharmaceuticals and personal care products" (7.8%), "repair and maintenance services" (7.2%) and "transport equipment and auxiliary products to transportation" (7%)

of other categories of public institutions) are involved in procurement and follow substantially the same rules.
Using winning rebate as a measure of procurement performance, we found that more decentralized units are generally less efficient than more central units in procuring goods and services. In particular, municipalities and public enterprises turned out to be the least efficient purchasers, while central government the most efficient one. This result remained true even after controlling for other important determinants of rebate, such as award procedure and criterion, contract-authority size and local characteristics, which also account for the quality of local institutions.
This suggested that performance is affected by some unobservable characteristics which vary between institutional classes of public purchasers. We argued that these unobservables much likely amount to the endowment of specialized competences and incentives of procurement professionals employed in the contracting authority. Most contracting authorities in Italy are too small to be able to achieve an efficient dimension of the technical offices in charge of procurement, and hence are much likely to lack all the proper professional competences needed to set up efficient procurement practices and achieve best value for money in procurement. Bureaucratic incompetence is therefore confirmed to be a possibly much relevant source of waste of public money, as was already found by Bandiera et al. (2009). These considerations seem particularly relevant when considering that municipalities and public enterprises are the categories of public purchasers that currently award most contracts in Italy.
In conclusion, although our results are preliminary and cannot be directly interpreted as casual implications, there is evidence that 1) there is a general performance gap in the Italian system of public procurement, in the sense that the classes of contracting authorities that award most contracts are also the least efficient in doing so; and 2) at the basis of this performance gap is most likely a lack, in most contracting authorities, of competent and specialized professionals.
Therefore, a policy implication suggested by our results, is that the degree of decentralization of procurement in Italy should be reconsidered and downsized. The number of contracting authorities should be substantially reduced, so that it would be possible to concentrate in those remaining qualified and specialized human resources. These professionals should also be well remunerated, which would foster motivation and reduce the incentives for corruption and collusion. An option for implementing this rationalization could be to strongly reduce or eliminate the possibility for (smaller) municipalities to act as contracting authorities,

and shifting their share of procurement at upper levels, like provinces (for less standardized goods), which are close to local needs, or regions (for more standardized goods), which are both likely to have better competences than municipalities, and would also allow for some degree of purchase aggregation. This partial centralization would also ensure that SMEs are not handicapped with respect to larger competitors[64].

In sectors where potential economies of scale are larger or the government is a dominant purchaser - most notably defense and health - procurement should be probably fully centralized, in order to enable the public purchaser to fully exploit bargaining power and achieve potentially large savings (Dimitri et al. (2006a)). For example, health procurement nowadays largely occurs on a very decentralized basis, i.e., single hospitals and other local health authorities independently procure what they need. In this sector there are potentially substantial missed gains from centralization[65]. In these purchases where full centralization is desirable, a more extensive use could be done of the national procurement agency - Consip - which has an internationally acknowledged reputation of efficiency and best practice. Also, some measures should be implemented to ensure that SMEs are not disadvantaged[66].

Also, it could be valuable to centralize and streamline the collection on procurement data, which would enable to detect wastes and other potential problems on time.

[64] See e.g., Gustavo Piga's considerations at `http://www.gustavopiga.it`.

[65] According to Dimitri et al. (2006a), in some specific markets for sophisticated medical equipment (e.g., MR, ecotomography) the government is virtually a monopsonist.

[66] A possibility is to provide set-asides, as it is currently the case in the US.

Appendix A

A.1 Appendix to Chapter 2

A.1.1 Game-theoretic Definition of the Game

In game-theoretic terms, our elimination all-pay contest with non-sunk bids can be defined as an extensive game with complete information and simultaneous moves (see Osborne and Rubinstein (1994), Ch.6). The game is described by the following elements:

1. A *set of players*: $\mathcal{N} = \{1, 2, ..., N\}$.

2. A *set of histories*: $\mathcal{H} = \left\{h^k, 0 \leq k \leq K\right\}$, where h^0 is the empty sequence (i.e., $\emptyset$) and $h^r = (x^k)_{k=1,...,r}$ with $r \leq K$.
   Each member of $\mathcal{H}$ is a *history*, i.e., a sequence of profiles of actions taken by players. A history h^r is terminal if $r = K$. The set of terminal histories is called $\mathcal{Z}$. The set of actions available for players after history h^r is $\mathcal{A}(h^r) = \{x^{r+1} : (h^r, x^{r+1}) \in \mathcal{H}\}$.

3. A *player function* P that assigns to each non terminal history (each member of $\mathcal{H}\backslash\mathcal{Z}$) a set of members of $\mathcal{N}$. $\mathcal{P}(h^r)$ being the set of players who take an action after history h^r:

   $$\mathcal{P}(h^0) = \{1, 2, ..., N\}, \mathcal{P}(h^r) = \left\{i : x_i^r \geq x_{(q^r)}^r\right\} \qquad \text{(A.1)}$$

   $x_{(1)}^r \geq x_{(2)}^r \geq ... \geq x_{(q^r)}^r$

4. For each player i a *preference relation* $\succeq_i$ on $\mathcal{Z}$. These preferences are represented by the payoff function of player i at the final stage K, i.e.,

$$\Pi_i(h^K) = \begin{cases} v_i - \sum_{k=1}^{K} x_i^k, & \text{if } \{x_i^K > x_{(q^K)}^K\} or \{x_i^K = x_{(q^K)}^K and \text{ rem. prizes} > \text{ties}\} \\ v_i/m^K - \sum_{k=1}^{K} x_i^k, & \text{if } \{i \text{ ties at } x_{(q^K)}^K and \text{ ties} > \text{rem. prizes}\} \\ -\sum_{k=1}^{r} x_i^k \quad (r \leq K), & \text{otherwise} \end{cases} \tag{A.2}$$

A.1.2 Proof of Proposition 2.1

Arguments needed for the characterization of the equilibrium in this case are totally analogous to those used by Hillman and Riley (1989) and Hillman and Samet (1987) for characterizing the equilibria of the one-stage all-pay auction, respectively for the asymmetric and the symmetric case. The only difference is that in place of players' ex-ante valuations v_i, we will consider here players' net valuations at Stage-a, NV_i. For the sake of clarity, in the following we reformulate all the main arguments so that they fit our case.

Lemma A.1 *No pure-strategy equilibrium can exist in the Stage-b subgame, neither in the "asym-asym" case nor in the "asym-sym" case.*

Proof.

"Asym-asym" case. For any bid of the other player which is below the lower net valuation NV_L, each player has an incentive to slightly overbid the other player, so that there is a race to the top until NV_L (there is no equilibrium below NV_L). There is no equilibrium above NV_L either, since player L will never bid more than her net valuation, and consequently neither player H would bid above. Also, there is no equilibrium for ties at NV_L, since player L would be better off bidding zero, and the race to the top would start again. Therefore, the "asym-asym" case cannot have an equilibrium in pure strategies.

"Asym-sym" case. For any bid of the other player which is below the common net valuation NV_S, each player has an incentive to slightly overbid the other player, so that there is a race to the top until NV_S (there is no equilibrium below NV_S). There is no equilibrium above NV_S either, since no player will bid more than her net valuation. Also, players will never tie at NV_S, since they are better off by bidding zero. Therefore

the " asym-sym" case neither can have an equilibrium in pure strategies. Q.E.D

Lemma A.2 *No player will, in equilibrium, ever spend a positive amount with strictly positive probability, i.e., equilibrium strategies are continuous mixed strategies.*

Proof. Suppose to the contrary that player i spends some $x_i^b = \beta > 0$ with strictly positive probability. Then player j will always beat that bid with a marginally greater bid (the probability that j beats i rises discontinuously as a function of x_j^b at $x_j^b = \beta$). Therefore, there is some $\epsilon > 0$ such that j will bid in the interval $[(\beta - \epsilon), \beta]$ with zero probability. But then, agent i would be better off by bidding $\beta - \epsilon$ rather than β, since her probability of winning would be the same, contradicting the hypothesis that $x_i^b = \beta$ is an equilibrium strategy in the subgame.

Lemma A.3 *In equilibrium the two players must have the same maximum spending level.*

Proof. From Lemma A.2 it follows that, if $\bar{x}_i^b$ is player i's maximum spending level, player j wins with probability 1 by spending $\bar{x}_i^b$ and vice versa. Hence, the upper bound of the support is the same for both players and it is equal to NV_L in the "asym-asym" case and NV_S in the "asym-sym" case.

Lemma A.4 *In equilibrium the minimum outlay is zero for each player.*

Proof. Suppose to the contrary that player i picks $x_i^b = \beta > 0$ as her minimum bid (i.e., she spends less than $x_i^b = \beta > 0$ with zero probability). Then, any bid in the interval $(0, \beta)$ would yield a negative payoff to player j, since the probability of winning is zero in that interval. Since player j can always bid zero, it follows that she neither will bid in the interval $(0, \beta)$. But then player i could reduce her bid below β without changing her probability of winning, contradicting the hypothesis that agent i's optimal minimum spending level was some $\beta > 0$. Hence, the lower bound of the support is the same for both players and it is equal to zero.
Given these results, if we define $1 - F_i(x_i^b)$ to be the probability that player i spends more than x_i^b, then $F_i(x_i^b)$ is continuous over $(0, \infty)$. If $0 < F_i(0) < 1$ then player i spends a strictly positive amount with probability less than 1 and her alternative is to spend zero.

Lemma A.5 *At most one agent bids zero with strictly positive probability.*

Proof. If both players bid zero with positive probability then each has a chance of winning. However, this will not occur in equilibrium, for if one player spends zero with positive probability, the other can with an arbitrarily small positive bid increase her probability of winning and hence her expected payoff.

A.1.3 Proof of Proposition 2.2

Player i's expected payoff (with $i = \{H, L, S\}$) is:

$$E\Pi_i(h^b) = (v_i - x_i^a - x_i^b)F_j(x_i^b) + (-x_i^a - x_i^b)[1 - F_j(x_i^b)] = v_i F_j(x_i^b) - x_i^a - x_i^b \tag{A.3}$$

Equilibrium requires that, for any bid in her support, each player earns a constant expected payoff, given the mixed strategy of the other player.
The equilibrium condition we need to impose for player i is therefore as follows:

$$E\Pi_i(h^b) = v_i F_j(x_i^b) - x_i^a - x_i^b = u_i^* \quad \forall x_i^b \in [0, NV_n] \tag{A.4}$$

where u_i^* is a constant and $n \in \{L, S\}$. Setting $x_i^b = NV_n$, we are able to derive the expression for player i's equilibrium expected payoff:

$$u_i^* = NV_i - NV_n \tag{A.5}$$

Therefore for the "asym-asym" case we have the two following cases:

Case1. If player i is shortlisted with the *lower net valuation*, i.e., $i = L$ and $NV_i = NV_L$, then she will get on average a *zero* equilibrium payoff, $u_L^* = 0$.

Case2. If player i is shortlisted with the *higher net valuation*, i.e., $i = H$ and $NV_i = NV_H$, then she will get on average a *positive* equilibrium payoff, $u_H^* = NV_H - NV_L > 0$.

whereas for the "asym-sym" case we have $NV_i = NV_j = NV_S$, so that both of them will on average get a zero equilibrium payoff $u_S^* = 0$.

Consequently, the equilibrium conditions for the "asym-asym" case will be as follows:

$$E\Pi_H(h^b) = v_H F_L(x_H^b) - x_H^a - x_H^b = NV_H - NV_L \quad \forall x_H^b \in [0, NV_L] \tag{A.6}$$

$$E\Pi_L(h^b) = v_L F_H(x_L^b) - x_L^a - x_L^b = 0 \quad \forall x_L^b \in [0, NV_L] \tag{A.7}$$

The equilibrium mixed strategies are uniquely determined as the solutions of the system of the two above equations, and are as follows:

$$F_L(x_L^b) = \begin{cases} \frac{NV_H - NV_L}{v_H} + \frac{x_H^a + x_L^b}{v_H}, & \forall x_L^b \in [0, NV_L) \\ 1, & \forall x_L^b \geq NV_L \end{cases} \tag{A.8}$$

$$F_H(x_H^b) = \begin{cases} \frac{x_L^a + x_H^b}{v_L}, & \forall x_H^b \in [0, NV_L) \\ 1, & \forall x_H^b \geq NV_L \end{cases} \tag{A.9}$$

On the other hand, the equilibrium conditions for the "asym-sym" case are as follows:

$$E\Pi_i(h^b) = v_i F_j(x_i^b) - x_i^a - x_i^b = 0 \quad \forall x_i^b \in [0, NV_S] \tag{A.10}$$

$$E\Pi_j(h^b) = v_j F_i(x_j^b) - x_j^a - x_j^b = 0 \quad \forall x_j^b \in [0, NV_S] \tag{A.11}$$

from which the following equilibrium strategies are uniquely determined:

$$F_i(x_i^b) = \begin{cases} \frac{x_j^a + x_i^b}{v_j}, & \forall x_i^b \in [0, NV_S) \\ 1, & \forall x_i^b \geq NV_S \end{cases} \tag{A.12}$$

$$F_j(x_j^b) = \begin{cases} \frac{x_i^a + x_j^b}{v_i}, & \forall x_j^b \in [0, NV_S) \\ 1, & \forall x_j^b \geq NV_S \end{cases} \tag{A.13}$$

Therefore in both the "asym-asym" case and in the "asym-sym" case, the Stage-b subgame has a unique asymmetric equilibrium in mixed strategies Q.E.D.

A.1.4 Proof of Proposition 2.4

The proof is articulated in two parts. We first prove that the triple $(x_1^a = \epsilon, x_2^a = 0, x_3^a = 0)$ is an equilibrium of the Stage-a all-pay auction, and then that it is the unique pure-strategy equilibrium.

Proof that the triple $(x_1^a = \epsilon, x_2^a = 0, x_3^a = 0)$ **is an equilibrium of Stage-a all-pay auction**

We need to check whether any player has any incentive to deviate.
Consider player 1 first. Obviously, she would never deviate upward, but we need to check that in fact she does not find it profitable to bid zero rather than a positive amount. Player 1 will profitably deviate *iff* the expected payoff of deviating is higher than the expected payoff of not-deviating, namely [1]:

$$E\Pi_1(x_1^a = 0, x_{-1}^{a*}) > E\Pi_1(x^{a*}) \tag{A.14}$$

Notice that if player 1 deviates, so that all players bid zero, the marginal bid is zero and we are in the "more marginal bidders than tickets" case and ties are broken randomly. In this case two possible events may occur:

- with probability $2/3$ player 1 is shortlisted. In that case she will meet player 2 with probability $1/3$ and player 3 with probability $1/3$. By Proposition 2.3 we have that, given equality between bids, player 1 will always have NV_H whoever the other shortlisted player among player 2 and 3 will be. Her expected continuation payoff will be $u_1^* = NV_1 - NV_i = v_1 - v_i$, with $i \in \{2, 3\}$;
- with probability $1/3$ player 1 is not shortlisted. However she makes no loss since her bid is zero.

The expected payoff from deviating is hence:

$$E\Pi_1(x_1^a = 0, x_{-1}^{a*}) = \frac{1}{3}(v_1 - v_2) + \frac{1}{3}(v_1 - v_3) \tag{A.15}$$

On the other hand, when player 1 does not deviate and bids $\epsilon > 0$, she is shortlisted and pays her bid with certainty. With probability $1/2$ player 1 will meet player 2 and with probability $1/2$ she will meet player 3, but whether she will have NV_H, NV_L or NV_S depends on ϵ:

[1] Remember that each possible history of length-1 is a profile of actions, so that $h^a = x^a$, with $x^a \in \mathbb{R}_+^3$.

if $\epsilon < v_1 - v_i$ (with $i \in \{2,3\}$): then $NV_1 > NV_i$, i.e., $v_1 - \epsilon > v_i$, so that $1 = H$ and $u_1^* = NV_1 - NV_i = (v_1 - \epsilon) - v_i$.

if $\epsilon > v_1 - v_i$: then $NV_1 < NV_i$, so that $1 = L$ and $u_1^* = 0$

if $\epsilon = v_1 - v_i$: then $NV_1 = NV_S$, so that $1 = S$ and $u_1^* = 0$

Therefore, for the expected payoff of not deviating one should make three cases [2]:

$$E\Pi_1(x^{a*}) = \begin{cases} \frac{1}{2}(v_1 - v_2) + \frac{1}{2}(v_1 - v_3) - \epsilon, & \text{if} \quad 0 < \epsilon < v_1 - v_2 \\ \frac{1}{2}(v_1 - \epsilon - v_3), & \text{if} \quad v_1 - v_2 \leq \epsilon < v_1 - v_3 \\ 0, & \text{if} \quad \epsilon \geq v_1 - v_3 \end{cases} \tag{A.16}$$

Remember that continuation payoffs are expressed in terms of net valuations, so that they take into account Stage-a bids. Interpretation is that player L (who gets a zero continuation payoff) is able on average to exactly cover the sum of her outlays, whereas player H on average is able to more than cover the sum of her outlays.

It is clear that the payoff function in Equation A.16 is maximized when ϵ is as closest as possible to zero (of course it must be strictly positive, otherwise she would be deviating) so that player 1 will optimally choose the smallest ϵ above zero [3]. Therefore, to see when it is profitable to deviate for player 1 (Equation A.14) we need to compare the payoff of deviating (Equation A.15) with only the first line of the payoff of not deviating (Equation A.16). We easily get that the condition in Equation A.14 holds *iff*:

$$\epsilon > \frac{1}{3}v_1 - \frac{1}{6}(v_2 + v_3) \tag{A.17}$$

Since the ϵ that player 1 optimally chooses is as close as possible to zero, she will never find it profitable to deviate.

Consider now player 2. From Proposition 2.3 we know that she does not find it convenient neither to overlap nor to overbid player 1, since this way she would be shortlisted with NV_L with certainty. Hence, the

[2] Notice that since $v_1 > v_2 > v_3$, when the condition $\epsilon \leq v_1 - v_2$ holds, then it also holds that $\epsilon < v_1 - v_3$. Specularly, when $\epsilon \geq v_1 - v_3$, then $\epsilon > v_1 - v_2$.

[3] The fact that the optimal ϵ is undetermined is due to the tie-breaking rule. If tie-breaking were in favor of player 1 (i.e., player 1 wins in all ties), player 1 would optimally bid exactly zero.

only possibly profitable deviation would be to underbid player 1 by an amount δ. Therefore, player 2 will deviate *iff*:

$$E\Pi_2(x_2^a = (\epsilon - \delta), x_{-2}^{a*}) > E\Pi_2(x^{a*}) \tag{A.18}$$

If player 2 does not deviate and bids zero, she has $\frac{1}{2}$ probability to get shortlisted. In that case she meets player 1 and always get shortlisted with the NV_L, since by the maximization problem of player 1 (Equation A.16) we have that player 1's optimal bid ϵ is such that $NV_1 > NV_2$, so that player 2's expected payoff from shortlisting is 0. With $\frac{1}{2}$ probability she is not shortlisted and she gets an actual payoff of zero, since she bid zero. Therefore:

$$E\Pi_2(x^{a*}) = 0 \tag{A.19}$$

On the other hand, if player 2 deviates and underbids player 1, she gets shortlisted with certainty. She happens to have NV_H (and hence get a positive payoff $u_2^* = NV_2 - NV_1$) *iff*

$$v_2 - (\epsilon - \delta) > v_1 - \epsilon \to v_1 - v_2 < \delta \quad \forall \epsilon > 0 \tag{A.20}$$

Otherwise she has NV_L (and gets $u_2^* = 0$).
Notice that since $\delta < \epsilon$ by definition, then we have that the condition from player 1's maximization problem (Equation A.16) i.e. $\epsilon < v_1 - v_2$, implies $\delta < v_1 - v_2$, so that the condition above on δ is never met, and:

$$E\Pi_2(x_2^a = (\epsilon - \delta), x_{-2}^{a*}) = 0 \tag{A.21}$$

Therefore player 2 never finds it profitable to deviate.
Also, notice that since $v_2 > v_3$, then $\delta < v_1 - v_2$ implies $\delta < v_1 - v_3$, so that player 3 neither has any incentive to deviate.
Therefore, since no player has any incentive to deviate, we can conclude that $(x_1^a = \epsilon(\simeq 0), x_2^a = x_3^a = 0)$ is an equilibrium of Stage-a all-pay auction Q.E.D.

Proof that the triple $(x_1^a = \epsilon, x_2^a = 0, x_3^a = 0)$ is the unique equilibrium of Stage-a all-pay auction

The proof is by contradiction and articulated in lemmas.

Lemma A.6 *No triple of the form $(x_i^a > x_j^a > x_k^a)$, with $x_k^a \geq 0$, can be an equilibrium.*

Proof. Suppose it is. Then no player has any profitable deviation. Consider players i and j. Either $v_i > v_j$ or $v_j > v_i$. If $v_i > v_j$, then by Proposition 2.3 i makes a profitable deviation by underbidding (at limit overlapping) to x_j^a. On the other hand, if $v_j > v_i$, then i makes a profitable deviation by bidding zero. Therefore $(x_i^a > x_j^a > x_k^a)$ is never an equilibrium Q.E.D.

Lemma A.7 *No triple of the form* $(x_i^a = x_j^a > x_k^a)$*, with* $x_k^a \geq 0$*, can be an equilibrium.*

Proof. Suppose it is. Then no player has any profitable deviation. Again, consider players i and j. Either $v_i > v_j$ or $v_j > v_i$. If $v_i > v_j$, then j makes a profitable deviation by bidding zero. On the other hand, if $v_j > v_i$, then i makes a profitable deviation by bidding zero. Therefore $(x_i^a = x_j^a > x_k^a)$ is never an equilibrium Q.E.D.

Lemma A.8 *No triple of the form* $(x_i^a = x_j^a = x_k^a)$*, with* $x_k^a \geq 0$*, can be an equilibrium.*

Proof. Suppose it is. Then no player has any profitable deviation. There are two possible cases:

3.1 $(x_i^a = x_j^a = x_k^a = 0)$
We have just proved that player 1 finds it always profitable to bid a positive amount rather than zero. Therefore 1 makes a profitable deviation by bidding a positive amount rather than zero.

3.2 $(x_i^a = x_j^a = x_k^a > 0)$
Player 3 makes a profitable deviation by bidding zero rather than a positive amount.

In both cases we reach a contradiction with the initial assumption, so that $(x_i^a = x_j^a = x_k^a)$ can never be an equilibrium Q.E.D.

Corollary A.1 *From Lemmas A.6-A.8 it follows that all plausible equilibria must be of the form* $(x_i^a > x_j^a = x_k^a)$*, with* $x_k^a \geq 0$.

Lemma A.9 *No triple of the form* $(x_3^a > x_1^a = x_2^a)$*, with* $x_1^a = x_2^a \geq 0$ *can be an equilibrium (i.e., player 3 cannot be the highest bidder).*

Proof. Suppose it is. Then no player has any profitable deviation. But player 3 does a profitable deviation by bidding zero rather than a positive amount. Therefore $(x_3^a > x_1^a = x_2^a)$ cannot be an equilibrium Q.E.D.

Lemma A.10 *No triple of the form ($x_2^a > x_1^a = x_3^a$), with $x_1^a = x_3^a \geq 0$ can be an equilibrium (i.e., player 2 cannot be the highest bidder).*

Proof. Suppose it is. Then no player has any profitable deviation.
Consider player 1. We need to check whether she has any incentive to slightly overbid player 3, such that $x_1^{a\prime} = x_3^a + \epsilon \leq x_2^a$, with $\epsilon > 0$.
If she does not deviate she will get shortlisted with probability $1/2$. In this case she will meet player 2 and by Proposition 2.3 she will always have the NV_H, and get a positive continuation payoff $u_1^* = NV_1 - NV_2 = v_1 - x_1^a - (v_2 - x_2^a)$. With probability $1/2$ she will not get shortlisted and will incur a loss equal to her bid, $u_1^* = -x_1^a$, with $x_1^a \geq 0$. Therefore, the expected payoff of non deviating is:

$$E\Pi_1(x^{a*}) = \frac{1}{2}(v_1 - v_2 + x_2^a) - x_1^a \tag{A.22}$$

Now suppose that she deviates and bids $x_1^{a\prime} = x_3^a + \epsilon = x_1^a + \epsilon$, with $x_1^a = x_3^a \geq 0$. In this case she will get shortlisted with certainty, and always with NV_H, so that the expected payoff from deviating is:

$$E\Pi_1(x_1^{a\prime} = (x_1^a + \epsilon), x_{-1}^{a*}) = v_1 - v_2 + x_2^a - x_1^a - \epsilon \tag{A.23}$$

from which we easily get that

$$\forall \epsilon : 0 < \epsilon < \frac{1}{2}(v_1 - v_2 + x_2^a) \tag{A.24}$$

it holds that

$$E\Pi_1(x_1^{a\prime} = (x_1^a + \epsilon), x_{-1}^{a*}) > E\Pi_1(x^{a*}) \tag{A.25}$$

i.e., player 1 will find it convenient to deviate. Notice that player 1 will optimally choose an ϵ which is closest as possible to zero, so that Equation A.25 will always hold and player 1 will always deviate. Therefore the triple ($x_2^a > x_1^a = x_3^a$), with $x_1^a = x_3^a \geq 0$ cannot be an equilibrium Q.E.D.

Corollary A.2 *From the previous steps it follows readily that the only possible equilibrium of the Stage-a all-pay auction is ($x_1^a = \epsilon \cong 0, x_2^a = x_3^a = 0$). Moreover since the optimal x_1^a is very close to zero, it will always be the case that $NV_1 > NV_2$ if player 2 is shortlisted, and $NV_1 > NV_3$ if player 3 is shortlisted, so that only the "asym-asym" case occurs in equilibrium.*

Q.E.D

A.1.5 Proof of Proposition 2.5

We know from Equations 2.6 and 2.7 that, in the event a player gets shortlisted (which we will refer to as *SH* in the following for notational convenience), she will get a positive continuation payoff *iff* her net valuation will be higher than the net valuation of the other shortlisted player, and a zero continuation payoff if her net valuation will be lower or equal than her opponent's; if instead she does not get shortlisted (*NO-SH* in the following), she will incur a loss equal to her Stage-a bid. Therefore, each player i's expected payoff from playing mixed strategies in Stage-a is as follows:

$$\begin{aligned} E\Pi_i(h^a) &= (NV_i - NV_j)P(NV_i > NV_j|i,j\ SH)P(i,j\ SH)+ \\ &+ (NV_i - NV_k)P(NV_i > NV_k|i,k\ SH)P(i,k\ SH) - x_i^a P(i\ NO\text{-}SH) \end{aligned} \tag{A.26}$$

with $i, j, k \in \{1, 2, 3\}$.

Remember that a couple of players i, j get shortlisted with certainty if their Stage-a bids are the two highest i.e., we have either $(x_i^a > x_j^a > x_k^a)$ or $(x_j^a > x_i^a > x_k^a)$ or $(x_i^a = x_j^a > x_k^a)$. On the other hand, when either $(x_i^a > x_j^a = x_k^a)$ or $(x_j^a > x_i^a = x_k^a)$ occur, there is $\frac{1}{2}$ probability that both i and j are shortlisted, whereas in case $(x_i^a = x_j^a = x_k^a)$, there is $\frac{1}{3}$ probability that both i and j are shortlisted. Since events are mutually exclusive, the probability that the couple of players i, j are shortlisted is as follows:

$$\begin{aligned} P(i,j\ SH) &= P(x_i^a > x_j^a > x_k^a) + P(x_j^a > x_i^a > x_k^a) + P(x_i^a = x_j^a > x_k^a) \\ &+ \frac{1}{2}P(x_i^a > x_j^a = x_k^a) + \frac{1}{2}P(x_j^a > x_i^a = x_k^a) + \frac{1}{3}P(x_i^a = x_j^a = x_k^a) \end{aligned} \tag{A.27}$$

On the other hand, in the events $(x_i^a < x_j^a < x_k^a)$, $(x_i^a < x_k^a < x_j^a)$ and $(x_i^a < x_j^a = x_k^a)$ player i never gets shortlisted, whereas in the events $(x_i^a = x_k^a < x_j^a)$, $(x_i^a = x_j^a < x_k^a)$ and $(x_i^a = x_j^a = x_k^a)$ there is a positive probability that player i does not get shortlisted (respectively, $\frac{1}{2}$ in the first two events and $\frac{1}{3}$ in the third). Therefore the probability of no shortlisting for player i (with $i \in \{1, 2, 3\}$) is:

$$P(i\ NO\text{-}SH.) = P(x_i^a < x_j^a < x_k^a) + P(x_i^a < x_k^a < x_j^a) + P(x_i^a < x_j^a = x_k^a) + \frac{1}{2}P(x_j^a > x_i^a = x_k^a) + \frac{1}{2}P(x_k^a > x_i^a = x_j^a) + \frac{1}{3}P(x_i^a = x_j^a = x_k^a) \tag{A.28}$$

Similarly to what noticed for the pure-strategy analysis, we have here that relatively stronger players have an advantage over weaker ones, since they can restrict optimally their support so to make sure to get a positive continuation payoff, *conditional on shortlisting*.
In fact, one can see that by choosing the interval $[0, v_1 - v_2)$ as her support, player 1 makes it sure that for any bid she may plausibly expect from player $j \in \{2, 3\}$, i.e., for all $x_j^a \in [0, v_j)$[4], it will always be true that $x_1^a < (v_1 - v_j) + x_j^a$, so that $P(NV_1 > NV_j|1, j\ SH) = 1$ and $P(NV_j > NV_1|1, j\ SH) = 0$. Therefore, player 1 is able to optimally choose the support to make it sure that, in case she gets shortlisted, she will have the higher net valuation, and hence get a positive continuation payoff, regardless of whom the other shortlisted player is.
On her hand, player 2 can do a similar reasoning and pick $[0, v_2 - v_3)$ as her support, which ensures that in case she gets shortlisted with player 3, she always has the higher net valuation and gets a positive continuation payoff: for any plausible bid from player 3 - i.e., for all $x_3^a \in [0, v_3)$ - it will always hold that $x_2^a < (v_2 - v_3) + x_3^a$, so that $P(NV_2 > NV_3|2{,}3\ SH) = 1$ and $P(NV_3 > NV_2|2{,}3\ SH) = 0$, whereas she knows that if she gets shortlisted with Player 1 she will get a zero continuation payoff.
Consequently, player 3 knows that in case she gets shortlisted, she cannot do nothing to prevent her opponent to have the higher net valuation. So she expects a zero continuation payoff from shortlisting regardless of whom the other shortlisted player is.
Note that the presence of an upper bound on players' rational bidding has an impact on the probability of shortlisting, but players do not have an interest in getting shortlisted if they expect not to take a positive continuation payoff: their goal is to maximize their expected payoff, rather than getting shortlisted per se.
Given the considerations above, we have that players' expected payoffs from randomizing in Stage-a are as follows:

[4]Notice that no player would bid her own entire valuation in Stage-a, since in case she gets shortlisted she will have no resources left to bid in Stage-b, so that the other shortlisted player would be able to win with an infinitesimal amount, making her losing the entire budget.

$$E\Pi_1(h^a) = (NV_1 - NV_2)P(1{,}2\ SH) + (NV_1 - NV_3)P(1{,}3\ SH) - x_1^a P(1\ NO\text{-}SH) \tag{A.29}$$

$$E\Pi_2(h^a) = (NV_2 - NV_3)P(2{,}3\ SH) - x_2^a P(2\ NO\text{-}SH) \tag{A.30}$$

$$E\Pi_3(h^a) = -x_3^a P(3\ NO\text{-}SH) \tag{A.31}$$

Since $E\Pi_3(h^a) \leq 0$, player 3 never finds it convenient to randomize and, due to Assumption 2.2 in the model, we conclude that player 3 will bid zero with probability 1, i.e., $P(x_3^a = 0) = 1$.
Considering that (i) players randomize independently, (ii) given $x_3^a = 0$ then $P(x_i^a < x_3^a) = 0$ (with $i \in \{1, 2\}$) and (iii) $P(x_i^a = x_j^a) = 1 - P(x_i^a > x_j^a) - P(x_i^a < x_j^a) \quad \forall i, j \in \{1, 2, 3\}$, we can explicit the expected payoff of Player 1 (Equation A.29) as follows:

$$\begin{aligned}
E\Pi_1(h^a) &= (NV_1 - NV_2)[P(x_1^a > x_2^a)P(x_2^a > x_3^a) + P(x_2^a > x_1^a)P(x_1^a > x_3^a) + \\
&+ (1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))P(x_2^a > x_3^a) + \frac{1}{2}P(x_1^a > x_2^a)(1 - P(x_2^a > x_3^a)) + \\
&+ \frac{1}{2}P(x_2^a > x_1^a)(1 - P(x_1^a > x_3^a)) + \frac{1}{3}(1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))(1 - P(x_2^a > x_3^a))] + \\
&+ (NV_1 - NV_3)[\frac{1}{2}P(x_1^a > x_2^a)(1 - P(x_2^a > x_3^a)) + \\
&+ \frac{1}{3}(1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))(1 - P(x_2^a > x_3^a))] - x_1^a[P(x_1^a < x_2^a)(1 - P(x_2^a > x_3^a)) + \\
&+ \frac{1}{2}P(x_2^a > x_1^a)(1 - P(x_1^a > x_3^a)) + \frac{1}{3}(1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))(1 - P(x_2^a > x_3^a))]
\end{aligned} \tag{A.32}$$

Notice that in Equation A.32, we assumed that Player 1's support is $[0, v_1 - v_2)$, so that she might play zero with a positive probability. In the following we show that Player 1's expected payoff from keeping zero in the mix, i.e., randomizing over $[0, v_1 - v_2)$ is lower than the expected payoff she could get by dropping the bid on 0 from the mix, i.e., randomizing over $(0, v_1 - v_2)$.
By imposing $P(x_1^a > 0) = 1$ in Equation A.32, we can calculate

$$
\begin{aligned}
&E\Pi_1(\text{mix on } (0, v_1 - v_2)) = (NV_1 - NV_2)[P(x_1^a > x_2^a)P(x_2^a > x_3^a) + \\
&+ (1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))P(x_2^a > x_3^a) + P(x_2^a > x_1^a) + \\
&+ \frac{1}{2}P(x_1^a > x_2^a)(1 - P(x_2^a > x_3^a)) + \frac{1}{3}(1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))(1 - P(x_2^a > x_3^a))] + \\
&+ (NV_1 - NV_3)[\frac{1}{2}P(x_1^a > x_2^a)(1 - P(x_2^a > x_3^a)) + \\
&+ \frac{1}{3}(1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))(1 - P(x_2^a > x_3^a))] + \\
&- x_1^a[P(x_1^a < x_2^a)(1 - P(x_2^a > x_3^a)) + \frac{1}{3}(1 - P(x_1^a > x_2^a) - P(x_1^a < x_2^a))(1 - P(x_2^a > x_3^a))]
\end{aligned}
\tag{A.33}
$$

By imposing $E\Pi_1(\text{mix on } (0, v_1 - v_2)) \geq E\Pi_1(\text{mix on } [0, v_1 - v_2)) = E\Pi_1(h^a)$ we get the condition $(v_1 - v_2)(1 - P(x_1^a > 0)) + x_2^a(1 - P(x_1^a > 0)) \geq 0$ which is always true. Therefore player 1 will optimally never put mass on zero. From Equation A.30 we know that the only chance for player 2 to get a positive expected payoff from randomizing is to get shortlisted with 3. But the probability that both player 2 and player 3 will be shortlisted is 0, since we know that player 1 will get shortlisted with certainty. Therefore, player 2 neither has any advantage from randomizing, since if she gets shortlisted she will meet player 1 for sure, and hence get a zero continuation payoff. By Assumption 2.2 in the model we conclude that also player 2 prefers to bid zero with probability 1 rather than randomizing. Given that players 2 and 3 play zero with probability 1, player 1 will optimally bid a infinitesimal positive amount ϵ, and we are back to the pure-strategy case.
Therefore there is no mixed strategy equilibrium for the Stage-a all-pay auction Q.E.D.

A.1.6 Proof of Proposition 2.7

Notice that since Stage-a yields basically no revenue, the relevant comparison is between the Stage-b all-pay auction and the standard all-pay auction with two asymmetric players. Recalling from Baye et al. (1996) the equilibrium of the standard asymmetric all-pay auction (with $v_1 > v_2$),

$$
\begin{cases}
F_1(x_1) = \frac{x_1}{v_2} & \forall x_1 \in [0, v_2] \\
F_2(x_2) = \frac{v_1 - v_2 + x_2}{v_1} & \forall x_2 \in [0, v_2]
\end{cases}
\tag{A.34}
$$

we have that player 1's spending is distributed uniformly on the interval $[0, v_2]$, and so her expected outlay is $E[x_1] = v_2/2$.
Conditional upon bidding positive, player 2's outlay also is distributed uniformly on $[0, v_2]$, so that her expected outlay is $E[x_2] = (v_2/2)\,(v_2/v_1)$[5]. Therefore, the total expected revenue from a standard two-player all-pay auction is:

$$E[x_1 + x_2] = \frac{v_2}{2} + \frac{v_2}{2}\left(\frac{v_2}{v_1}\right) = \frac{v_2}{2}\left(1 + \frac{v_2}{v_1}\right) \qquad \text{(A.36)}$$

Turning to the Stage-b all-pay auction, we have from Proposition 2.6 that the upper bound of the equilibrium support is *ex-ante undetermined*, since player L will be player 2 with probability $\frac{1}{2}$ and player 3 with probability $\frac{1}{2}$. Therefore, player 1's outlay will be distributed uniformly on $[0, v_2]$ in half of the cases and on $[0, v_3]$ in the other half, so that her expected outlay will be:

$$E[x_1^b] = \left(\frac{1}{2}\right)\frac{v_2}{2} + \left(\frac{1}{2}\right)\frac{v_3}{2} \qquad \text{(A.37)}$$

As for player 2, in case she is shortlisted, she bids according to an uniform distribution on the interval $[0, v_2]$ conditional upon spending positive [6]. Therefore her expected outlay will be:

$$E[x_2^b] = \left(\frac{1}{2}\frac{v_2}{v_1}\right)\frac{v_2}{2} \qquad \text{(A.38)}$$

Analogously, player 3's expected spending will be:

$$E[x_3^b] = \left(\frac{1}{2}\frac{v_3}{v_1}\right)\frac{v_3}{2} \qquad \text{(A.39)}$$

Therefore, neglecting player 1's first-stage bid which is very close to zero, we have that the total expected revenue from the two-stage all-pay auction is as follows:

[5]Decomposing player 2's equilibrium distribution in its continuous and discrete parts, we can write:

$$F_2(x_2) = 1 - \frac{v_2}{v_1} + \left(\frac{v_2}{v_1}\right)\frac{x_2}{v_2} \qquad \text{(A.35)}$$

where v_2/v_1 is the probability of bidding positive and $[1 - v_2/v_1]$ is the probability of bidding zero.

[6]Notice that we need conditioning on both the event of shortlisting and the event of spending positive.

$$E[x_1^b + x_2^b + x_3^b] = \frac{v_2}{4}\left(1 + \frac{v_2}{v_1}\right) + \frac{v_3}{4}\left(1 + \frac{v_3}{v_1}\right) \tag{A.40}$$

which can be easily seen to be smaller than $E[x_1 + x_2]$ in the standard all-pay auction (Equation A.36) Q.E.D.

A.2 Appendix to Chapter 3

A.2.1 Proof of Proposition 3.2

The proof is analogous to that in LT (p. 520) and exploit a simple revealed preferences argument. Revealed preferences imply that if a_L^* is optimal for β_L, then it must hold that[7]:

$$t + \mathbb{E}[{a_L^*}^F] - \psi(\beta_L - C + a_L^*) \geq t + \mathbb{E}[{a_H^*}^F] - \psi(\beta_L - C + a_H^*) \quad \text{(A.41)}$$

Analogously, if a_H^* is optimal for β_H, it must hold that:

$$t + \mathbb{E}[{a_H^*}^F] - \psi(\beta_H - C + a_H^*) \geq t + \mathbb{E}[{a_L^*}^F] - \psi(\beta_H - C + a_L^*) \quad \text{(A.42)}$$

Adding up (A.41) and (A.42), one obtains:

$$\psi(\beta_L - C + a_H^*) + \psi(\beta_H - C + a_L^*) - \psi(\beta_L - C + a_L^*) - \psi(\beta_H - C + a_H^*) \geq 0 \quad \text{(A.43)}$$

or

$$\int_{a_H^*}^{a_L^*} \int_{\beta_L}^{\beta_H} \psi''(\beta - C + a)\, d\beta\, da \geq 0 \quad \text{(A.44)}$$

which, together with $\psi''(.) > 0$ and $\beta_L < \beta_H$ implies $a_L^* \geq a_H^*$ Q.E.D.

A.2.2 Proof of Proposition 3.4

As in the case where cost-padding is unfeasible, the politician is affected by incomplete information only trough the rent to be given to the efficient type, which depends on the effort of the inefficient type. The maximization with respect to the effort of the efficient type is hence the same as when cost-padding is unfeasible (Equation (3.25)).

[7]Subscript j indicating the type of the politician is omitted here.

A.2.3 Proof of Proposition 3.6

The values of $\underline{\rho}_M$ and $\underline{\rho}_O$ are directly derived from condition (3.32) where the relevant values of $\mathbb{E}(\alpha_j^F)$, $j \in \{M, O\}$ are determined in Proposition 3.1. Straightforward calculations yield results (ii) and (iii). Result (i) is obtained by observing that $(\partial \underline{\rho_j}/(\partial\alpha) > 0$ iff

$$\psi(e_H^{CP}) - \psi(e_H^{CP} - \alpha) > \psi'(e_H^{CP} - \alpha)\alpha \tag{A.45}$$

For the Mean Value Theorem we have $\psi(e_H^{CP}) - \psi(e_H^{CP} - \alpha) = \psi'(x)\alpha$ where
$e_H^{CP} - \alpha < x < e_H^{CP}$, from which we have that the inequality in (A.45) is verified. Q.E.D.

A.2.4 Proof of Proposition 3.7

Writing constraints (3.36) and (3.37) in the form

$$\Phi(e_H) - \mathbb{E}[\Pi_L] \leq 0 \tag{A.46}$$

$$\Gamma(e_H) - \mathbb{E}[\Pi_L] \leq 0 \tag{A.47}$$

we have that the Lagrangian for problem (3.38) is:

$$\mathcal{L} = \nu[S - (1+\lambda)[\beta_L - e^{FB} + \psi(e^{FB})] - \lambda\mathbb{E}[\Pi_L]] + \\ (1-\nu)[S - (1+\lambda)[\beta_H - e_H + \psi(e_H)]] + \xi[\mathbb{E}[\Pi_L] - \Phi(e_H)] + \zeta[\mathbb{E}[\Pi_L] - \Gamma(e_H)] \tag{A.48}$$

where ξ and ζ are the Lagrange multipliers of constraints (A.46) and (A.47) respectively.

Lemma A.11 *Constraints (A.46) and (A.47)are qualified.*

Proof. The gradients of constraints (A.46) and (A.47) are respectively
$\nabla = (\Phi'(e_H); -1) \neq (0;0) \quad \forall e_H$ and $\nabla = (\Gamma'(e_H); -1) \neq (0;0) \quad \forall e_H$
Further,

$$\begin{vmatrix} \Phi'(e_H) & -1 \\ \Gamma'(e_H) & -1 \end{vmatrix} = -\Phi'(e_H) + \Gamma'(e_H) \neq 0 \quad \forall e_H \geq 0 \tag{A.49}$$

Therefore constraints are qualified Q.E.D.

Lemma A.12 *The objective function $U(e_H, \mathbb{E}[\Pi_L])$ is concave and both constraints (A.46) and (A.47) are convex, so that, given constraint qualification, the Khun-Tucker necessary conditions for a maximum are also sufficient, and each maximizer is a global maximizer (e.g., see Chiang and Wainwright (2005)).*

Proof. The Hessian matrix of the objective function is:

$$H = \begin{vmatrix} -(1-\nu)(1+\lambda)\psi''(e_H) & 0 \\ 0 & 0 \end{vmatrix} \tag{A.50}$$

Since $U_{e_H,e_H} = (1-\nu)(1+\lambda)(-\psi''(e_H)) < 0$, $U_{\mathbb{E}[\Pi_L],\mathbb{E}[\Pi_L]} = 0$ and $|H| = 0$ we can conclude that H is semi-definite negative everywhere and hence the objective function is concave.
Similarly, it is straightforward to check that the Hessian matrices of, respectively, constraints (A.46) and (A.47)

$$H = \begin{vmatrix} \Phi''(e_H) & 0 \\ 0 & 0 \end{vmatrix} \qquad H = \begin{vmatrix} \Gamma''(e_H) & 0 \\ 0 & 0 \end{vmatrix} \tag{A.51}$$

are semi-definite positive everywhere, so that both constraints are convex Q.E.D.

Applying the Khun-Tucker necessary conditions, we need to consider four possible cases according to which of the constraints is binding:

Case1 no constraint is binding: $\xi = 0, \zeta = 0$

Case2 (A.46) binding, (A.47) not binding: $\xi > 0, \zeta = 0$

Case3 (A.47) binding, (A.46) not binding: $\xi = 0, \zeta > 0$

Case4 both constraints are binding: $\xi > 0, \zeta > 0$

Lemma A.13 *Only Case2 and Case3 yield a solution.*

Proof.

Case1 $\xi = 0, \zeta = 0$

The FOC relative to the variable $\mathbb{E}[\Pi_L]$ gives $-\nu\lambda = 0$, which is clearly impossible (as we expected, since the incentive compatibility constraint for the efficient type should be binding in equilibrium).

Case2 $\xi > 0, \zeta = 0$ ("Classical Regime")

Provided that the following condition

$$\Phi(e_H^{CL}) \geq \Gamma(e_H^{CL}) \tag{A.52}$$

holds, the unique solution for this case is: $\{e_H^{CL}; \Pi_L^{CL} = \Phi(e_H^{CL}); \xi^{CL} = \nu\lambda\}$, where

$$e_H^{CL} : \psi(e_H^{CL}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\Phi'(e_H^{CL}) \tag{A.53}$$

The solution is identical to the case where cost-padding is unfeasible. Condition (A.52) corresponds to (3.39) in text.

Case3 $\xi = 0, \zeta > 0$ ("Repressed Cost Padding Regime")

Provided that the following condition

$$\Gamma(e_H^{RC}) \geq \Phi(e_H^{RC}) \tag{A.54}$$

holds, the unique solution for this case is $\{e_H^{RC}; \Pi_L^{RC} = \Gamma(e_H^{RC}); \zeta^{RC} = \nu\lambda\}$, where

$$e_H^{RC} : \psi(e_H^{RC}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\Gamma'(e_H^{RC}) \tag{A.55}$$

Condition (A.54) corresponds to the right hand of (3.41) in text.

Case4 $\xi > 0, \zeta > 0$

The FOCs imply $\zeta^{4*} < 0$, impossible.

Therefore only Case2 and Case3 give solutions Q.E.D.

Lemma A.14 $e_H^{RC} > e_H^{CL}$.

Proof. Since $\Phi'(e) > \Gamma'(e) \quad \forall e \geq 0$, the result follows by inspection of the FOCs in (A.53) and (A.55).

Lemma A.15 *The solutions found in Case2 and Case 3 are mutually exclusive. Therefore for each regime there is a unique solution, which by virtue of Lemma A.12 is global.*

Proof. Given Lemma A.14, it must be the case that if (A.52) holds for e_H^{CL}, it must hold also for $e_H^{RC} > e_H^{CL}$. Therefore, when (A.52) holds, (A.54) cannot hold. With a similar reasoning one can conclude that when (A.54) holds, (A.52) cannot hold. When (A.52) holds, $(e_H^{CL}, \Phi(e_H^{CL}))$ is the only mazimizer, while when (A.54) holds, $(e_H^{RC}, \Gamma(e_H^{RC}))$ is the only maximizer Q.E.D

A.2.5 Proof of Proposition 3.8

The values of $\overline{\rho}_M$ and $\overline{\rho}_O$ are directly derived from condition (3.39) where the relevant value of $\mathbb{E}(\alpha_j^F)$ with $j \in \{M, O\}$ is used. Straightforward calculations yield results (i), (ii) and (iii), while (iv) can be be obtained by exploiting the Mean Value Theorem to show that $\partial\overline{\rho_j}/\partial\alpha < 0$ Q.E.D.

A.2.6 Checks on the IR_L and IC_H constraints

Type1 Optima

Check on IR_L:

$$\mathbb{E}[\Pi_L] \geq t_H + \mathbb{E}[\alpha_j^F] - \psi(\beta_L - C_H + \alpha) > t_H + \mathbb{E}[\alpha_j^F] - \psi(\beta_H - C_H + \alpha) \geq 0 \tag{A.56}$$

where the first inequality comes from IC_L, the second from the fact that $\beta_H > \beta_L$ and the third from IR_H, Q.E.D.

Check on IC_H:

In this case IC_H is:

$$\mathbb{E}[\Pi_H] \geq t_L + \mathbb{E}[\alpha_j^F] - \psi(\beta_H - C_L + \alpha) \tag{A.57}$$

Combining the fact that IC_L is binding at the optimum:

$$t_L^{CP} - \psi(\beta_L - C_L^{CP}) = t_H^{CP} + \mathbb{E}[\alpha^F] - \psi(\beta_L - C_H^{CP} + \alpha) \tag{A.58}$$

with the facts that $\beta_H > \beta_L$ and $C_H^{CP} > C_L^{CP}$ (since $e_H^{CP} < e_L^{CP}$) yields:

$$t_H^{CP} + \mathbb{E}[\alpha^F] - \psi(\beta_H - C_H^{CP} + \alpha) \geq t_L^{CP} + \mathbb{E}[\alpha^F] - \psi(\beta_H - C_L^{CP} + \alpha) \tag{A.59}$$

Q.E.D.

Type4 Optima

We need to distinguish between the two cases a) $a_L^m = 0$ and b) $a_L^m = \alpha$.

Case a) Check on IR_L:

$$\Pi_L \geq t_H - \psi(\beta_L - C_H) > t_H - \psi(\beta_H - C_H) \geq 0 \tag{A.60}$$

where the first inequality comes from IC_L, the second from the fact that $\beta_H > \beta_L$ and the third from IR_H, Q.E.D.

Case a) Check on IC_H:

The relevant solution is the "classical regime"(indicated by superscript CL), so

$$\begin{aligned} & t_H^{CL} - \psi(\beta_H - C_H^{CL}) > t_H^{CL} - \psi(\beta_H - C_L^{CL}) = \\ & = t_L^{CL} + \psi(\beta_L - C_H^{CL}) - \psi(\beta_L - C_L^{CL}) > t_L - \psi(\beta_H - C_L^{CL}) \end{aligned} \tag{A.61}$$

where the first inequality comes from the fact that $C_H^{CL} > C_L^{CL}$ (since $e_H^{CL} < e_L^{CL}$), the equality comes from the fact that IC_L is binding at the optimum (i.e., $t_L^{CL} - \psi(\beta_L - C_L^{CL}) = t_H^{CL} - \psi(\beta_L - C_H^{CL})$) and the third inequality from $\beta_H > \beta_L$, Q.E.D.

Case b) Check on IR_L:

$$\mathbb{E}[\Pi_L] \geq t_H + \mathbb{E}[\alpha_j^F] - \psi(e_H - \Delta\beta + \alpha) > t_H + \mathbb{E}[\alpha_j^F] - \psi(e_H) > t_H - \psi(e_H) \geq 0 \tag{A.62}$$

where the first inequality comes from IC_L (and using $\beta_L - C_H + \alpha = e_H - \Delta\beta + \alpha$), the second from the fact that $\Delta\beta > \alpha$ by Assumption 3.2 (and using $\beta_H - C_H = e_H$), and the last from IR_H, Q.E.D.

Case b) Check on IC_H:

In this case IC_H is:

$$\Pi_H = t_H - \psi(\beta_H - C_H) \geq t_L - \psi(\beta_H - C_L) \tag{A.63}$$

or, in terms of e_H and e_L

$$\Pi_H = t_H - \psi(e_H) \geq t_L - \psi(e_L + \Delta\beta) \tag{A.64}$$

Using the fact that IC_L is binding at the optimum:

$$t_L^{RC} - \psi(\beta_L - C_L^{RC}) = t_H^{RC} + \mathbb{E}[\alpha_j^F] - \psi(\beta_L - C_H^{RC} + \alpha) \tag{A.65}$$

or, in terms of e_H^{RC} and e_L^{RC}

$$t_L^{RC} - \psi(e_L^{RC}) = t_H^{RC} + \mathbb{E}[\alpha_j^F] - \psi(e_H^{RC} - \Delta\beta + \alpha) \tag{A.66}$$

and the fact that $\Delta\beta > \alpha$ (by Assumption 3.2), we get

$$t_H^{RC} - \psi(e_H^{RC}) \geq t_L^{RC} - \psi(e_L^{RC} + \Delta\beta) \tag{A.67}$$

A.3 Appendix to Chapter 4

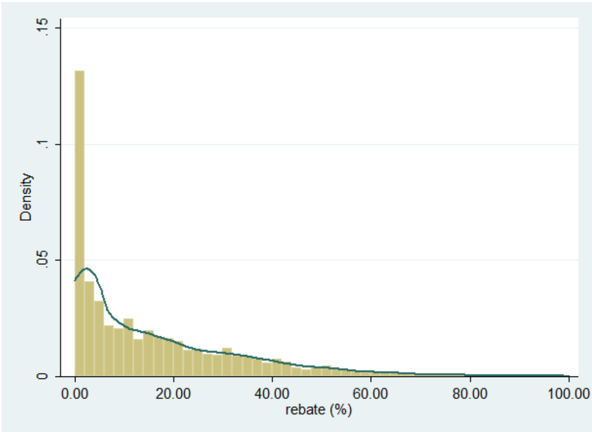

Figure A.1: Empirical distribution of winning rebate (against a Kernel density estimate)

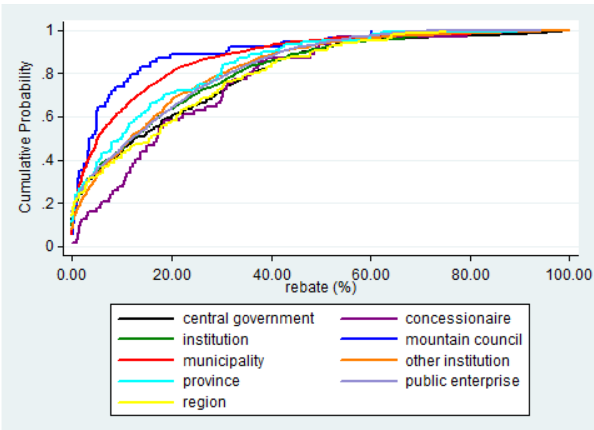

Figure A.2: Empirical cumulative distribution of winning rebate by institutional class of CA

Table A.1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
rebate (%)	16.328	18.495	0	99.946	4805
central government	0.085	0.279	0	1	4805
concessionaire	0.013	0.113	0	1	4805
institution	0.148	0.355	0	1	4805
public enterprise	0.271	0.445	0	1	4805
region	0.03	0.172	0	1	4805
municipality	0.247	0.431	0	1	4805
province	0.022	0.148	0	1	4805
mountain council	0.011	0.105	0	1	4805
other institution	0.172	0.377	0	1	4805
offers number	4.274	5.600	1	67	4805
open	0.758	0.429	0	1	4805
restricted	0.103	0.304	0	1	4805
negotiated	0.037	0.188	0	1	4805
negotiated without call	0.103	0.304	0	1	4805
lowest price	0.413	0.492	0	1	4805
met	0.537	0.499	0	1	4805
not specified	0.05	0.218	0	1	4805
population	695.096	973.627	0	2617.175	4805
reserve price	2010.871	4836.994	0.131	77656.867	4805
service	0.648	0.478	0	1	4805
ordinary	0.837	0.37	0	1	4805
utilities	0.156	0.363	0	1	4805
security	0.007	0.084	0	1	4805
behalf	0.035	0.183	0	1	4805
potential bidders	156.66	111.243	1	380	4805
incumbency	2.681	3.939	1	39	4805
CA experience	7.345	13.053	1	98	4805
repeated interact	1.143	0.594	1	12	4805
local win	0.282	0.45	0	1	4805
regional win	0.148	0.355	0	1	4805
national win	0.543	0.498	0	1	4805
international win	0.027	0.162	0	1	4805
center	0.325	0.468	0	1	4805
north	0.471	0.499	0	1	4805
south	0.204	0.403	0	1	4805
2011	0.04	0.195	0	1	4805
2012	0.465	0.499	0	1	4805
2013	0.426	0.495	0	1	4805
2014	0.07	0.254	0	1	4805

Notes: *rebate (%)* is the winning rebate in the tender; *central government*, *concessionaire*, *institution*, *public enterprise*, *region*, *municipality*, *province*, *mountain council* and *other institution* are CA type dummies; *offers number* is the number of bids received in the tender; *open*, *restricted*, *negotiated* and *negotiated without call* are dummies for the type of award procedure; *lowest price*, *met* and *not specified* are dummies for the award criteria; *population* is the number of resident inhabitants (in 1000) in the municipality where the CA is located; *reserve price* is the starting value of the tender set by the CA in 1000 euros (2010 equivalents); *service* is a dummy for whether the purchase was relative to a service rather than to a supply; *behalf* is a dummy for whether the CA was awarding on behalf of another entity; *potential bidders* is the number of suppliers observed in the dataset in the industrial sector to which the tender refers; *ordinary*, *utilities* and *security* are dummies for the directive which rules the tender; *incumbency* is the number of contracts awarded to the winning firm by all the CAs in the dataset in the previous tenders; *CA experience* is the number of contracts awarded by the CA in the previous tenders; *repeated interact* is the number of past interactions between the winning firm and the CA; *local win*, *regional win*, *national win* and *international win* are dummies for whether the winning firm was registered, respectively, in the same province, region, country of the CA or in a different country; *center*, *north* and *south* are dummies for the macro-area where the CA is located.

Table A.2: Rebate by institutional class of CA

CA type	N	mean	sd	min	max
central government	410	19.79	21.23	0	98.42
concessionaire	62	21.98	18.63	0	86.37
institution	710	18.37	19.85	0	99.95
mountain village	54	9.33	14.49	0	60.23
municipality	1187	12.16	17.08	0	98.16
other institution	826	17.36	18.53	0	99.88
province	107	15.39	17.47	0	89.29
public enterprise	1303	17.01	17.42	0	94.17
region	146	19.57	19.31	0	75.00
total	4805	16.33	18.50	0	99.95

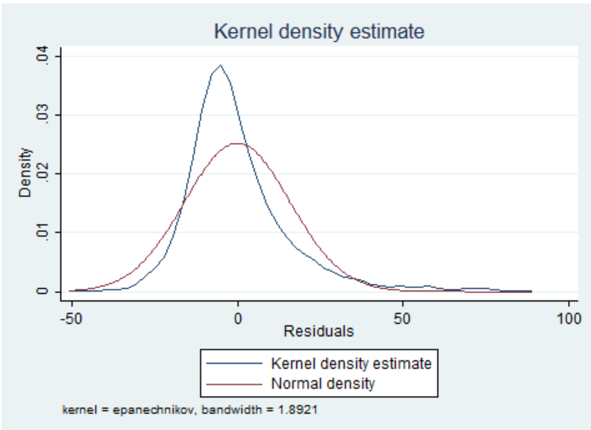

Figure A.3: Regression residuals

Table A.3: Winning rebate and CA class, OLS

	(1) rebate (%)	(2) rebate (%)	(3) rebate (%)	(4) rebate (%)	(5) rebate (%)	(6) rebate (%)
central government	7.638***	7.319***	6.077***	6.534***	6.043***	6.565***
	(2.318)	(2.605)	(1.333)	(1.551)	(1.660)	(1.496)
concessionaire	9.827***	7.549***	5.611*	5.425*	5.235*	5.479*
	(2.974)	(2.629)	(2.976)	(2.840)	(2.869)	(2.782)
institution	6.210***	5.031***	4.656**	4.268**	4.385**	4.253**
	(1.942)	(1.596)	(1.759)	(1.733)	(1.758)	(1.679)
public enterprise	4.850**	2.875***	3.407***	2.457**	3.365***	2.466***
	(2.108)	(0.956)	(1.022)	(0.944)	(1.079)	(0.902)
region	7.416***	3.981*	4.397**	4.329***	4.326***	4.399***
	(2.295)	(2.294)	(1.694)	(1.587)	(1.583)	(1.624)
province	3.235	3.432	1.305	1.877	1.757	1.787
	(2.163)	(2.116)	(2.109)	(1.925)	(1.885)	(1.815)
mountain council	-2.827	-1.721	-0.477	-1.134	-0.844	-1.156
	(1.749)	(1.399)	(1.651)	(1.511)	(1.433)	(1.446)
other institution	5.206***	4.277***	3.668***	3.336***	3.397***	3.459***
	(1.238)	(0.725)	(0.750)	(0.719)	(0.741)	(0.755)
offers number			0.911***			
			(0.104)			
ln(offers number)				7.997***	8.044***	8.026***
				(0.603)	(0.591)	(0.595)
negotiated			-0.620	-0.098	0.494	0.111
			(1.890)	(1.810)	(1.832)	(1.806)
negotiated without call			-9.972***	-5.568***	-5.549***	-5.400***
			(1.458)	(1.308)	(1.579)	(1.320)
restricted			-2.211*	-2.078	-1.855	-2.076
			(1.249)	(1.289)	(1.196)	(1.259)
lowest price			3.666***	3.848***	3.853***	3.865***
			(0.694)	(0.679)	(0.666)	(0.723)
not specified			-1.121	-0.965	-1.010	-0.944
			(0.954)	(1.082)	(1.062)	(1.119)
population			-0.000	-0.000	-0.000	
			(0.001)	(0.001)	(0.001)	
reserve price			-0.000	-0.000	-0.000	
			(0.000)	(0.000)	(0.000)	
service					0.989	
					(1.210)	
potential bidders					0.000	
					(.)	
utilities					-1.773	
					(1.453)	
security					3.241	
					(4.062)	
behalf					-2.698	
					(2.246)	
incumbency					0.016	
					(0.098)	
CA experience					0.014	
					(0.043)	
repeated interact					0.384	
					(0.472)	
regional win					-1.475***	-1.487***
					(0.479)	(0.470)
national win					-0.487	-0.510
					(0.601)	(0.583)

international win					-3.510^{*}	-3.633^{*}
					(1.906)	(1.916)
Constant	12.157^{***}	14.819^{***}	8.117^{***}	3.177	8.289^{***}	3.161^{*}
	(1.853)	(1.208)	(1.761)	(2.316)	(2.302)	(1.856)
province FE	No	Yes	Yes	Yes	Yes	Yes
year FE	No	Yes	Yes	Yes	Yes	Yes
sector FE	No	Yes	Yes	Yes	Yes	Yes
R^2	0.022	0.123	0.223	0.266	0.269	0.267
Adjusted R^2	0.020	0.092	0.195	0.239	0.240	0.240
p	0.000	.	.	.	.	.
province FE		0.000	0.000	0.000	0.000	0.000
year FE		0.214	0.098	0.111	0.111	0.120
sector FE		0.000	0.000	0.000	0.000	0.000
Observations	4805	4805	4805	4805	4805	4805

Notes: *rebate (%)* is the winning rebate in the tender; *central government*, *concessionaire*, *institution*, *public enterprise*, *region*, *province*, *mountain council*, and *other institution* are CA type dummies (the omitted category is *municipality*); *offers number* is the number of bids received in the tender; *negotiated*, *negotiated without call* and *restricted* are dummies for the type of award procedure (the omitted category is *open*); *lowest price* and *not specified* are dummies for the award criteria (the omitted category is *met*); *population* is the number of resident inhabitants (in 1000) in municipality where the CA town is located; *reserve price* is the starting value of the tender set by the CA in 1000 euros (2010 equivalents); *service* is a dummy for whether the purchase was relative to a service rather than to a supply; *potential bidders* is the number of suppliers observed in the dataset in the industrial sector to which the tender refers; *utilities* and *securities* are dummies for the directive which rules the tender (the omitted category is *ordinary*); *behalf* is a dummy for whether the CA was awarding on behalf of another entity; *incumbency* is the number of contracts awarded to the winning firm by all the CAs in the dataset in the previous tenders; *CA experience* is the number of contracts awarded by the CA in the previous tenders; *repeated interact* is the number of past interactions between the winning firm and the CA; *regional win*, *national win* and *international win* are dummies for whether the winning firm is registered in the same region of the CA, or in the same country or in a different country (the omitted category is *local win*, i.e., registered in the same province); *province FE* are 109 dummies for the CA province; *year FE* are 3 dummies for the year of award; *sector FE* are 41 dummies for the object of the tender. Standard errors robust to clustering at the sector level are in parentheses. Significance at the 10% level ($p < 0.10$) is represented by *, at the 5% level ($p < 0.05$) by **, and at the 1% level ($p < 0.01$) by ***. Standard regression tests are reported at the bottom of the table. Outcomes are expressed in terms of p-value.

Table A.4: Robustness checks

	(1) rebate (dec.)	(2) rebate (dec.)	(3) rebate (%)	(4) rebate (%)	(5) rebate (%)	(6) rebate (%)	(7) rebate (%)
main							
central government	0.066***	0.506***	8.517**	8.782*	5.319***	6.565***	5.423***
	(0.015)	(0.109)	(2.080)	(4.579)	(1.775)	(1.248)	(1.352)
concessionaire	0.055*	0.453**	7.168**	5.340*	5.138*	5.479**	5.085*
	(0.028)	(0.183)	(2.375)	(2.770)	(2.787)	(2.394)	(2.598)
institution	0.043**	0.370***	7.135**	5.090**	3.882**	4.253***	3.305*
	(0.017)	(0.143)	(1.768)	(2.282)	(1.719)	(1.295)	(1.689)
public enterprise	0.025***	0.254***	3.927**	2.037	2.851***	2.466***	2.075**
	(0.009)	(0.085)	(1.297)	(1.433)	(1.015)	(0.688)	(0.842)
region	0.044***	0.351***	4.417*	3.849	4.094**	4.399**	3.605**
	(0.016)	(0.125)	(1.977)	(2.857)	(1.611)	(1.786)	(1.643)
province	0.018	0.137	1.800	2.521	1.427	1.787	1.039
	(0.018)	(0.156)	(1.356)	(2.543)	(1.724)	(1.583)	(1.832)
mountain council	-0.012	-0.126	-0.971	-1.098	-0.980	-1.156	-1.437
	(0.014)	(0.193)	(2.485)	(2.277)	(1.418)	(2.414)	(0.950)
other institution	0.035***	0.311***	3.293**	0.887	3.125***	3.459**	2.813***
	(0.008)	(0.077)	(1.167)	(1.240)	(0.779)	(1.352)	(0.790)
ln(offers number)	0.080***	0.570***	8.411***	7.599***	7.765***	8.026***	8.112***
	(0.006)	(0.029)	(1.037)	(0.789)	(0.668)	(0.314)	(0.572)
lowest price	0.039***	0.273***	3.445**	3.132***	4.990***	3.865***	4.061***
	(0.007)	(0.052)	(0.996)	(1.054)	(0.791)	(0.661)	(0.702)
not specified	-0.009	-0.113	-1.049	-1.838	-1.149	-0.944	-1.348
	(0.011)	(0.098)	(1.898)	(1.532)	(1.070)	(1.004)	(1.167)
negotiated	0.001	0.005	-3.561	0.730	1.803	0.111	-0.003
	(0.018)	(0.134)	(1.926)	(2.320)	(3.154)	(2.353)	(1.768)
negotiated without call	-0.054***	-0.583***	-2.475	-5.813***	-6.068***	-5.400***	-5.422***
	(0.013)	(0.140)	(1.395)	(1.952)	(1.702)	(0.804)	(1.370)
restricted	-0.021	-0.153*	-0.916	-2.599**	-1.005	-2.076**	-2.026
	(0.013)	(0.089)	(1.061)	(1.111)	(1.200)	(0.897)	(1.232)
regional win	-0.015***	-0.091*	-1.155**	-1.198*	-1.515***	-1.487*	-1.849***
	(0.005)	(0.052)	(0.346)	(0.687)	(0.445)	(0.774)	(0.589)
national win	-0.005	-0.014	-0.479	-0.239	-0.283	-0.510	-0.729
	(0.006)	(0.046)	(0.927)	(0.930)	(0.534)	(0.504)	(0.568)
international win	-0.036*	-0.274	-2.546	-3.243	-2.905	-3.633**	-3.977*
	(0.019)	(0.191)	(1.798)	(2.970)	(2.529)	(1.813)	(2.100)

Constant	0.032*	-2.797***	-1.442	5.012	3.199	3.161***	3.449**
	(0.019)	(0.154)	(2.499)	(5.883)	(2.243)	(1.130)	(1.651)
province FE	Yes	Yes	Yes	Yes	Yes	Yes	No
year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
region FE	No	No	No	No	No	No	Yes
R^2	0.267		0.330	0.271	0.281	0.267	0.250
Adjusted R^2	0.240		0.285	0.235	0.249	0.240	0.238
p	.	.	.	.	.	.	.
province FE	0.000	0.000	0.689	0.000	0.000	0.000	
year FE	0.120	0.059	0.037	0.039	0.104	0.100	0.157
sector FE	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	4805	4805	2065	2265	4021	4805	4805

Notes: *rebate (%)* is the winning rebate in the tender expressed in percentage terms; *rebate (dec.)* is the winning rebate in the tender expressed in decimal terms; *central government*, *concessionaire*, *institution*, *public enterprise*, *region*, *province*, *mountain council*, and *other institution* are CA type dummies (the omitted category is *municipality*); *ln(offers number)* is the natural logarithm of the number of bids received in the tender; *negotiated*, *negotiated without call* and *restricted* are dummies for the type of award procedure (the omitted category is *open*); *lowest price* and *not specified* are dummies for the award criteria (the omitted category is *met*); *regional win*, *national win* and *international win* are dummies for whether the winning firm is registered in the same region of the CA, or in the same country or in a different country (the omitted category is *local win*, i.e., registered in the same province); *province FE* are 109 dummies for the CA province; *year FE* are 3 dummies for the year of award; *sector FE* are 41 dummies for the object of the tender; *region FE* are 19 dummies for the region of the CA. Specification (2) is estimated with a GLM method which uses the logit link function and the binomial distribution. All other specifications are estimated with OLS. In specification (6) standard errors robust to clustering at the province level are in parantheses. In all other specifications standard errors robust to clustering at the secor level are in parentheses. Significance at the 10% level ($p < 0.10$) is represented by *, at the 5% level ($p < 0.05$) by **, and at the 1% level ($p < 0.01$) by ***. Some standard regression tests are reported at the bottom of the table: outcomes are in terms of p-value.

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